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Edited by
Adiel Teixeira de Almeida
Danielle Costa Morais
Suzana de França Dantas Daher

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Preface

Group Decision and Negotiation 2012 was organized by Federal University of Pernambuco, Brazil during May 20-24, 2012. GDN 2012 was the 12th annual meeting organized by the INFORMS Section on Group Decision and Negotiation, in cooperation with the EURO Working Groups on Decision and Negotiation Support and Group Decision Support Systems. The series of GDN conferences started in Glasgow in 2000, and continued in La Rochelle (2001), Perth (2002), Istanbul (2003), Banff (2004), Vienna (2005), Karlsruhe (2006), Montreal (2007), Coimbra (2008), Toronto (2009), and Delft (2010). The meetings in Istanbul, Banff, and Toronto were held as streams within a larger INFORMS Conference.

GDN conferences traditionally bring together researchers from Africa, the Americas, Asia, Europe, and Oceania, with a stimulating variety of backgrounds, and from a wide diversity of disciplines – from economics, operational research and game theory to social sciences and information systems. While many of us come from different backgrounds, we all share a common focus: research into complex decision problems, involving multiple stakeholders (with different perspectives, issues and emotions), and requiring decision aid for both process and content.

The aim of GDN research is not only to improve our understanding of group decision and negotiation processes, methods, tools, and techniques, but also to support decision makers and negotiators and help them achieve better results. The contributions in these proceedings reflect the richness of GDN research. Using a variety of research approaches in real organizational settings and laboratory situations, they focus on the development, application and evaluation of concepts, theories, methods, and techniques.

GDN 2012 included a Doctoral Consortium that offered PhD students an opportunity to present and discuss their dissertation research with faculty and other students. This consortium was held on Sunday 20 May.

We are grateful to the individuals and institutions that helped us make this conference a reality. We would especially like to thank Federal University of Pernambuco, SOBRAPO (Brazilian Society for Operational Research), ABEPRO (Brazilian Society of Production Engineering), INFORMS section on Group Decision and Negotiation and EURO Workgroup on Decision Support Systems, for their recognition and assistance. We are grateful for financial support from the Federal University of Pernambuco, CAPES (Federal Agency of Support and Evaluation of Postgraduate Education), FACEPE (Research Funding Agency of the State of Pernambuco), CHESF (Companhia Hidroelétrica de São Francisco), CDSID (Center for Decision Systems and Information Development) and IPSID (Decision Systems and Information Research Institute). We also take this opportunity to thank the members of the Program Committee for their commitment and their efforts, which enabled us to review efficiently and effectively the more than one hundred submissions we received.

We are confident that the keynotes and research presented at GDN 2012 will assist and inspire decision makers and negotiators as they address their problems. Coming from many different backgrounds, the presenters brought unique perspectives and experience to the conference, stimulated new ideas and established new friendships. Their works, collected in these proceedings, make a unique contribution to knowledge in Group Decision and Negotiation. We warmly recommend every one of them for your reading.

D. Marc Kilgour and Melvin F. Shakun (Conference Chairs)

Adiel Teixeira de Almeida (Program Chair)

Danielle Costa Morais and Suzana de França Dantas Daher (Organizing Chairs)

Group Decision and Negotiation 2012, Recife, Pernambuco.

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Reframing framing: Emotion and interactivity in group decision and negotiation?

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Abstract: The purpose of this paper is to relate the concept of framing in decision-making and negotiation to interaction. It explores the relation between reciprocal adaptation, interactive alignment theory and theory of Theory of Mind by observing authentic data. It uses two types of activity: an everyday sharing between two friends and a plea bargain negotiation. The study finds that problem reframing or negotiation is affected by interactivity and led by discursive mechanisms such as reciprocal adaptation, which realizes interactive alignment and complex reasoning. The type of activity predicts the functionality of reciprocal adaptation. It notices that in plea bargains interactive alignment realizes complex Theory of Mind reasoning and that due to multi-functionality of discourse features alignment can't be measured based on statistical occurrences.

Keywords: emotion, reciprocal adaptation, negotiation, group decision, interactive alignment

1. Introduction

The purpose of this paper is to relate the concept of framing in decision-making and negotiation to interaction. The study explores if and how activity and interaction affect the decision process. In particular, it seeks evidence for and against interactive alignment theory and theory of Theory of Mind by observing authentic data. It uses two types of activity, one is an everyday interactive sharing between two friends and the other is an example of strategic interaction, namely a plea bargain negotiation, both from Heritage's and Maynard's corpora. Since discourse entities are multi-functional qualitative, ethno-methodological analysis of audio-recorded interactions is applied. The study starts with examination of interactive theories and then continues with examples of analysis, which comment on and test these theories using the above-mentioned data.

2. Theoretical foundations

Negotiation and group decision-making are defined as processes of problem reframing. Since negotiation and group decision taking are most often conducted interactively one needs to redefine the concept of framing by adding the socio-interactive aspect of its meaning. Thus by problem reframing we mean not only cognitive-affective reframing but also socio-interactive restructuring of a problem. Prospect theory (Kahneman and Tversky, 1986) did not offer understanding on decision taking as socio-interactive reframing, but only as a cognitive-affective process. In order to understand negotiation and group decision taking we need to understand how the socio-interactive framing affects the decision process.

The concept of framing has different definition and application in the fields of decision studies and in social studies. Behavior and decision taking related to e.g. the function of money, framing is defined as a cognitive process, which limits and directs the interpretation of and the emotional relation to the perceived and imagined loss and gain. In other words, here the process is cognitive and emotive. One of the ways in which people frame, for instance, losses and gains, is that losses regularly hurt more than gains feel good (ibid.).The framework or the structure that maintains this state of preferences affects decision taking.

In interaction studies and sociology, the concept of frame is a bit different. Goffman's (1974) original description and understanding of framing is described in short as 'organization of experience' in interactive and social order. Frames are not only cognitive but also social interactive constructions i.e. the frame is set also by the activity and the situation as such, including roles, settings, goals. For instance, in a courtroom, the judge sits in the middle of both parties, independently of how the defendant understands the situation. It follows that in Goffman, a situation is not created by the interactants but a frame is.

Gumperz’ (1982: 13) definition of reciprocal adaptation is also related to framing: “the procedure...where each participant gradually learns to adapt and to enter into the other's frame of reference." In his view, reciprocal adaptation is involved in interactive reframing of situations, knowledge and arguments and it does not presuppose conscious or less conscious processing of information. This communicative, cultural and learning mechanism is not only cognitive but also linguistic, emotive and behavioral i.e. speakers adapt to each other on different levels: lexical and semantic choice, syntax, posture, gaze, proximity, orientation, tone of voice, etc. It is a mechanism behind linguistic phenomena such as creole-like varieties of languages and interactive emotions such as empathy and rapport (Martinovski 2010). Similarly, human users adapt to the speech and behavior of the Virtual Agent (Bell 2003, Martinovski and Traum 2003). Thus, there are basic interactive mechanisms, which characterize human interaction and affect participants' frames of reference, such as reciprocal adaptation.

Earlier studies (Martinovski, Traum and Marsella 2007) indicate that empathy (elicitation, acceptance, rejection, refusal of empathy) may be seen as a general cognitive-emotive capacity necessary for successful human interaction. This view relates to the Theory of Theory of Mind, which claims that interactants consciously or less consciously build theories of each others' and own goals, knowledge, characteristics, social and emotional status, facilitated by specific neural resources and processing. Three competitive theories explain how Theory of Mind building occurs: by simulation, by imitation or by representation. Martinovski (2007) finds manifestation of all three cognitive-emotive processes in discourse.

According to Pickering and Garrod (2006), communication in discourse is accomplished through an interactive process they call alignment and successful communication through good alignment: 'the development of similar representations in the interlocutors … interlocutors align situation models during dialogue.' (ibid. p.1). The main claim of their theory is that 'automatic processes play a central role and explicit modelling of one’s interlocutor is secondary' in communication’ (ibid.). The alignment involves situation models and non-situational knowledge such as language knowledge. Interlocutors align their situational knowledge but they also align knowledge of situation and language (for instance, what they think 'right' means with the word 'right'). The situation models include notions such as 'space, time, causality, intentionality, and reference to main individuals under discussion' (ibid. p. 2). Alignment is based on willingness for cooperation and on mechanistic automatic imitation (of lexical choices, syntax, tone of voice, etc.): 'Our underlying conceptualization of conversation is collaborative, in that we treat it as a “game of pure cooperation” … in which it is in both interlocutors’ interest for it to succeed for both interlocutors' (ibid. p. 22) and 'the interactive-alignment account proposes that alignment is primitive. It is a form of imitation and drops out of the functional architecture of the system… In these accounts, imitation is an automatic, non-inferential process and is in some sense the default response. Generally, imitation does not appear to require any decision to act' (ibid. p.18) Thus, alignment does not involve building of entire theory of the other but an primitive turn-to-turn alignment on different linguistic levels of the message: phonetic, syntactic, semantic, etc. Each level is processed and aligned for it self and misalignment on one level enhances alignment on another level. Pickering and Garrod point out also that children can't inhibit alignment, which speaks for the forcefulness of this interactive mechanism. They base their view on situated interaction where participants have to find interactively each other's position in a maze without being able to see it and assume that the same mechanism works on everyday conversation. 'Such models are assumed to capture what people are “thinking about” while they understand a text, and therefore are in some sense within working memory (they can be contrasted with linguistic representations on the one hand and general knowledge on the other). Successful dialogue occurs when interlocutors construct similar situation models to each other.' (ibid. p. 1-2) They emphasize 'that this account differs from Clark (1996), who assumes that speakers carefully track their addressees’ mental states throughout conversations' (ibid. p. 10) and that 'the important point is that effects of partner specificity do not imply that interlocutors need employ complex reasoning whenever they produce an expression. Instead, they have a strong tendency to employ the form that they have just encountered' (ibid. p. 20).

Interactive alignment is similar to the concept of reciprocal adaptation in that they refer to framing in terms of similar discourse processes and do not demand conscious processing during interaction, although the connection has not been made nor explored yet in the literature.

Reciprocal adaptation, developed around 1982:
“the procedure...where each participant gradually learns to adapt and to enter into the other's frame of reference."

Interactive alignment, developed around 2004:
"the development of similar representations in the interlocutors … interlocutors align situation models during dialogue.'

In that sense, Pickering and Garrod's answer to Goffman's question is: Interactants use interactive alignment to frame their activities in order to make sense of a situation, where alignment is primitive, automatic, based on imitation and realizes on both production and comprehension level. However, it is hardly the case that alignment is the process through which interactants make sense of a situation since by definition this processes is primitive i.e. does not involve complex reasoning or active long-term memory based monitoring. Rather it is more likely to see it as a way of preliminary or first layer framing. Gumperz' answer to Goffman's question is then: Interactants gradually learn to frame their activities through reciprocal adaptation in order to make sense of a situation. It is a more general term than alignment because it does not pose a condition of automaticity and short-term memory basis.

The mechanistic aspect of communication, of actual meeting between people, does bring changes into negotiation, which is otherwise characterized by pre-set values, preferences and strategies, therefore emotive adaptation in negotiation is of great interest and it has not been studied sufficiently. However, even more complex cognitive-emotive processes such as some forms of Theory of Mind (ToM) building can bring changes to negotiation and decision taking. For example, Martinovski, Marsella and Traum (2007) found that empathy and rejection of empathy involve ToM reasoning. Martinovski and Mao (2009) describe how emotions function as arguments and Martinovski (2011) found that emotions are conflict management engines, which involve opposite reciprocal adaptation.

The present paper explores the relation between discursive concept and theories such as framing, reciprocal adaptation, interactive alignment, and Theory of Mind building. It studies if and how activity and interaction affect decision processes such as negotiation. For that purpose, it seeks evidence for and against interactive alignment theory and theory of Theory of Mind by observing reciprocal adaptation in authentic data. It uses two types of activity, one is an every day interactive sharing between friends and the other is an example of strategic interaction, namely a plea bargain negotiation, both from Heritage's and Maynard's corpora. Since, discourse entities are multi-functional qualitative ethno-methodological analysis of recorded interactions is suitable and necessary.

3. Reciprocal adaptation in empathy exchanges

The following example from Heritage illustrates a successful ritualistic 'empathic moment'. The transcription conventions are: '[ ]' stands for overlapped speech; ':' stands for prolonged vowel; '=' stands for latching speech; '/' indicates pause; capital letters indicate emphatic speech; '+' indicates cut-off; '( )' stands for inaudible speech; '?' stands for rising intonation; '.' stands for falling intonation; ',' stands for continuing intonation; each line in the transcription indicates an intonation unit; {0.9} stands for seconds of pause; PE – parallel empathy, G – giving, RE – reactive empathy, E – elicitation.

The empathy episode starts with an announcement of trouble on line 2. It is welcomed and elicited on line 3 and followed by a narrative background on lines 4-13. Starting with an empathic narrative conjunction, turn 14 gives the punch line, which elicits empathy (Martinovski 2006).

Example (1) [Holt Xmas 85:1:4]

1. Joy:	ye-:s I'm alright,
2. Les:	oh:. hh yi-m- you know I-I- I'm boiling about something hhhheh [1 heh hhhh]
3. Joy:	[1 wha::t.]
4. Les:	well that sa:le. {0.2} at- at . the vicarag {0.6}
5. Joy:	oh ye[2 :s],
6. Les:	[2 t] {0.6} u ih your friend 'n mi:ne wz the:re {0.2}
7. ( ):	(h[3 h hh)]
8. Les:	[3 mmis] ter: R:,
9. Joy:	(oh ye:s hheh) {0.4}
10. Les:	and em: we really didn't have a lot'v cha:nge that day becuz we'd been to bath 'n we'd been: christmas shoppin:g, {0.5} but we thought we'd better go along t'th'sale 'n do what we could, {0.2} we hadn't got a lot . of s:e- ready cash t'spe:nd. {0.3} t[4 hh]

11. Joy: [4 Mh].=
12. Les: =In any case we thought th'things were very expensive.
13. Joy: oh did you. {0.9}
14. Les: AND uh we were looking rou-nd the sta:lls 'n poking about 'n he came up t'me 'n be said Oh: hhello leslie, . still trying to buy something f'nothing,
15. Joy: PEG-> .hhhahhhhhh! {0.8 } oo[5 : : :: LESLI E]
16. Les: PEE-> [5 oo:.ehh heh heh] {0.2}
17. Joy: PEG-> i:s [6 n ' t he]
18. Les: REE-> [6 what] do you sa:y. {0.3}
19. Joy: PEG-> oh isn't he drea:dful.
20. Les: PEE-> eye-:-:s: {0.6}
21. Joy: PEG-> what'n aw::f'l ma::[7:::n]
22. Les: PEE-> [7 ehh] heh-heh-heh
23. Joy: PEG-> oh:: honestly, I cannot stand the man it's \ just {no[8 :}]
24. Les: RPEE-> [8 I] bought well I'm gon' tell Joyce
that,ehh[7 heh]=
25. Joy: [9 ( )]=
26. Les: RPEE=[9 heh-heh he-e] uh: eh [10 eh hhhhh]
27. Joy: PEG-> =[10 O H : : : :.] I do think he's dreadful
28. Les: PEE-> tch oh: dea-r
29. Joy: PEG-> oh: he r[11 eally i]:s,
30. Les: RPEE-> [11 he dra-]ih-he (.) took the win' out'v
my sails c'mpletel(h)y .
31. Joy: REG-> I know the awkward thing is you've never
got a ready a:n[12 swer have you. that's
ri:ght,]
32. Les: REE-> [12 no: I thought'v lots'v ready a]nswers
a:fterward[13 s],
33. Joy: REG-> [13 yes] that's ri::gh[14 t].
34. Les: REG-> [14 yes] .
35. Joy: REG-> but you c'n never think of them at the
ti:[15 me a:fterwards I always think. oh I
should've said that. or I should've said
thi]s.
36. Les: REG-> [15 no:.no:. oh y e s e h- r i : g h t.] {0.7}
37. Joy: REGE-> b[16 ut] I do:'nt think a'th'm at the ti:me
38. Les: REG-> [16 mm:]. ehh huh huh {0.8}
39. Joy: oh:: g-oh 'n I think carol is going, t'the
[17 meeting t'ni g h t,]

Emotive reciprocal adaptation is manifested linguistically most expressively when Joy offers elicited empathy on line 15 and Les implicitly accepts it on line 16. The exclamations on lines 15 and 16 are similar: Les starts her exclamation with a similar sound to this of Joy 'oo' and continues with a slight differentiation. In that sense, the speakers align with each other in tone and sound, starting with an imitation, although the functions of the utterances are different. Then starts a separation of parallel and reactive empathy (Davis 1994, Martinovski 2006). On lines 17, 19, 21, 23, 27, and 29 Joy gives examples of what is meant by parallel empathy i.e. she expresses a mirrored feeling or disapproval of the person by whose actions Les feels hurt, in that way mirroring Les' dislike of this person's actions. In that sense, this is a parallel form of entering into each other's frame of reference i.e. of reciprocal adaptation through emotional alignment. On line 30 Les expresses her internal distress, which changes the character of the elicited empathy i.e. line 31 illustrates reactive empathy. This empathy type is realized here with a role-play simulation expressed by the use of the generalizing pronoun 'you', which is another linguistic formulation of the reciprocal adaptation mechanism. The tag-question is an elicitor of consent, which again turns the roles around: Joy is supposed to be the empathy giver but she often becomes the empathy elicitor as a form of empathy giving. On line 35 Joy exchanges the impersonal "you" with a reference to herself, voicing Les' internal discomfort and embarrassment for which she seeks empathy. This voicing is expressed as a quotation of internal dialogue. Thus Joy internalizes Les' inner state i.e. she displays reactive emotive empathy. This exchange of roles and positions is part of the reciprocity ritual.

Line 35, however, is an example of verbalized simulation process, which is in the lines of theory of Theory of Mind rather than interactive alignment theory. On line 37 Joy has taken Les' internal position and talks about her own experiences, which is another example of cognitive reciprocal adaptation. Les now functions both as a receiver and a giver of empathy, the process has reached its climax and suddenly on line 39 Joy announces a completely new topic.

The adaptation is at first more somatic, uncontrollable and then becomes more cognitive as they turn to comparisons of experiences and mental representations of experiences. In this empathy process both speakers verify, confirm, and reconfirm for each other the legitimacy of their experiences, values, and attitudes and in the processes they often mirror each other's verbal actions. The empathy process in Example (1) is fulfilled: there was elicitation, giving, and acceptance of empathy and where was also identification (e.g. line 31), incorporation (e.g. line 35), reverberation (e.g. line 37), and finally detachment (line 39). The sudden change at the end of Example (1) and the repetitive turn of the roles in the process of empathizing suggest that the empathy process is rather rehearsed and therefore ritualistic. We observe interactive alignment but also Theory of Mind building processes during empathy exchange. Interactive alignment has diverse linguistic manifestation, e.g., exclamations, tone of voice, tag-questions, parallel and reactive empathy forms. Interactive Theory of Mind building manifests at the incorporation and reverberation empathy stages and take the form of explicit reasoning from the other's point of view through generalized pronouns. Thus, reciprocal adaptation in ritualistic informal empathy exchange is realized by frequent interactive alignment and interactive Theory of Mind reasoning. The next section studies if the same format of reciprocal adaptation takes place in a more strategic and formal activity such as a plea bargain.

4. Reciprocal adaptation and emotion in a plea bargain

In comparison to friendly sharing and empathy exchange, a plea bargain is a more formal activity, which involves strategic and tactical interaction, where the parties have opposing goals. It is a negotiation where participants have conflicting roles and goals. Pickering and Garrod predict manifestations of misalignment in such activities. Would there also be Theory of Mind building processes? To answer this question I first outline the structure of the plea bargain and then analyze manifestations of both alignment and complex reasoning.

4.1. Description of the instantiation of the activity

The parties have to agree first that they are willing to settle the case, then to establish the Penal Code provision that applies to the crime and at last, they try to agree on the settlement value. This particular instance of a negotiation involves sequences and phases of the main activity and different kinds of sub activities and topics (sub-activities in italics; major negotiation accomplishments in **bold**):

1. Brings up Frank Bryan's case – Judge (Jge)
2. *Inserted talk about a different case procedure referring back to a topic discussed before line 1 where the judge brings up Frank Bryan's case* - Prosecutor (Prs)
3. Return to the case topic – Jge
Parties present their interpretation of events
Defense offers settlement and reference to Penal code, insists that this is a case of disorderly conduct (CPC: 647f) rather than Arrest Resistance case (CPC: 148).
4. A meta-comment on the origin of his settlement strategy – Defense (Def) to Jge
5. **Agrees to settle, suggest a type of crime**, 148 rather than 647f – Prs
6. Discussion on events, type of crime and arrest period – Def and Prs
7. *Didactic instruction* – Jge to Prs
8. Aggressive refusal to involve defendant's prior criminal history - Def
9. *Side talk about rain* – Jge
10. **Plea Bargain Agreement** – Prs, Def

Phases are defined as larger units of talk distinguished by topic, activity and location in the conversation. Sequences are units of talk, which involve at least an adjacency pair and which build up phases in conversation. Each of the phases in the negotiation has particular initiation signals and initiators. The order of the phases provides a context and grounds the rest of the phases, i.e. this sequential order provides the organic structure of the interaction. The negotiation is transcribed according to selected conversation analysis standards: ‘,’ denotes continuous intonation; ‘.’ – falling intonation; ‘:’ - prolonged sound; [] - overlap; ‘=’ - latching; ‘_’ - emphasis; ‘Jge’ – Judge; ‘Def’ - Defence attorney; ‘Prs’ – Prosecutor (District attorney).

4.2. Interactive alignment vs. complex ToM reasoning

I have studied this plea bargain earlier from different angles: discursive strategies for reaching agreement (2007), the role of emotion in conflict transformation (2010) and the role of reciprocal adaptation of emotion in conflict management (2011). Here I will concentrate on the occurrences of interactive alignment and interactive Theory of Mind reasoning in relation to reciprocal adaptation and emotion in negotiation.

4.2.1 Introduction phase

Already at the very start of the plea bargain the incompatibility of interactive alignment theory or theory of ToM is questioned. The judge introduces the topic, asks about the identity of the defendant (line 3) and the defense attorney responds (line 4-6). The prosecutor is not joining the topic yet and throws in another topic, as a subtopic (lines 7,8).

Example (2) [Frank Bryan]

1 Jge: A:n now that brings us to Frank Bryan.
2 ( ): ˙hhh[h hhhh
3 Jge: [Is he the poor chap sitting out there all by h[imself,
4 Def: [Ye:ah he's
5 the sweet man with the nice smile, (0.5) a:nd this is ay six
6 forty seven ef an' a one forty eight. ((throat clear))=
7 Prs: =(thi-) these (Wednesday) specials by the way are on: th- the
8 date set for trial one eleven¿

The question of the judge expresses abundance of empathy: 'poor chap', 'all by himself', light tone of voice, positive rhetorical intonation. The response of the defense counsel aligns with this choice of description by adding sympathy and kindness to the character of his client: 'sweet man', 'nice smile', mild tone of voice. (It is possible and common that perpetrators of crime do not look aggressive, thus how the defendant looks is the least important evidence related to the case.) This is a clear interactive alignment and interactive framing of the case but it is hardly likely that this alignment is primitive, unconscious, mechanistic and imitative. Just the opposite, if the defense attorney aligns so obviously to the judge’s formulation it is a clear indication of their Theory of Mind of the case and its outcome. Utterance on line 6 topicalizes the preferable 'disorderly conduct' ('six forty seven ef') interpretation instead of the 'arrest resistance' ('one forty eight') interpretation and adds a throat clear, which function seems to be to non-verbally mark or problematize the 'arrest resistance' story. On the surface, this is grounding though interactive alignment using a question-answer pair, semantically similar lexical choices producing cooperatively achieved orientation in the case. However, the emotionally charged formulations by the judge and the defense counsel and the similarity of their descriptions manifest a case-theory-building intentionality or intentionally synchronized framing of the case. Each formulation directs the outcome of the plea bargain; together they are even stronger. The prosecutor is met from the start with two opposing parties and he is 1:2. This explains the fact that the prosecutor does not align at first but he does not misalign either, later (see Example 3 below) he monitors the story told by the defense and only at the end of the plea bargain clearly aligns but negatively (on line 211 below) and addresses issues of importance to law, namely that the defendant has a prior related to both resistance to arrest and disorderly conduct. In that sense, already at the start of the plea bargain, we see manifestations of both interactive alignment and complex ToM reasoning at the same time, which in their combination express the strategic character of the activity.

4.2.2 Interactive story telling and leading questions

Story telling is an interactive way of framing, of making sense of a situation or a case. Interrogation is another. In a plea bargain, there is no interrogation of witnesses, but the defense takes the opportunity to frame the problem at hand by telling a story. Below I give the entire phase of the story telling which ends with the decision to settle the case rather than go to a trial. On line 31 below the defense counsel opens the plea bargain with a yes-no question, initiated by a lip parting gesture, emphasizing 's' in 'strike', pronounces 'actually' rather informally, and ends with a rising intonation. Then he waits for an answer for a long time, even after the prosecutor's 'hmm:' on line 33, which is not a sign of misalignment; of its tone we understand it expresses lack of knowledge. Since one is asking and the other has no answer, both align in lack of knowledge, interactively. However, when the defense attorney establishes that the prosecutor is not prepared to answer this crucial for the final verdict question the defense attorney takes the privileged opportunity to frame the case through a story, the way he wants to see it, i.e. suitable for his client. Now, did the defense counsel ask an honest question or did he trigger on purpose the fact that there is no violence? The fact is that he repeats the same question one more time on lines 58-59. There the question is formulated as a leading tag-question, it starts with a volume escalation, rather colloquial humoristic lexical choice, it is uttered in overlap, and this time it does not allow or await an answer. This indicates that the defense counsel did not ask a question he did not already have an answer too. On the surface we have alignment of 'no knowledge', but really we have a planned and explicit modeling of the interlocutor and case framing. The defense uses such a leading question again on line 71, with a tag question and ample time for a response, thus emphasizing it. The fact that the defendant has been in jail already is an important fact for the defense, because it claims that time has been served already although crime is not clearly established. It is important for the judge to memorize that fact as well i.e. it informs the judge that the man he found to be a 'poor chap' has already sat in jail for unknown amount of time, increasing the reasons for empathy. That is, again we see that interactive alignment realizes complex reasoning rather than automatic processing i.e. this question does not seek information, it seeks to strategically show and influence a ToM process, not just interactive alignment of information.

Example (3) [Frank Bryan]

29 Jge: Now on Frank Bryan?
30 (2.0)
31 Def: ˙hh ((lips parting)) Did he acshually strike an officer¿
32 (2.0)
33 Prs: Hmm:, ((not sure, high pitch))
34 (1.0)
35 Def: ˙hh See this tu- i- he's comes he's drunk. and he comes home
36 to his own house at wh-whe- where e'd have a fight with 'is
37 family, ˙hhh an' he's out in front of 'is in 'is own front yard
38 with 'is (0.2) parently: havin' such a fight er[: least]
39 Prs: [His mu-] his
40 mother having called the police.
41 Def: M(h)oth(h)er h(h)aving c(h)alled thu(h) c(h)ops, ˙hhh i- it's
42 a fa:mily thing.<He's screamin' an' an' ish then sayin' fuck.
43 an' all that kinda stuff. ˙hh or motherfuck. I assume, a:nd
44 u:m
45 ( ): [˙hh shh ˚huh(huh)
46 (J): [hihhihhihhihhihhihhihhihhihhihhihhihhihhihihihhihh=
47 Def: [yih kno:w, ˙hh getting into what=
48 (J): =[hihhihhihhihhih ih hh ih hh ˙hh hh ˙hh hh ˙hh ih hih]ih hih=
49 Def: =[(˚>i- trans i-<) happening there, (.) and he's drunk.]
50 (J) =ih [˙hh ( )]
51 Def: [And this] is I mean the same i- a very happy golucky
52 good natured guy, as you can tell for sitteen out in the
53 courtroom, ˙hh £an' when the ºpolice come onto his own home,
54 his ca(h)stle (h)he dec(h)ides (h)he ai(h)n't go(h)in'º
55 w(h)ithout makin' some trouble.£ ˙hhh=

56 ((º = volume escalation)),
57 (J): =He[:
58 Def: [ºAn' I don't think he swingsº on anybody
59 [does he?]
60 ( ): [(No i)]( )[( )] ((garbled))
61 Def: [He doe:]s (.) take a menacing sta:nce, ˙hh but
62 on the other hand he doesn't attempt ta strike an officer.<I
63 assume that the officer's highl- high- degree of
64 prufessionalism: pruvents my client from getting himself into
65 further tr(h)ouble. ˙hhh[hh
66 Prs: [Yeah, thee he (slipped and fell) of
67 [uh: the (court) apparently >[which's caused< that uh:: a:=
68 Def: [Yeah hhhh [h h h h h h
69 Prs: =laceration above his uh: (0.4) on i- [on i- ( )]
70 Def: [He's terr]ibly sorry
71 he did this.<I believe they took him to jail. did they not?
72 (0.3)
73 Prs: They did. and it was somewhere in the- in thee=
74 Def: =˙hh hhhm=
75 Prs: =process of being uh:b (0.5)
76 Def: ˙hh hh[m
77 Prs: [he did resist being[handcuffed. and resist wa:lking=
78 Def: [˙hh-
79 Prs: =from the residence and in the process of that resistance he:
80 (1.5) quote collapsed. and str[uck his head on the floor. end=
81 Def: [˙hhh
82 Prs: =q[uote,]
83 Jge: [Hh:]hih[(hih)
84 Def: [Y(h)e(h)ah well e-[he mighta had a certain=
85 Prs: [(and)
86 Def: =amount 'a justice a(h)r(h)ead(h)y hea hI (h)on't th(h)ink
87 th(h)e puhlice w(h)ere puhttin' up w(h)ith 'im. ˙hh[hhhh.]
88 Prs: [Wu- one]
89 senses thet u:m u::h i: other than that it was a lot of talk.
90 o:f u- assuming fighting stances an' then ru[nning] away.
91 Def: [Y e a]h
92 Prs: U[h:
93 Def: [It's a verbal:. w:: one forty eight. and a real six forty
94 seven ef. Now u: >if you< I would like to settle this case.
95 Prs: Well I'd li[ke to settle (it)

The defense attorney's story telling is not a monologue. It involves: intonation shifts, style shifts, volume escalations, laughter, lexical jokes, rich adjectives, pointed reformulations, other-repetitions, emphasis and repetition of crucial for the story aspects ('own house', 'own front yard', own home, 'his castle'), interruptions, latching, initial feedback givers and elicitors, etc. All these are linguistic-discursive means for framing or reframing a problem. The prosecutor adds and corrects, contributing to the interactive framing of the case, which ends up with agreement to settle. However, the moments of clear alignment, such as this on lines 40 and 41 do not support the primary role of mechanic alignment. On these lines the defense repeats literally the prosecutor's addition that it is the mother who called the police. He does not do such an other-repetition before or after during the framing of the case. He choses to align there and uses that as a support of his framing, but this is not simply because it is easier to imitate but because it fits his framing of the story, his goal, after explicit modeling of the interlocutors and the effect of the fact, not only the prosecutor but also the judge. He makes a joke out of this fact, which entertains the judge, makes him laugh, i.e. mitigates the severity of his client's actions. Thus alignment here realizes a complex strategy using ToM modeling, not automatic processing. The final lines above 94 and 95 exhibit alignment and also realize agreement through other repetition, but again the decision of agreement has come first and then the decision of alignment through repetition, not the other way around.

4.2.3 Meta-comments as interactive manifestations of ToM reasoning

Evidence for the interactive ToM building is the 'intermission', the subjectivity directly after the agreement to settle:

Example (4) [Frank Bryan]

96 Jge: [Yo(h)u ha(h)lwa(h)ays s(h)ay tha(h)a(h)at
97 [˙i h h][˙ihh][h u h][h u h]
98 Def: [Well as- I][I lea][rned that (t][rade) from Harr]y Moberg,
99 Jge: ˙uhh[hOh:] hah [hah][h a h ˙h h] ( )=
100 Def: [uh:] [bee][cuz with Harry], (0.2) >you=
101 Jge: =[((thrt clr))]
102 Def: =[start talkin'] to each other through clenched< teeth.
103 [And after about] five] minutes of (.) challenging each=
104 Jge: [ah hih!hihhih] ( )]
105 Def: =other to go [to trial, and I know 'at 'e doesn't try any=
106 [((sound of small item dropped on table))
107 Def: =ca(h)ses see(h)ee, [˙hh o(h)nly r(h)eason's I g(h)otta go to=
108 Jge: [( )
109 Def: =trial a[gainst one'a his new kids, r(h)ight?=
110 Jge: [˙hhh
111 Jge: =Huh!=
112 Def: =˙hh Or [(hi)his (n- old pro like) mister Franklin, ˙hhh=
113 ( ): [( )

The subjectivity is initiated by the judge's laughing comment on the settlement, line 96. As a response, the defense lawyer starts a story, which explains and describes what happened in lines 1 to 95 and what will continue for the rest of the plea bargain. He tells a story of a colleague, a famous lawyer, who strategizes interactively in such a way that he always makes the opponent agree to settle after some time of mutual challenging. This meta-comment reveals that the defense counsel's contributions build on chess game-like premeditated processes, which are often repeated and passed on:

Example (5) [Frank Bryan]

Def: =And so I finally tried to get the conversation around t(h)a what
we were talkin' about. like sett'lin' the ca(h)ase ˙hhh It
ˆworks.<Harry and I cuddo a lot of business that wa(h)ayhh
[wu-

In that sense, this meta-explanation grounds the judge's laughing meta-comment but it also frames the plea bargain as a routine, however, not a routine of automatic alignment but a routine of strategic planning based on complex interactive ToM modeling.

4.2.4 Emotion as manifestation of ToM-reasoning-based strategies; positive and negative reciprocal adaptation

Reciprocal adaptation or the procedure by which participants gradually enter each other's frame of reference may realize in different ways. Rather than claiming that there is resistance to adaptation, the data indicate that there is adaptation even in negative contexts. For instance, in Example 6 below the prosecutor offers facts, which aggravate the guilt of the defendant and indirectly suggest a harsher verdict. He does that after refusing to respond to empathy elicitation by the defense counsel. In effect, the defense counsel interprets the prosecutor’s stance taking as a challenge (204-6) and responds with a sudden explosive expression of anger, contempt and a threat (line 207). This emotional reciprocal adaptation takes a form of mirroring: a calm and sober threat to his client's interests is met with an emotionally loaded counter threat. On top of that, the defense repeats lexically the prosecutor on lines 216 and 220 with mocking intonation. This is good lexical alignment but no cooperation and no success in communication, in the sense of communication as alignment. In the sense of communication as a meeting with otherness this is good communication, because it expresses otherness. Rather than getting into the other's frame of reference and accepting it, the Defense counsel gets into the other's frame of reference, rejects it and, with the emotional display, blames the other party. Thus there is adaptation in negative terms but it is not in the mechanistic alignment format but rather as a well-planned ToM process, predicting and preventing other's interactive moves and reactions (as described by the defense counsel himself in the 'intermission' phase).

Example (6) [Frank Bryan]

204 Prs: He has ub a: one prior. (0.3) conviction in this jurisdiction
205 with thee uhm (0.8) sheriff's office, of of interestinly
206 enough. u:v striking a public officer and of disturbing peace.
207 Def: Will you knock it off. ((disgusted tone)) (0.5) You wanna make
208 a federal case out of this¿
209 Prs: N:o, [I I just] think [that that i]t's it's not uh this uh=
210 Def: [˙h h h] [h h m]
211 Prs: =happy go lucky chap's uh first (1.0) encounter with uh um (1.8)
212 Def: [Statistic]ly if ya got black skin:. you ar (0.2) you ar (.)=
213 Prs: [( )]
214 Def: =hhighly likely to contact the police. I think
215 uh:substantially more likely than if you're white.<*Now come*
216 on.<Whadda want from 'im. (0.6) He's got a prior.
217 (1.8)
218 Jge: Well we know he spent ten ho:urs, ehhem (1.0) end
219 uh:: [we know he's been down here fer] mo:re
220 Def: [(He) o: n l y s p e n t ten] ((mock shock))
221 (0.8)
222 ( ): ((throat clear))=

To this explosion of anger, the prosecutor reacts with self-explanation, he stutters and has difficulties formulating a sentence (line 209). The self-explanation on line 209-211 consists of a rejection of The defense counsel's story or ToM of the defendant using a quotation ('happy go lucky chap') of the defense's own formulation on line 51-52, in the beginning of the plea bargain. At the time, the prosecutor did not say much as the defense counsel was telling his view of the story, just answering leading questions and adding details that could change the story but nothing explicit. All of a sudden now, the prosecutor directly rejects the story and the picture the defense counsel drew of the case based on the available evidence. According to interactive alignment theory the alignment happens from turn to turn but here we have an interactive alignment using negative lexical quotation, which jumps over 100 turns in the conversation. Such instances are rather manifestations of the strategic character of the interaction in this activity, which presupposes conscious ToM building and monitoring. The ToM processing is calculative even on the level of timing: when the relevant evidence if to be mentioned in the conversation appears crucial as to its effect to the goal of the opposing parties.

Locally, on lines 211-213, we don't have adaptation in the form of mirroring but in the form of opposite reaction: The prosecutor adapts to threat and blame by rejection, confusion, defense, reference to contradicting evidence, increase of self-repetitions, pauses, hesitation sounds, and final silencing i.e. by reframing the problem through an opposite story or ToM frame plus reactive emotional alignment.

The defense counsel continues his ridicule by use of mocking back channels, initial and final interruptions, latching, ridiculing, mocking repetitions, etc. (lines, 207, 208, 216, 220). In this manner, he gains once again a dominant role in the conversation. Emotionally loaded imperative expressions such as 'knock it off', 'come on' and vocal gestures such as throat clearing act as more powerful persuasion devices than the arguments. Defense's sudden and timely anger display on line 207-219 has a successful strategic effect because 10 turns later on line 239 the opponent himself suggests to settle on terms preferred and suggested by the defense.

5. Conclusion

This paper describes problem reframing or negotiation as a process affected by interactivity and led by discursive mechanisms such as reciprocal adaptation, which can realize as interactive alignment or/and complex processing. The type of activity interlocutors are involved in predicts the functionality of reciprocal adaptation. We noticed that in plea bargains interactive alignment realizes complex reasoning. We also observed that in the case of empathy we have automatic alignment in the early phase of empathy process and ToM reasoning in the later phase. Discourse features such as other-repetition can't be classified simply as alignment because they can realize complex ToM processes i.e. understanding of alignment can't be based on statistical occurrences.

References

Bell, Linda. (2003) *Linguistic Adaptation in Spoken Human-Computer Dialogues.* Doctoral Thesis, Kungliga Tekniska Högskolan, Stockholm.

Davis, M.H. (1994) *Empathy: A social psychological approach.* Madison, WI: Brown and Benchmark.

Goffman, E. (1967) *Interaction Rituals: Essays on Face-to-Face Behavior,* New York: Pantheon.

Kahneman D., Tversky, A. (1986) Rational Choice and the Framing of Decisions. *The Journal of Business*, Vol. 59, No. 4, Part 2: The Behavioral Foundations of Economic Theory. (Oct., 1986), pp. S251-S278.

Martinovski, B. (2006) Cognitive and Emotive Empathy in Discourse. In *Proceedings of CogSci 2006*, Vancouver, Canada.

Martinovski, B. (2007) Empathy and theory of mind and body in evolution. In Ahlsén, E. et al. (eds) *Communication - Action* - Meaning. A Festschrift to Jens Allwood. University of Gothenburg, Department of Linguistics, pp. 343-361.

Martinovski, B. (2010) Emotion in Negotiation. *Handbook on Group Decision and Negotiation.* M. Kilgour and C. Eden (eds.), Amsterdam: Springer.

Martinovski, B. (2011) Reciprocal adaptation and emotion in conflict transformation. In *Proceedings of International Conference in Conflict Resolution*, Istanbul, Turkey.

Martinovski, B., Traum. D. (2003) The Error is the Clue: Breakdown in Human-Machine Interaction. *Proceedings of ISCA Tutorial and Research Workshop International Speech Communication Association,* Switzerland.

Martinovski, B., Traum D. Marsella S. (2007). Rejection of empathy in negotiation. *Journal of Group Decision and Negotiation.* Vol. 16, no. 1.

Martinovski, B., Mao W. (2009). Emotion as an argumentation engine: Modeling the role of emotion in negotiation. *Journal of Group Decision and Negotiation.* Vol. 18, no. 3.

Pickering, M. J., Garrod S. (2006). Alignment as the Basis for Successful Communication, *Research on Language and Computation*, Vol 4, pp 203-228.

Design Approaches for Collaboration and Negotiation Systems

Supporting Collaborative Design: Lessons from a case study at the ESA concurrent design facility.

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Abstract: Design and engineering increasingly face complex and dynamic requirements, and often require involvement of experts from a variety of disciplines. To ensure interoperability of sub systems, and to include customers, users and other stakeholders in the design, a collaborative approach to design and engineering is critical. In this paper, we present a set of challenges and guidelines listing elements of collaboration support for effective collaborative design and engineering. The guidelines are developed in an iterative design circle between observations and interviews at a concurrent design facility at ESA and literature on Group Support Systems, collaboration support (Computer Supported Collaborative Work) tools and principles, and Collaboration Engineering.

Keywords: Collaborative Design, Concurrent Design, Group Support Systems, Collaboration Engineering, Computer Supported Collaborative Work, Collaboration Support, Design Support.

1 Introduction

Design and engineering systems are facing increasing complexity and dynamic or even uncertain requirements, design constraints and success criteria (Herder & Bruijn, 2009). To design in such volatile context, flexibility and agility in the design process are critical, especially early in the design phase (Neufville & Scholtes, 2011). Approaches to support design and engineering in software engineering as well as other domains such as e.g. product design (Shyamsundara & Gadhb, 2002) (Shen, Ong, & Nee, 2010) have thus evolved from linear and rigid waterfall models (Royce, 1987) over the more iterative spiral models (Boehm, 1988) to more agile approaches like e.g. eXtreme Programming (Beck, 2000). Another key development in design and engineering methodologies is the increased need to involve a broad range of perspectives in the design which has led to participatory design approaches (Schuler & Namioka, 1993). By including different stakeholder perspectives and supporting interaction between design experts from different domains to create shared understanding of the design requirements, such design approaches aim to create a holistic perspective on system performance in which different subsystems are attuned and have appropriate interfaces. In this line, creating shared understanding is listed as one of the critical challenges of collaborative design (Lu, Elmaraghy, Schuh, & Wilhelm, 2007; Piirianen, Kolfschoten, & Lukosch, 2009). In order to support more agile and participatory design approaches, it is important to have a thorough understanding of the collaborative processes and the different ways in which a design environment can support collaboration and the creation of shared understanding.

In this paper, we present the results of a study at the Concurrent Design Facility (CDF) at the European Space Agency in the Netherlands. In the study, we identified the key factors that support collaboration in the Concurrent Design Facility. We looked both at hard requirements (e.g. resources for communication) and soft requirements (e.g. trust). We did observations and interviews to derive the success factors related to collaborative design, and compared these with literature on Collaboration Engineering and Group Support Systems to determine key collaboration challenges and associated guidelines for collaboration support.

2 Collaborative Design

A typical design or problem solving process (Couger, 1995, Ackoff, 1978, Mitroff et al., 1974, Simon, 1973, Checkland, 1981) contains various iterative and dynamic steps, and for each of these steps several collaborative activities and practices can be identified. These are listed in table 1.

Table 1. Collaborative activities in problem solving.

Step	Collaborative activities
Problem Identification	Goal setting
	Project kick off meetings
	Strategy building
Analysis and Modeling	Requirements negotiation
	Stakeholder analysis
	Focus groups
	Collaborative modeling
Identify alternatives	Creativity
	Brainstorming
	Prototyping
Selection	Consensus building
	Multi criteria decision making
	Expert panels
	User feedback sessions
Implementation	Communities of practice
	User/customer panels
	User training
	Technology transition

While all these collaborative processes are different in nature, Collaboration Engineering, a discipline to design collaborative work practices (Kolfschoten & Vreede, 2009), has distilled several patterns of collaboration, Generate, Reduce, Clarify, Organize, Evaluate and Build Consensus (Kolfschoten, Vreede, Briggs, & Sol, 2010). These patterns are derived in studies where collaboration is facilitated by an external facilitator (Briggs, Vreede, & Nunamaker, 2003). While these patterns describe the collaborative activities in problem solving, they ignore the self-coordinating activities of teams to form a community and focus their effort on the design project. The total overview of activities is then listed below.

1. Share and generate knowledge
2. Focus to distill the information important for decision making
3. Clarify to create shared understanding
4. Organize information to reduce complexity and create overview
5. Evaluate and compare alternatives
6. Build consensus and commitment to decisions
7. Coordinating effort and establishing a team bond

For each of these collaborative activities we will next present the main sub processes in these activities, and the challenges that groups face in these activities, as identified in literature.

Share and generate knowledge. Knowledge sharing is extensively described as a key process underlying collaboration. Classically it is decomposed in explicit and tacit knowledge sharing (Nonaka, 1994). Explicit knowledge sharing concerns exchanging e.g. data, documents, reports, accounts and recordings, while tacit knowledge sharing concerns exchanging stories or experiences though streaming, or face to face, in more informal settings. When the design team needs to create new knowledge as opposed to sharing their experiences or expertise, they can do this for three purposes; to be creative and come up with new solutions, to gather input from the group such as e.g. requirements or concerns, and to get feedback on their design choices. Ideation, also called brainstorming (Osborn, 1953) is about finding new, creative, unique, useful innovative ideas for design or solutions. Divergence (Briggs, et al., 2003) concerns getting constructive input from the group to create an overview of different perspectives and relevant insights for decision making. This step is often used in the analysis phase of a design to get input from users. Finally, reflecting (Cheng & Deek, 2007) concerns creating understanding of the relative value or quality of a property or characteristic of design concepts or design alternatives. Reflecting is used in user evaluations and feedback panels. Critical challenges in information exchange and knowledge sharing are that complex engineering tasks require knowledge sharing across disciplines and knowledge transition to operational level, which requires overcoming differences in language, education and culture. Further, participatory design approaches require knowledge sharing with the client, users, and stakeholders involved in the design, who are often less knowledgeable about the specific workings of the domain. When new knowledge is generated, for instance for innovative products and services, they require cross-domain creativity. Creativity is a challenge on its own, as it requires out-of-the-box thinking. Further, the complexity of systems often requires involvement of different experts creating larger volumes of information about a product which can cause information overload (Eppler & Mengis, 2004).

Focus to distill the information important for decision making. Once the group has shared and generated information about the design, they need to focus and reduce the information to a manageable set of concepts. Two key approaches are used to help the group focus, one is filtering in which concepts that meet the criteria to fit in the scope of the decision are selected, and on is summarizing or abstracting, in which the knowledge of the group is distilled to a set of concepts that cover the complete set of perspectives regarding the issue, but are concisely formulated without overlap or redundancy. Focusing can be challenging as it requires consideration and analysis of a large volume of information which is cognitively complex. Further, it can be difficult for the group to find the right level of abstraction for decision making. Finally, it is important in this phase to keep all the different perspective, as the purpose is to focus, not yet to evaluate and make choices. In this process, keeping people on board is critical.

Clarify to create shared understanding. An important aspect of collaborative design, and especially design of complex systems is to create shared understanding and shared mental models of the design. Briggs et al (2005) describe three aspects of misunderstanding; differences of meaning, information asymmetry and differences of mental models. These misunderstandings can be caused by different stakes, domains, languages, cultures, education levels, backgrounds, etc. The more diverse and global the design team is, the more of these misunderstandings can occur. Besides differences in participants, misunderstanding can also be based on a mix up of the system as it currently functions, as it should function according to standards and prescriptions, and as it should be changed to meet new requirements and needs (Barjis, Kolfschoten, & Verbraeck, 2009).

Organize information to reduce complexity and create overview. Organizing helps the group to identify relations among concepts and to structure the information shared by the group (Briggs, et al., 2003) there are many different modeling convention to organize ideas. Organizing requires high cognitive effort of the participants. The most conventional are to categorize ideas in clusters or categories, to sequence concepts to represent a timely order or process and to identify and create shared understanding about causal relationships among concepts (Kolfschoten & Brazier, 2012). When organizing, it is challenging to integrate different perspectives such as system and process perspectives, and models from different domains, created in different languages. Furthermore, the challenge of balancing rigor and relevance; use of rigorous methodology versus practical implementation driven by budgets and deadlines, which often plagues engineering and design efforts, especially in the conceptual design phase (Piirianen, Kolfschoten, & Lukosch, 2010). Finally, a challenge that is critical in organizing is to keep a link between models of different abstraction levels.

Evaluate and compare alternatives. Evaluation and comparison of alternative design choices is an important phase of the design effort, and occurs especially around critical go no-go decisions in the product life cycle. Evaluations can reflect two aspects; judgments of quality, and elicitation of preference (Cheng & Deek, 2007). Furthermore, evaluations can be made by voting, or by means of more qualitative feedback such as reviews, feedback or reflections. A challenging aspect of evaluation is to untangle objective quality assessments from subjective stakeholder arguments, both at an individual level (career versus project) and at a group level (assessment versus negotiation). This results often in satisficing quality, in which conflicting stakes, quality criteria, and requirements are balanced (Piirianen, et al., 2010).

Build consensus and commitment to decisions. Once alternatives have been evaluated, groups face the challenge of decision making. Depending on the organizational structure of the organization, these decisions are made by one or more stakeholders. However, often it is useful to base decisions on consensus of experts, and to get commitment from critical stakeholders about the decisions, to develop buy-in which is required for effective implementation of decisions. Challenges in this occur when the consensus of the design team reflects a different opinion then the responsibilities of the leader. Decisions during the design process are often based on expertise from different domains, requires designers to trust each other in their judgment of decision implications, as no single person can oversee the full complexity of the system. Further, a critical challenge is to move from consensus to commitment, to create ownership and transfer solutions to practice and sustainable use.

Coordination and team building. During the constructive process of design and problem solving, the design team needs to coordinate their effort in a structure of roles, tasks and rights. While coordination requires some level of leadership, teams of experts often coordinate many activities amongst themselves. This triggers more soft coordination mechanisms such as reciprocity. Important for coordination is to create a team bond, a professional relation based on a shared set of behavioral rules. Challenging in this process is that the team needs to record the rationale behind their choices for future evaluation and organizational learning, to create a history. Next, team members and stakeholders can have different levels of interdependency, which makes them focus on either short or long term collaboration. Another challenge is that teams can develop a tunnel vision when they close themselves off for external critique. Finally, team members can use strategic behavior and hidden agenda's to achieve their goals. Furthermore, besides teams, communities can be organized around a design challenge. Critical for the effectiveness of such communities is to engage participants, to keep them interested in participating. This is for instance critical in open source design and development, and requires the design of reward systems for effort.

With this overview of collaborative activities and associated challenges, we studied the successful concurrent design facility of the European Space Agency (ESA), to derive a first set of guidelines for effectively supporting collaborative design.

3 Key Components of Concurrent Design

We did 8 hours of observations of the Concurrent Design (CD) facility at ESA (Bandecchi, Melton, Gardini, & Ongaro, 2000; CDF, 2011). We studied the documentation about the facility and interviewed participants, a facilitator and staff in various roles in informal (group) interviews lasting from 30 minutes to 1 hour. The interviewer and observer took notes, which were worked out in an interview and observation report, which was checked by two CD staff members for errors and incomplete issues. Based on this verification, some minor additions were made. The documentation, observations and interviews were used to derive an overview of the facility, the roles involved and the process used for the concurrent design effort. Below, in Table 2-4 we list the process steps, roles and resources typically involved in CD.

Table 2. Steps of concurrent design.

Steps of the design cycle	
Welcoming new people.	If new experts join the team they are introduced, and introductions are made in the first session.
Setting the agenda.	In this step an overview of the progress and deadlines is presented and the presentations planned for the session are indicated.
Presentations.	In this phase presentations of important findings for design decisions can be given face to face or from remote positions. Presentations are stored on a central drive to use them later for reporting.
Discussion and decision.	Design decisions are made and parameters are agreed upon. A discussion usually takes place between the expert, the customer and the facilitator to determine the choice, sometimes other experts can explain implications of the choice for their systems right away.
Setting new tasks.	For open task, and for new tasks resulting from the design decision, experts are set to work on their calculations. Individual calculation of implications and design choices. In this phase experts work on actual design tasks for their subsystems. When they have results they notify the facilitator. Results are also recorded in the integrated design model, to ensure that other experts that use these numbers work with the most recent numbers for parameters that affect them.
Intermediate results.	When experts have results during the session that impact design decisions, they present them to the group, this can cause an iteration of steps 3-5.
Evaluation of KPI.	The integrated design model is reviewed for performance on mass or another KPI. During the session often the KPI calculation of subsystems changes and this is regularly reviewed. The KPI is also used to measure progress of the process as it shows who is finished calculating the parameters for his/her subsystem.
Closure.	At the end of the session tasks are assigned for next session.

Table 3. Roles in concurrent design.

Role	Description
Team Leader (i.e. Facilitator)	Responsible for planning, progress, facilitation of design sessions, decision making, customer relations, quality guarding, budget, and inviting experts.
Systems Engineer & assistant	Responsible for overview of the design on system level, recording decisions, identifying missing values and weaknesses in the design.
Domain experts	Responsible for design and calculation of feasibility of various domains and subsystems.
Technical Author	Recording of the minutes of the sessions and compilation and editing of the Concurrent Design study reports
Customer	Responsible for requirements.

Table 4. Resources available at the concurrent design facility.

Type	Description
Interface	Dual screens for participants with group and personal calculations
Presentation tools	Viewers, presentation screens and projectors.
Interaction tools	Audio & video conferencing, screen sharing, file sharing.
Integrated design model (IDM)	Software (Excel-based) visualizes interdependencies among design decisions related to different domains and subsystems.
Visualization tools	SmartBoards, 3D printers and prototyping tools.

Overall the CD approach offers tools to support communication and explanation of design decisions to increase shared understanding and learning in the design team. This process supports therefore the validity of the design though the rigor of the process and the informal peer-reviewing throughout the process. Finally the 'pressure cooker' approach of having all designers in the room or linked though video conferencing increases efficiency and flexibility of the design. The system and approach resembles a Singerian inquiry system (Churchman, 1971), in which multiple perspectives at the design are considered and integrated. This approach support the design team in creating a more holistic system view, based on multiple perspectives and consensus building in decision making.

While the process of CD is established, its precise goals and added value were not articulated as such. This is required, in order to assess its success and the need for collaboration support. Based on interviews with participants and facilitators of the CDF at ESA, and the literature on Group (Decision) Support Systems and Learning Systems we created a further overview of the added value of the CD process. We list here the five success factors we identified, and include a link to literature that further explains this success factor.

1) **Validity of design decisions**:

a. Interface management in the integrated design model, standardized for ESA, which helps the design team to stay aware of accurate values of interdependent parameters. Honda et al describe (Honda, Cucci, & Yang, 2009) how it is important that the implications of subsystem design are considered for the design of the overall system. Supporting the linking of subsystems and the interfaces between them is therefore a critical success factor for concurrent design.

b. Direct validation by other experts when design decisions are presented, and concerns are shared in the group. In CD experts present design tradeoffs to the group, and jointly discuss implications for design decisions in iterative cycles. Linstone and Turoff describe the Delphi approach in which consensus among experts is developed in iterative cycles to improve validity of decisions (Linstone & Turoff, 1975). Expert validation is therefore another critical success factor.

2) **Learning and Shared Understanding**: education of participants; experts are usually focused on their own subsystem and have limited knowledge of the interaction of their subsystem with other subsystems. In CD participants learn about these interactions, further they learn a lot about the implications of their design decisions for the overall performance of the system, broadening their knowledge beyond the scope of the sub-system of their expertise. Kolb's learning cycle includes experience, experimenting, reflection and conceptualization (Kolb, 1984). Likewise, CD is setup in a way that supports such full learning cycle as expert designers create simulations, that they present in the team, are supported to reflect on the implications of their design choices for the overall design, and based on this jointly make new design decisions. Supporting a complete learning cycle is a critical success factor as it enhances learning and shared understanding among the design team.

3) **Rigor**: The systems engineer keeps an integral overview of the progress of the study, and together with the facilitator ensures that the design process is followed step by step, which ensures completeness, and helps to detect errors improving rigor of the study (Hevner, March, Park, & Rahm, 2004). Following an approach and rigorous documentation is important to ensure complete consideration of design decisions. Therefore, rigor is a critical success factor.

4) **Flexibility**: with the presence of the customer in the CD sessions, implications of calculations can directly be discusses enabling direct discussion of adjustment of requirements to compromise impossibilities in the design. In the easy win win approach by Boehm et al. this inclusion of stakeholders is considered critical in order to ensure that both the design and user perspective are considered, and tradeoffs are made based on complete information (Boehm, Gruenbacher, & Briggs, 2001). Flexibility of the approach to facilitate consensus building and compromising tradeoffs is therefore an important success factor.

5) **Efficiency**: design cycles are short due to parallel work; dependencies between calculations can be discussed to avoid wasting time on calculations that later become invalid due to changing parameters, while keeping track of the critical path of the design. Remote participation enables reduction of travel time (Bostrom, Anson, & Clawson, 1993; Romano, Nunamaker, Briggs, & Mittleman, 1999). The efficiency of parallel work to enable full benefit of a collaborative approach is therefore a critical success factor.

4 Guidelines for Collaboration Support

Based on the observations at the ESA CDF facility, we generalized an overview of guidelines for collaboration support in an engineering context. We extended this overview with a number of intangible guidelines for effective collaboration that we derived from a reflection of the success factors listed above. Based on the overview of collaborative activities in design and engineering we discuss the guidelines derived from the case study and the literature.

Share and generate knowledge. An important factor in complex design challenges that require collaboration is the knowledge and skills or experiences to perform the task, or access to such knowledge (Briggs, 1994; Kolfschoten, et al., 2010). One prerequisite to access such knowledge is to learn from past projects for current problem situations. However, while it seems to be possible to capture explicit knowledge (e.g. about products and technical problems), softer types of knowledge (i.e. knowledge about the processes that a team had deployed to achieve their goals and why these processes seemed to have worked well or badly) are more difficult to retain and require novel approaches that e.g. rely on storytelling (Buttler, Lukosch, & Verbraeck, 2011; Lukosch, Klebl, & Buttler, 2011). Preferably, the team has knowledge or experience from different past projects and perspectives. This enables them to consider for instance different aspects of a problem or different implications of a decision, which can improve quality and support for the outcomes. Furthermore, in order to use expertise optimally, access to specific tools, databases or software might be required. Collaboration helps to create mutual learning and synergy when knowledge is shared and combined.
In CDF, there was little use of brainstorming tools as it focuses on feasibility studies in which most designs are based on existing solutions. However, when facing more creative tasks teams can benefit from the use of brainstorming tools to foster creativity, which can be combined with the use of frameworks to trigger multiple perspectives (Knoll & Horton, 2010).
Group Support Systems (GSS) help the group to capture the knowledge they generate, and to structure and manipulate it. Often they make use of so called ACTIVITY LOGS (Schümmer & Lukosch, 2007) which help to understand the interaction that has taken place. Ability for multiple people to add or edit shared documents is useful to support not only knowledge sharing, but especially also to support knowledge creation.

Guideline 1: Invite different users and stakeholders, and collaborate in multi-disciplinary teams to support effective knowledge sharing, knowledge reuse and multi-perspective thinking.
Guideline 2: Capture softer types of knowledge by fostering reflection and experience sharing among all stakeholders.
Guideline 3: For creative solutions use brainstorming tools in combination with frameworks to trigger multiple perspectives.
Guideline 4: Create a shared space for file sharing in which version management and access rights are easily managed.

Focus to distill the information important for decision making. Once design alternatives are explored, the CD process was facilitated to select those alternatives that were worth further investigation, to make a deliberate choice. While the ESA cases usually did not consider many options, focusing was less difficult. When many options are brainstormed, convergence to focus on those that need to be further considered is a critical process. Key here is not to lose valuable ideas, while creating sufficient focus to enable evaluation and comparison of alternatives.

Guideline 5: Create parsimony in the information, keep all feasible alternatives, but describe them concisely to remove overlap and redundancy, make choices based on evaluation.

Clarify to create shared understanding. In order to collaborate, the group needs to be able to communicate. Face-to-face communication conveys a message not just with its content, but also with expression, tone, body language, emotion, gestures, etc. Just communicating with text is therefore a very empty message, and makes it more difficult to develop aspects such as trust, affection or empathy (Romano, et al., 1999). Media Richness Theory (MRT) describes the ability to communicate through various communication media (Daft & Lengel, 1986). MRT states that the more ambiguous and uncertain a task is, the richer format of media helps to accomplish the task. Media Synchronicity Theory (MST) has been derived from and focuses on the ability of media to support the communication processes of individuals as they work on tasks (Dennis, Fuller, & Valacich, 2008). MST suggests that communication performance will be enhanced when media capabilities are properly aligned with the requirements around the conveyance of information and the convergence of meaning. For future understanding and improvement of collaborative interaction it is thus important to note what kind of media has been used.

Guideline 6: Use rich media to enable clarification and explanation, including video, audio, and shared workspaces.
Guideline 7: Separate content from meta-discussions, but if possible record and link them for future reference.

Organize information to reduce complexity and create overview. CDF offered a large set of visualization tools. Visualization of relations between concepts in a design is a critical means in problem solving. Visualization usually contain either models or sketches, but alternative approaches are e.g. to create mind-maps, ontology's, storyboards, or prototypes. The ability to visualize something can really enhance communication and enable participants to create shared understanding, as visualizations create boundary objects, that help collaborators to explain different perspectives and identify different viewpoints (Arias, Eden, Fischer, Gorman, & Scharff, 2000). The CDF facility circled their design cycles around the integrated design model. This model offers a structure that serves as a frame to link the design choices and discussions. Some more technical, complex, or design domains require even richer visualization for instance in 3D printing, prototyping or animation. CDF offers some interesting tools for simplistic 3D prototyping with pre-modeled blocks, and 3D printing. The modularity of these blocks allows the design team to flexibly adapt the model to explain different perspectives.

Guideline 8: Support different types of visualization to create and explain relations between elements of the design.
Guideline 9: Where possible, make visualizations modular en flexible to enable adaptation, this facilitates comparing of alternatives and explaining different structures.
Guideline 10: Use a framework to structure and organize information effectively

Evaluate and compare alternatives. The CDF evaluations are done in a spreadsheet that keeps track of all design parameters, and their certainty and then adds these to evaluate key performance indicators for the overall system. These are regularly updated and reviewed. For evaluation, it is important to have clear criteria and to be able to compare alternatives. Choices for design alternatives in CDF are documented by the systems engineer, and explained in a final report, for future reference. Often the client and the SE had a strong voice in the design decisions made, yet their preference was not recorded during the evaluations, only in the end decision. A better overview of quality assessment and preference would facilitate the evaluation process. When a group makes a choice or decision, this is important to record, so the group can later refer to it (Conklin & Begeman, 1988; Mohan & Ramesh, 2007). A minute's taker can do this, or it can be done in some separate document or on a shared page. Face to face this could be a flipchart, online; it can be a shared document or page. Important is that all participants can verify that the decision is captured as they understood it, to ensure support for the decisions made at a later point in time. When knowledge creation is complex, face to face groups often rely on more extensive support to capture knowledge such as voting systems, or Group Support Systems where all participants use a computer or other input device to contribute to the meeting (Nunamaker, Briggs, Mittleman, Vogel, & Balthazard, 1997).

Guideline 11: Evaluate in rounds, and clarify or analyze (generate, organize, focus) in between.
Guideline 12: Document the key considerations in favor and against an alternative for future reference.
Guideline 13: Separate preference from quality assessment to enable decision maker to separate stakes from objective evaluation, and in case of design in which aesthetic is important, taste and quality.
Guideline 14: for complex quality assessments use a multi criteria decision matrix to capture scores and enable rapid calculation of group assessments.

Build consensus and commitment to decisions. It is important that the group has a mandate to accomplish their task. This means that they need sufficient decision power to make the decisions required for their task (Bruijn & Heuvelhof, 2008). Decision making by consensus is usually preferable over autocratic decision making. While consensus building is not always easier, it does add to the usability and sustainability of the results, as these will be better supported. This democratic approach also is important during the process to ensure constructive feedback and reflection. This implies that people feel comfortable to contribute, and to perform their task. In CDF, the process of decision making was, although based on data and the design model rather informal as a procedure, and showed opportunity for the use of more rigor to ensure complete evaluation. Such procedure could also include a so-called 'devil's advocate' consideration to actively invite critique for scrutiny, and to avoid tunnel vision.
Commitment is based on proposals. CDF facilitators used this principle often to get feedback from the group and to stimulate thinking in choices rather than possibilities. Proposals help the group to make the transition from brainstorming and analysis of alternatives to evaluation and choice.

Guideline 15: Create clear rules for decision making to ensure rigor and to avoid perceived unfairness.
Guideline 16: Actively invite critique on design alternatives to avoid implicit acceptance.
Guideline 17: To move from exploring design alternatives to choice, make a proposal for the group to discuss.

Coordinating effort and establishing a team bond. The CDF environment has a communication system that supported turn-taking for speaking. In a face-to-face setting, groups often develop a 'code of conduct' on how to behave effectively and how to organize speaking terms, etc. In an online environment, or with larger groups, this is more difficult. Coordinating speaking turns, the use of the right tools for the right tasks and the synchronization of activities require the ability to coordinate access to communication channels and collaboration tools. For this purpose, it is useful if one participant (facilitator) can coordinate access by means of concurrency control (Greenberg & Marwood, 1994) or floor control mechanisms (Dommel & Luna-Aceves, 1997), and has the ability to grant or deny access during the collaboration process.
The CDF approach offers a cycle of steps, which is conveyed in an agenda. Further, the facilitator and Systems Engineer guided the group in their collaborative effort. In order to give a group a complete and clear set of instructions we need to specify 'rules' to guide their actions. To support coordination, six levels of coordinating mechanisms need to be created (Briggs et al., 2009):

- The group goal and the individual stakes in participating.
- The quality of the outcome, and criteria for quality of the deliverables.
- The agenda, the steps the group moves though to accomplish their goals, and the deadlines for these steps
- The techniques, tools and methods used by the group, the way they work.
- The roles in the group.
- The behavior of the group members.

CDF offers an overview of the people in the room, and their expertise and role. It also places the agenda on a central position. The goal was listed in the design model, but could be further clarified. The criteria for outcomes and deliverables were less clear and were managed by the facilitator. Techniques and tools were familiar for the users, as well as behavioral rules.
When working online, it is less easy to find out who the other people in the group are, and what their expertise is. Yet this type of information is needed in order to build trust and to make optimal use of the skills and expertise available in the group (Rusman, Bruggen, Sloep, Valcke, & Koper, 2010). For this purpose it is useful to support having and extensive profile, and enabling the creation of a virtual image of the participants. Furthermore, for some tasks it is important to create awareness support to understand

what participants are doing (Dourish & Bellotti, 1992), and where they are (Antunes, Sapateiro, Pino, Herskovic, & Ochoa, 2010).

In CDF, we observed different levels of engagement and motivation for experts to participate in the design studies. People make an assessment of utility of participation, and the likelihood that participation will help them to achieve personal goals (Briggs, 2006). People's drive to participate can have many sources, ranging from economic motivations to affective motivations, based on a person's relation with the group. This range of motivations needs to be aligned with the group goal. Trust in the abilities and effort and intentions of others is critical for motivation. Also, when participants perceive a process as ineffective, this can reduce motivation. Motivation is increased when the process is pleasant and when people feel appreciated for their contribution, and if they feel they make progress on their work (Kolfschoten, et al., 2010). When groups are collaborating effectively, participants are engaged in the task. The state in which people are fully concentrated on a task and immerse themselves in the collaboration is also called flow. Engagement helps people to focus on the task (Czikszentmihalyi, 1990).

Guideline 18: Create awareness of activity and facilitate turn taking and joint editing to coordinate effort.
Guideline 19: Create a clear overview of goals, deliverables, agenda, techniques, roles and behavior, and keep an overview of progress for all of these.
Guideline 20: Share sufficient personal information among participants to support trust building and optimal use of the expertise in the group
Guideline 21: Explore participant's personal motivation for participation, and ensure sufficient goal alignment and incentive for participation.
Guideline 22: When working with longer-term or recurring teams, create sufficient team-bond to sustain relations and create commitment.

5 Conclusions and Further Research

Collaboration among designers, users and stakeholders adds to the complexity of multidisciplinary system design. In this paper, we presented a set of guidelines for collaborative design, derived from literature and a study at the ESA concurrent design facility. The guidelines cover different phases of a collaborative design or problem solving process, and cover process, people and problem analysis activities. Collaborative activities are required throughout the design cycle, and their complexity increases with the complexity of the designed artifact. Designers need to structure their collaborative effort mainly to increase shared understanding, and to validate their design and ensure rigor. Furthermore, collaborative design can increase flexibility and efficiency.

The guidelines presented here have several implications for research and practice. In practice, the guidelines can be used by collaboration engineers, facilitators and practitioners to design collaborative work practices for design and engineering projects. For research, the guidelines can serve as a basis for the development of design patterns or a design pattern language for collaborative design, and a framework for the organization and selection of collaborative design activities. Further research is required to validate the guidelines that we derived in a different setting and to generalize them across different approaches to collaborative and participatory design.

References

Antunes, P., Sapateiro, C., Pino, J. A., Herskovic, V., & Ochoa, S. F. (2010). Awareness Checklist: Reviewing the Quality of Awareness Support in Collaborative Applications. In G. Kolfschoten, T. Herrmann & S. Lukosch (Eds.), *Collaboration and Technology* (Vol. LNCS 6257). Berlin Heidelberg: Springer Verlag.

Arias, E., Eden, H., Fischer, G., Gorman, A., & Scharff, E. (2000). Transcending the Individual Human Mind—Creating Shared Understanding through Collaborative Design. *ACM Transactions on Computer-Human Interaction, 7*(1), 84-113.

Bandecchi, M., Melton, B., Gardini, B., & Ongaro, F. (2000). *The ESA/ESTEC Concurrent Design Facility.* Paper presented at the EuSEC.

Barjis, J., Kolfschoten, G. L., & Verbraeck, A. (2009). Collaborative Enterprise Modeling. In E. Proper, Harmsen, F., Dietz, J.L.G. (Ed.), *Advances in Enterprise Engineering II.* (Vol. LNBIP 28, pp. 50-62). Berlin: Springer-Verlag.

Beck, K. (2000). *Extreme Programming Explained, Embrace Change*: Addison-Wesley.
Boehm, B. (1988). A Spiral Model of Software Development and Enhancement. *IEEE Computer, 21*(5), 61-72.
Boehm, B., Gruenbacher, P., & Briggs, R. O. (2001). Developing Groupware for Requirements Negotiation: Lessons Learned. *IEEE Software, 18*(3).
Bostrom, R., Anson, R., & Clawson, V. K. (1993). Group Facilitation and Group Support Systems. In L. M. Jessup & J. S. Valacich (Eds.), *Group Support Systems: New Perspectives*: Macmillan.
Briggs, R. O. (1994). *The Focus Theory of Team Productivity and its Application to Development and Testing of Electronic Group Support Systems*. Tucson.
Briggs, R. O. (2006). *The Value Frequency Model: Towards a Theoretical Understanding of Organizational Change.* Paper presented at the International Conference on Group Decision and Negotiation, Karlsruhe.
Briggs, R. O., Kolfschoten, G. L., & Vreede, G. J. d. (2005). *Toward a Theoretical Model of Consensus Building.* Paper presented at the Americas Conference on Information Systems, Omaha.
Briggs, R. O., Kolfschoten, G. L., Vreede, G. J. d., Albrecht, C. C., Lukosch, S. G., & Dean, D. L. (2009). *A Seven-Layer Model of Collaboration: Separation of Concerns For Designers of Collaboration Systems.* Paper presented at the International Conference on Information Systems.
Briggs, R. O., Vreede, G. J. d., & Nunamaker, J. F. j. (2003). Collaboration Engineering with ThinkLets to Pursue Sustained Success with Group Support Systems. *Journal of Management Information Systems, 19*(4), 31-63.
Bruijn, J. A. d., & Heuvelhof, E. F. t. (2008). *Management in Networks: On Multi-Actor Decision Making*. London: Routledge.
Buttler, T., Lukosch, S., & Verbraeck, A. (2011). *Frozen Stories -- Capturing and Utilizing Frozen Stories for Teaching of Project Managers*. Paper presented at the International Conference on Computer Supported Education.
CDF, E. (2011). ESA Concurrent Design Facility. Retrieved 4-2-2011, 2011, from http://www.esa.int/esaMI/CDF/index.html
Cheng, K. E., & Deek, F. P. (2007). *A Framework for Studying Voting in Group Support Systems.* Paper presented at the Hawaii International Conference on System Sciences, Waikoloa.
Churchman, C. W. (1971). *The Design of Inquiring Systems, Basic Concepts of Systems and Organizations*. New York: Basic books, Inc publishers.
Conklin, J., & Begeman, M. L. (1988). gIBIS: a hypertext tool for exploratory policy discussion
ACM Transactions on Information Systems, 6, 303-331.
Czikszentmihalyi, M. (1990). *Flow. The psychology of optimal experience.* New York: Harper Perennial.
Daft, R. L., & Lengel, R. H. (1986). Organizational information requirements, media richness and structural design. *Management Science, 32*, 554-571.
Dennis, A. R., Fuller, R. M., & Valacich, J. S. (2008). Media, tasks, and communication processes: A theory of media synchronicity. *Management Information Systems Quarterly, 32*(3), 575-600.
Dommel, H.-P., & Luna-Aceves, J. G. (1997). Floor control for multimedia conferencing and collaboration. *Multimedia Systems, 5*, 23-38.
Dourish, P., & Bellotti, V. (1992). *Awareness and Coordination in Shared Workspaces.* Paper presented at the Computer Supported Collaborative Work.
Eppler, J. M., & Mengis, J. (2004). The Concept of Information Overload: a Review of Literature from Organizational Science, Accounting, Marketing, MIS and Related Diciplines. *The Information Society, 20*(5), 325-344.
Greenberg, S., & Marwood, D. (1994). *Real Time Groupware as a Distributed System: Concurrency Control and its Effect on the Interface*
Paper presented at the ACM 1994 Conference on Computer Supported Cooperative Work.
Herder, P. M., & Bruijn, H. d. (2009). System and Actor Perspectives on Sociotechnical Systems. *IEEE Transactions on Systems, Man, and Cybernetics, 39*(5), 981-992.
Hevner, A., March, S., Park, J., & Rahm, S. (2004). Design Science Research in Information Systems. *Management Information Systems Quarterly, 28*(1), 75-105.
Honda, T., Cucci, F., & Yang, M. C. (2009). *Achieving Pareto Optimality in a Decentralized Design Environment*. Paper presented at the International Conference on Engineering Design.
Knoll, S. W., & Horton, G. (2010). *Changing the Perspective: Improving Generate thinkLets for Ideation*. Paper presented at the Hawaii International Conference on Systems Science.
Kolb, D. A. (1984). *Experiential Learning*. Englewood Cliffs, NJ: Prentice Hall.
Kolfschoten, G. L., & Brazier, F. (2012). *Cognitive Load in Collaboration - Convergence*. Paper presented at the Hawaii International Conference on System Science.
Kolfschoten, G. L., & Vreede, G. J. d. (2009). A Design Approach for Collaboration Processes: A Multi-Method Design Science Study in Collaboration Engineering. *Journal of Management Information Systems, 26*(1), 225-256.
Kolfschoten, G. L., Vreede, G. J. d., Briggs, R. O., & Sol, H. G. (2010). Collaboration 'Engineerability'. *Group Decision and Negotiation, 19*(3), 301-321.
Linstone, H., & Turoff, M. (1975). *The Delphi Method: Techniques and Applications*: Addison Wesley Advanced Book Program.

Lu, S.-Y., Elmaraghy, W., Schuh, G., & Wilhelm, R. (2007). A Scientific Foundation of Collaborative Engineering. *CIRP Annals - Manufacturing Technology, 56*, 605-634.

Lukosch, S., Klebl, M., & Buttler, T. (2011). Utilizing Verbally Told Stories for Informal Knowledge Management. *Group Decision and Negotiation, 20*, 615-642.

Mohan, K., & Ramesh, B. (2007). Traceability-based knowledge integration in group decision and negotiation activities. *Decision Support Systems, 43*, 968-989.

Neufville, R. d., & Scholtes, S. (2011). *Flexibility in Design*. Cambridge, MA.: MIT Press.

Nonaka, I. (1994). A Dynamic Theory of Organizational Knowledge Creation. *Organization Science, 5*(1), 14-37.

Osborn, A. F. (1953). *Applied Imagination*. New York: Scribners.

Piirianen, K., Kolfschoten, G. L., & Lukosch, S. G. (2009). Unraveling Challenges in Collaborative Design: a Literature Study. In L. Carricio, N. Baloian & B. Fonseca (Eds.), *Groupware: Design, Implementation and Use* (Vol. LNCS 5784, pp. 247-261). Peso da Regua, Duoro, Portugal: Springer.

Piirianen, K., Kolfschoten, G. L., & Lukosch, S. G. (2010). *In Search for the Right Tools to fix the Right Problem: A Look into the Challenges of Collaborative Design.* Paper presented at the Hawaii International Conference on System Science, Kauai.

Romano, J. N. C., Nunamaker, J. J. F., Briggs, R. O., & Mittleman, D. D. (1999). *Distributed GSS Facilitation and Participation: Field Action Research.* Paper presented at the Hawaii International Conference on System Sciences, Los Alamitos.

Royce, W. W. (1987). *Managing the development of large software systems: concepts and techniques*
Paper presented at the 9th international conference on Software Engineering.

Rusman, E., Bruggen, J. v., Sloep, P., Valcke, M., & Koper, R. (Eds.). (2010). *The Mind's Eye on Personal Profiles; How to Inform Initial Trustworthiness Assessments in Virtual Project Teams* (Vol. LNCS 6257). Berlin Heidelberg: Springer Verlag.

Schuler, D., & Namioka, A. (1993). *Participatory design: Principles and Practices*
Erlbaum.

Schümmer, T., & Lukosch, S. (2007). *Patterns for Computer-Mediated Interaction*. West Sussex, England: John Wiley & Sons Ltd.

Shen, Y., Ong, S. K., & Nee, A. Y. C. (2010). Augmented Reality for Collaborative Product Design and Development. *Design Studies, 31*(2), 118-145

Shyamsundara, N., & Gadhb, R. (2002). Collaborative Virtual Prototyping of Product Assemblies over the Internet. *Computer-Aided Design, 34*(1), 755-768.

Designing Collaboration Support for Dynamic Environments

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Abstract: Collaboration within the product lifecycle can be defined as an integrated and information-driven approach that includes people, procedure and technology. In such processes, experts from different areas related to the product collaborate with each other, in different phases of the lifecycle. For example, in the usage phase, according to new maintenance strategies such as predict and prevent (PaP), maintenance teams formed by designers and maintenance experts have to work together to formulate the diagnosis of a certain product, preventing its downtime or breakdown. However, such task can be challenging because of the dynamics of the situation. In some cases the available time for collaboration can be limited and the performance of a product can quickly change. Therefore, in order to overcome such challenges, we present a system model to support collaboration in such a situation. This system supports the provision of product data streams, during the whole lifecycle on real-time and adapts the collaboration tools proposed by teams.

Keywords: Collaboration Support Tool, Collaboration, Collaboration Process Design, Collaboration Process Adaptation, Product Lifecycle Management.

1 Introduction

Nowadays products are managed across their lifecycle. A product lifecycle is a multi-stage process beginning with a first product idea, to its definition and realization, product support (including service and maintenance) and ending with the disposal of a product (Stark, 2004). Product lifecycle management (PLM) can be defined as a collaborative, integrated and information-driven approach that includes people, procedures and technology (Jia, Geng, & Huang, 2011). The objective of PLM technologies is to support organizations in planning and controlling their product lifecycles by providing methods and tools for information and process management as well as for the integration of enterprise software (Abramovici, 2007). Besides the management of data and processes, PLM offers tools for collaboration among networked participants in product value chains (Ming et al., 2008).

Due to changes in technology, business and economy, today's organizations act in a dynamic environment that leads to new challenges for their product lifecycle (e.g. changing market strategies or to support geographically dispersed design teams). From the literature, different needs for future PLM solutions can be identified. For example, Ming et al. (Ming et al., 2008) indicates the need for new technology solutions to support collaboration across multiple organizations and virtual teams. Here, intelligent support can be used to manage the collaboration activities that are tailored to the special needs of global and virtual teams (Hayes, Goel, Tumer, Agogino, & Regli, 2011). Abramovici (Abramovici, 2007) analyzed the future trends of given PLM solutions along the product lifecycle. He sees main weaknesses of existing PLM solutions in the poor support of product lifecycle activities outside the production phase and missing industry standards for PLM meta-data models and for PLM processes.

In the context of engineering, a suitable definition of good collaboration is the one introduced by Wood and Gray: collaboration occurs when a group of autonomous stakeholders of a problem domain engage in an interactive process, using shared rules, norms, and structures, to act or decide on issues related to that domain (Wood & Gray, 1991). According to this definition, collaboration in engineering becomes difficult not just because of the nature of a complex product, but also because collaboration is a

dynamic process that is based on human behavior. As a result, it is difficult to prescribe collaboration processes for a PLM, and consequently to support such processes.
Based on technology and sensors that can be used to generate data streams from products in use, this paper identifies a further potential in the use of data streams to characterize the dynamic environment of a product lifecycle. This information can provide a basis for the design of a new technology that supports collaboration in a dynamic environment like the PLM. For our study we focus on a part of the product lifecycle: the maintenance of a product. However, we envision generalizing and applying our findings to a broader scope of the product lifecycle.

Collaboration support has been studied in various research domains such as groupware, group (decision) support systems, concurrent design tools and group facilitation (Nunamaker, Briggs, Mittleman, Vogel, & Balthazard, 1996) (Kolfschoten, den Hengst, & de Vreede, 2007). As a result, different types of collaboration support technologies are developed with different aims based on different domain perspectives. In complex design and engineering phases, different tools and techniques are useful at different points in the product lifecycle. However, adopting and using collaboration support tools, requires expertise, and therefore might benefit from support.

This paper discusses the model of a system that improves collaboration within the product lifecycle process, for construction equipment. Based on design science research methodology by (Hevner, March, Park, & Ram, 2004), the paper presents a use-case scenario for the use of product data streams to characterize the dynamic environment of the product lifecycle in the construction industry. The scenario results from a workshop and online group interviews with different PLM experts in the construction industry and is used to define requirements for a collaboration support system that improves collaboration in PLM by using product data streams. Based on these requirements, this paper presents a system model of a collaboration support system for PLM.

2 Requirement Analysis

The requirement elicitation for this paper is based on a scenario, which resulted from a series of workshops and online interviews with twelve PLM experts from the construction industry in Sweden. For instance, product engineer, maintenance engineer, service engineer and researcher, participants were deemed to be appropriate subjects for this research, because they are familiar with different process stages of the PLM and experts in their domain. During the workshops and online interviews the participants were instructed to describe their work in relation to the PLM. A structured interview was used to identify existing challenges for processes, actors and data of the PLM. These challenges were used to collect ideas on how product data streams can the improvement of the PLM. The experts indicated that in modern product development, different knowledge domains are integrated in order to develop new services and sustainable product solutions. Traditionally, the product and services performance are evaluated through (i) the time that designers consume to develop the products, (ii) the costs assigned for product prototyping, (iii) laboratory tests and (iv) tests on the construction site together with selected customers.

In line with (Abramovici, 2007), the construction industry recognizes a need for new PLM systems that support product lifecycle activities outside the production phase. Currently, when the product is introduced to the market the link between the manufacturers and customers is usually broken. But risk and profit sharing incentives and agreements are still in place between supplier and customer. It is of high importance that the system supplying the function, and thus the available productivity, does operate according to the agreement, otherwise the supplier may have to cover the losses of the customer. Experts suggest keeping this link by using product sensors, which generate telemetric data that can be used as feedback to the manufacturer about product usage. In this way, manufactures can provide proactive maintenance services, in which, maintenance teams use telemetric data to diagnose malfunctioning products and execute preventive actions, avoiding equipment downtime. The key concept for tracking equipment data allows companies to migrate their traditional fail and fix (FAF) methodology into a predict and prevent (PAP) methodology. PaP addresses the fundamental needs of predictive intelligence tools to monitor the degradation of an equipment usage in order to allow interventions to be taken before a unscheduled downtime or unexpected breakdown (Levrat, Iung, & Crespo, 2008).

2.1. Scenario

Maintenance experts go through a maintenance process to analyze the use of product data streams and collaboration support for the use phase of the product lifecycle. In this scenario, a remote infrastructure is connected to a construction machine to keep it continuously functioning. For example, a machine can contain sensors to identify the position of the machine, measure fuel levels, vibration of the engine, temperature, and speed. If machine degradation is detected, e.g. the engine of a machine operating over certain thresholds, the monitoring infrastructure immediately reports a problem to the maintenance expert. The expert mobilizes a maintenance team to perform preventive actions. These actions aim to avoid machine breakdown. For this purpose, experts have to quickly analyze and understand machine problems, and to identify solutions. Due to the involvement of expertise from different backgrounds, this process often requires collaboration. The team has to identify machine failures, malfunctioning components, its causes and consequences, and it has to define action plans in a dynamic situation.

The experts we interviewed indicated that some maintenance support systems provide support to a maintenance team to analyze equipment telemetric data, but do not support the use of collaboration techniques neither collaboration processes (Blanzieri, Portinale, Ferrario, & Smyth, 2000) (Yu, 2003) (Garcia, Guyennet, Lapayre, & Zerhouni, 2004). Planning collaboration in a dynamic situation introduces new challenges that are not traditionally considered in collaboration process design. These challenges originate in the dynamics and short problem solving cycles in the process, causing uncertainty about the time available, the goals, requirements and participants for the collaboration process. The sudden variation of requirements for collaboration imposes difficult constraints for a collaboration process. This situation creates a challenge for domain experts, as they constantly need to adapt the way they work together. Generally, domain experts are not knowledgeable in collaboration process design, and neither have access to collaboration process designers such as facilitators. It is difficult to include a collaboration designer in a maintenance team, whenever machines are about to breakdown. But also facilitators and collaboration process designers generally create a process on beforehand. However, in a situation where time, group composition and goals change over the cause of the process, designers would be forced to constantly adapt the process during runtime. Therefore, a core challenge in this scenario is to capture and model the knowledge of collaboration process designs and reuse such knowledge to adapt the processes during runtime in a way that domain experts without facilitation or collaboration process design expertise can use it effectively.

2.2. Challenges of Collaboration

The scenario, introduced in the previous section, indicates that in dynamic situations like maintenance: (i) the time planned for a collaboration session can suddenly vary, (ii) the original goal of the session can dynamically change, (iii) the participants required to solve the problem can change, and consequently, (iv) the collaboration process is constantly redesigned during the session. This matches the four key design concerns in collaboration processes: the goal, the resources, the participants, and the tools/techniques to support the problem solving process (Kolfschoten & de Vreede, 2009). The next sections will discuss these challenges for collaboration design in more details, before we elicit the requirements for a collaboration support system for PLM.

2.2.1. Challenges for Collaboration Design: Varying Goal

One of the pre-requirements for designing collaboration processes is to understand the goal of the collaborative activity. In traditional approaches, the designer of the process has to understand in detail the outcomes that should be generated to design the process accordingly. Professional facilitators are skilled to adapt the process when their understanding of the collaboration goal changes. However, this can lead to a less efficient and effective collaboration process. Domain experts will not have this expertise.

In industrial machine maintenance processes, the goal of the collaboration might change. For example, a machine might break down, and its failure (e.g. temperature rise) could accelerate to create a potentially unsafe situation. Because of change in degradation speed, the collaboration support system used by maintenance team has to support detection of changed requirements to the intervention, and dynamically also change the collaboration process to mitigate the risk, and guide the group to decide on an intervention. Instead of collaborative fail cause identification, they have to work collaboratively on an isolation plan for the machine, avoiding people to get accidentally injured. Therefore, collaboration support systems should be able to adapt the collaboration techniques and sequence of activities planned in a collaboration process, to be executed by a maintenance team.

2.2.2. Challenges for Collaboration Design: Varying Resources

A normal practice in collaboration process design is to get information about the collaboration task, the group, the resources available, and in particular the total amount of time that is available to collaborate (Kolfschoten & de Vreede, 2009). Based on this information, the designer carefully chooses different techniques of facilitation to be used during the collaboration.

In dynamic situations, the time available might change, which requires process adaptation. For example, a maintenance team can face a hard deadline due to an underperforming cooling sub-system of a machine. Based on the time available, the team plans to discuss and investigate the problem before taking actions. However, a faster overheating than expected might force the team to abandon the original plan as they should quickly brainstorm to prevent machine failing.

Another resource that might be less available, or vary in availability, is presence. While mobile workers might have a smartphone to communicate, teams will not always be able to communicate face to face, or through a computer interface, they might face more restrained connectivity, which requires use of different collaboration techniques (Romano Jr, Briggs, Nunamaker Jr, & Mittleman, 1999).

Designing a suitable collaboration process, in the traditional way, is a matter of balancing between the available time and resources for a collaboration session and an estimation of the amount of time and attention the participants will spend on each process activity. However, in dynamic situations, the collaboration process should be flexible. Therefore, the collaboration support system should be able to adapt the process, techniques and tools.

2.2.3. Challenges for Collaboration Design: Changing Participants

A collaboration process is designed for a specific group of people. These people need to have the expertise and decision power to resolve the problem, and they need to be committed and motivated to solve the problem (Kolfschoten & de Vreede, 2009). If the goal and resources available for a collaborative problem solving process are changing, this might also require different people to solve the problem. When the problem becomes more severe, or time pressure increases, it might be required to invite experts or decision makers into the process, and also, when remote participants loose connectivity, they might need to be replaced.

In our example, it might be that a decision maker is required to decide to take the machine out of service, and an operator is required to ‘pull the plug’. These participants can then be invited in the collaboration process, so they can quickly catch up with the cause of events, and the previous discussions of the maintenance team.

2.2.4. Challenges for Collaboration Design: Changing Needs for Collaboration Support

A collaboration process has to be designed on demand in real-time, whenever collaboration occurs in dynamic situations.

In dynamic situations, the necessary context information is previously unavailable, making it difficult for designers to prepare a collaboration process for a specific session. If the designers have to model a process in such circumstances, they would have to consider all possible alternatives for the collaboration session, creating a complete but generic process. Although being generic and suitable to many different situations, the process however would not be proper to any particular one, making it less efficient and effective. In this context, a collaboration support system should record context information and, based on this, design the collaboration process in real time and adaptable to dynamic requirements.

2.3. Requirements for Flexible Collaboration Design

In the scenario described above, a collaboration process has to be designed on demand in real-time, whenever collaboration occurs in dynamic situations. Based on the above challenges, different requirements for a collaboration support within a PLM system can be identified. The scenario indicates the use of data streams as an input for the detection of a collaboration need. Further data streams can be used as an input for the collaboration process itself; providing information that will be needed in processes like failure analysis. The formation of the group during collaboration is a key issue for collaboration success. As employees of a company can work geographically distributed the identification of the right member for a team can be challenging, as status and availability might not be known. Furthermore, the scenario indicates different tools for collaboration that need to be used in different steps of the dynamic process. Currently, most of these tools are specialized for a specific collaboration task that can make it necessary to use a huge collection of tools during collaboration. Another key value of the scenario is the identification of the product lifecycle as a dynamic process, because data streams of a product can constantly change during its lifecycle. Therefore, collaborative processes and tools need to follow such dynamics and adapt themselves whenever it is necessary. In conclusion, we identify the following requirements for collaboration support within a PLM system:

- **R1 – to detect the need for collaboration support**: a PLM system needs to provide tools and methods to analyze data streams from product lifecycle to detect the need for collaboration;
- **R2 – to find the right experts**: a PLM system needs to provide tools and methods to support group formation and collaboration in virtual teams;
- **R3 – to find the right information**: a PLM system needs to provide tools and methods to filter relevant information from the product lifecycle data streams, information which is needed to support collaboration;
- **R4 – to support collaboration in a dynamic environment**: a PLM system need to provide tools and methods that support the design and execution of collaboration under the constraints of varying goals, resources, time available and expertise needed.

3 System Model for Collaboration Support in a Dynamic Environment

This section presents a system model for collaboration support in dynamic environments like the product lifecycle. This model describes how data streams can be used to describe the collaboration context. Dey et al. (Dey, Abowd, & Salber, 2001) define context as any information used to characterize a situation of an entity where an entity may be any object, person, or place. Context provides information about the interaction between a user and an application. From the literature review, different models can be found to describe a collaboration environment and collaboration situations. For example, Pattberg and Fluegge (Pattberg & Fluegge, 2007) define collaboration with an ontological approach that uses a structure of various levels of abstraction. These levels clarify the relation of a proven solution for a collaboration problem to a collaboration services and to the underlying communication technology of a collaboration process. Another model approach is given by Rajsiri et al. (Rajsiri, Lorré, Bénaben, & Pingaud, 2008). They define a collaboration network ontology that is composed of a collaboration ontology and a collaboration process ontology. The collaboration ontology characterizes the collaborative network, details and abstract services of participants. The collaborative process ontology defines the task of the participants at a functional level, which has input and output resources.

This paper adopts the ontological approach to describe the collaboration context and combines it with different data streams from the product lifecycle. The paper distinguishes different data streams that can be used to describe the context of a product lifecycle (SmartVortex, 2011). Streams from sensors and analysis equipment are produced by products in use by customers and contain telemetry data that are consumed by the expert of the manufacturer for maintaining the equipment. The data of these data streams can be used to measure the performance of a machine and detect the need for collaboration like a maintenance process. For example, one of the sensors of a machine can constantly measure the internal temperature of an engine and initiate an alarm if the temperature exceeds a predefined limit.
Streams of design, simulation and testing data are produced during the design and evaluation phase of the product lifecycle. These data streams can provide information from the product lifecycle that are needed

during collaboration. For example, during the maintenance process data from a machine design can provide information to detect the causes of a failure.

Collaboration tools, meeting notes, user interaction, user behavior, domain specific operations and business process execution generate a collaboration stream. The data within these streams can be used to characterize the context of a collaboration process and the interaction of the users with the collaboration support system. The model supports a methodological approach called MAIN+ (Boughzala, Assar, & Romano Jr., 2010) to support the selection of appropriated collaboration technologies according to a given collaboration situation. Here, based on a given process description the collaboration data stream will be used to analyze the collaboration situation for each task of the collaboration process. Based on this, the use of a tool will be suggested according to the nature of work and the form of the collaboration.

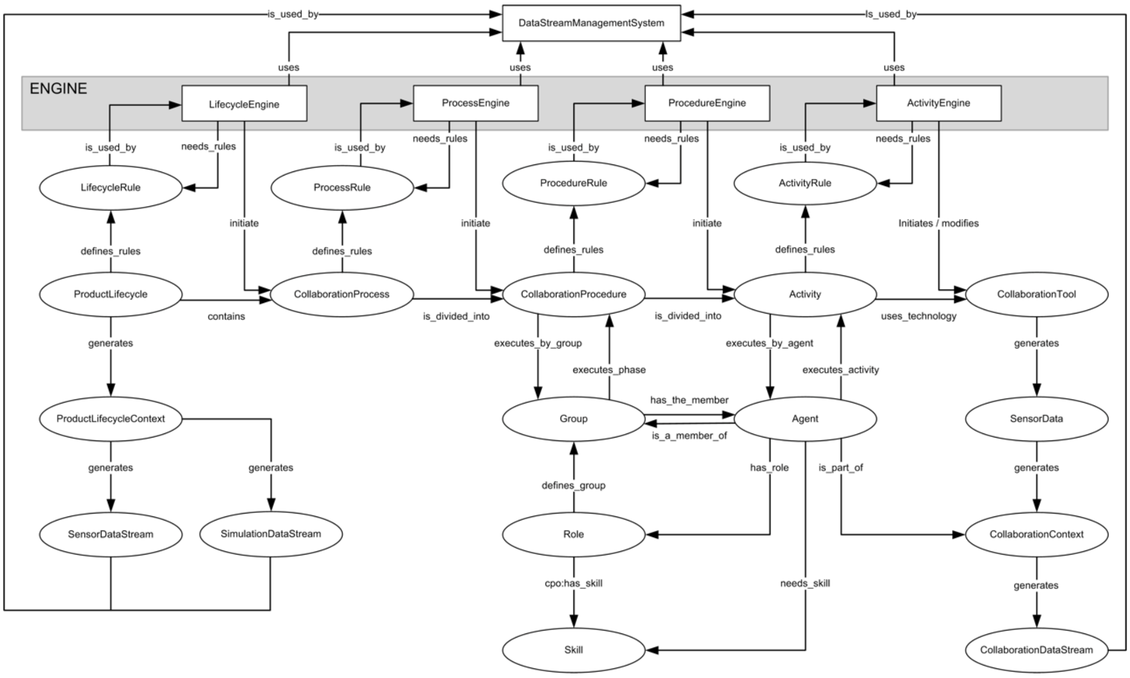

Fig. 1: System Model for Collaboration Support Using Data Streams.

The resulting model combines earlier research approaches to formalize a collaboration process into an ontological representation (Knoll, Plumbaum, Hoffmann, & de Luca, 2010) and intelligent collaboration support (Lukosch & Kolfschoten, 2011) with new concepts for the use of data streams. Figure 1 shows the model and the basic concepts and relations to describe collaboration in a product lifecycle context. Table 1 describes these concepts and their purpose.

According to the system model, the product lifecycle (*ProductLifecycle*) can be described as a sequence of different collaboration processes (*CollaborationProcess*) like the ideation process for the definition of a new product or the decision-making process during maintenance. A collaboration process can be characterized by observable group behaviors and the state of the concepts with which the group works. How a group moves through this process to create an intended state in the process can be prescribed into work tactics of a group. The proposed model represents these work tactics by the concept *CollaborationProcedure* that is related to a *Group*. During a *CollaborationProcedure* a *Group* of *Agents* moves through a sequence of activities (e.g. the maintenance process can be described as a sequence of the activities to analyze data stream, to identify causes and to generate solutions). The entity *Activity* denotes a scripted and reusable collaborative activity of an Agent using a defined tool for collaboration (*CollaborationTool*); e.g. a group can use a brainstorming tool to generate solutions for a problem.

Table 1. Dictionary of the system model for collaboration support.

Concept	Description
CollaborationProcess	Denotes a process of the product lifecycle in which a Group joint effort toward a goal
CollaborationProcedure	Denotes a work tactic for an intended behavior and outcome of a Group that is needed to achieve the intended goal of a CollaborationProcess
Activity	Denotes a change of an Artifact in a CollaborationContext by an Agent with a predefined Role
CollaborationTool	Denotes an artifact that is used by an Agent during an Activity
Agent	Denotes a system or a participant that participates at a CollaborationProcess
Skill	Denotes the required competence of a Role assumed by an Agent to fulfill an Activity
Role	Denotes a set of behaviors, rights and obligations of an Agent
Group	Denotes a set of Agents that has a certain Role
ProductLifecycleContext	Denotes the context information that is specified for the ProductLifecycle
CollaborationContext	Denotes the context information that is specified for a CollaborationProcess
LifecycleRule	Denotes a Rule that is specified for the selection of a CollaborationProcess in relation to the ProductLifecycleContext
ProcessRule	Denotes a Rule that is specified for the selection of a CollaborationProcedure for a Group in relation to the CollaborationContext
ProcedureRule	Denotes a Rule that is specified for the selection of an Activity for an Agent in relation to the CollaborationContext
ActivityRule	Denotes a Rule that is specified for the selection or modification of a CollaborationTool in relation to the CollaborationContext

An *Agent* is either a system or a participant, because some activities of a *CollaborationProcedure* can be fully automated by a system (e.g. sorting a list of contributions). The *Agent* entity has certain *Skills* that can be a prerequisite of a *Role* in a process. A *Role* is defined by the *ProcessProcedure* and denotes abstractly a set of behaviors, rights and obligations. The concepts *Role* and *Skill* are important to distinguish different *Agents* and thus to be able to define requirements for the *Group* of a *CollaborationProcedure*. According to different needed *Skills*, a *CollaborationProcedure* can provide concurrent *Activities* for the *Agents*. For example, diagnosis experts might need to work with blue prints whereas simulation experts are required to build a simulation model. As a result, the proposed model distinguishes activities for parallelization and synchronization.

During the product lifecycle, data streams can be used to identify the need for collaboration or to support collaboration by providing the necessary information. The system model described in Figure 1 uses an *Engine* and a *DataStreamManagementSystem* to initiate and modify collaboration. The *DataStreamManagementSystem* processes incoming data from the *SensorDataStream* the *SimulationDataStream* and the *CollaborationDataStream* into information that can be used by the *Engine* that consists of different engines using predefined rules for the initiation or modification of a collaboration process. The Engine uses different rules to initiate or support collaboration.

The *LifecycleEngine* uses *LifecycleRules* to analyze data from the *ProductLifecycleContext* to identify conflicts or process stages that need collaboration. (e.g. the detection of a failure of a used product in the support phase of the product lifecycle). If a *CollaborationProcess* is initiated, the *ProcessEngine* will select possible work tactics and generates a sequence of *CollaborationProcedure* that can be used by a *Group* to achieve the intended goal of the *CollaborationProcess*. Thereby the

ProcessEngine will use data from the *CollaborationContext* to analyze the availability of possible *Agents* and *CollaborationTools*. For example, if the intended *CollaborationProcedure* indicates specific *Skills* of the *Group*, the engine needs to select *Agents* with these *Skills*. During runtime, the engine can modify a *CollaborationProcedure*.

The *ProcedureEngine* focuses on the activity of an agent during a *CollaborationProcedure*. The engine analyzes and manages the concurrent activities of the agents. Therefore the engine logs the active activities of the participants. If the *CollaborationProcedure* indicates the synchronization of all activities, the engine can abort the active activity of the agents and initiates a common activity for all agents.

The *ActivityEngine* initiates and modifies the used *CollaborationTool* for an activity. The engine generates information from the data streams that is necessary for the execution of an activity, such as the task description or existing criteria for a decision-making process. Further, the engine provides data for the configuration of a *CollaborationTool*. For example, the interface of a *CollaborationTool* can be described in a XML syntax, which allows us to provide individual tools for the activities of an agent. During runtime, the engine uses the *CollaborationDataStream* to analyze the use of a *CollaborationTool* by an agent and if necessary to modify the tool by adapting the XML syntax.

4 Application Scenario: Collaboration Support during the Maintenance Processes

The system model for collaboration support, introduced in the previous section, represents abstract entities that describe a collaboration process in a dynamic environment. The maintenance process is a dynamic collaboration process for problem solving in machine maintenance (rf. Section 2). In this process experts need to constantly assess the status of a machine, be available for short notice collaboration and use appropriate tools to analyze the machine data.

These dynamic situations are reflected in the model (rf. Section 3) that contains four main entities: the lifecycle engine, process engine, procedure engine and activity engine. In this model, a maintenance process is associated to the support phase of a product lifecycle, which is controlled by the *lifecycle engine*.

```
  rule InitiateFailureSignDiagnosis
  when
    $sensordatastream: Data (type ==  ‘pressure’)
    eval ( $sensordatastream.data.value () >= 100)
  then
    initiateCollaborationProcess (Diagnosis, time, sensordatastream)
end
```

Fig. 2: Example for Lifecycle Rule for Failure Detection.

To detect the need for collaboration support (rf. requirement R1), the lifecycle engine analyzes given data streams from the operational product to detect a possible failure. One rule example could be the detection of a possible failure signs of a machine and the resulting initiation of collaboration process for problem analysis as part of a maintenance process (see Figure 2).

If a failure is detected, the engine can use a repository of different collaboration processes templates for maintenance, each corresponding to a different failure type. These templates describe a sequence of patterns for collaboration, which represents a class for different collaboration procedures that can be used to guide the interaction among experts to solve a certain maintenance problem.

Each collaboration procedure refers to a group of experts with predefined skills and roles. This property of a collaboration procedure can be used to support group formation and collaboration in virtual teams (rf. requirement R2). Here, the *process engine* analyses data streams from product operation and collaboration, as well as the characteristics of the available experts. With this information the *process engine* selects an appropriate collaboration procedure for an intended pattern of collaboration and invites the required experts for this process. For example, if the diagnosis of a machine takes several steps to be accomplished and the group does not have enough time available, the *process engine* has to select a procedure that suits the time constraint and provides a sequence of group activities that fit the skills of the experts.

The activities of the collaboration procedure and the usage of collaboration tools will be monitored and adapted for each expert individually by the *procedure engine* and *activity engine*. Based on the intended role of an expert in the collaboration process, these engines filter relevant information from the data streams to support the activities of the experts (rf. requirement R3). For example, during equipment maintenance, the group might generate ideas for possible causes for an equipment problem. They might then use a collaboration procedure to analyze given data streams and to mark exceptional areas in the stream. Depending on the available time they have and the skills of the experts, the *procedure engine* defines an individual sequence of activities for each expert. For example, an engineer is intended to analyze specific data streams according to his area of expertise.

The system model also supports collaboration in a dynamic environment (rf. requirement R4). The goal of the model is to provide experts with a system containing collaboration tools that adapt themselves according to the context of a specific scenario. For example, during a maintenance process, a group is using a tool to generate ideas about possible machine problems. At a certain point in time, the group identifies possible causes that require additional resources to verify their relation to a current failure. The different engines of the system recognize this resource by analyzing the data streams and they execute different adaptations: (*i*) they announce to the group the possible causes that require additional resources in order to make the group aware of a need for adaptation; (ii) they identify the availability of experts related to the identified causes and provides the group a list of possible experts that can be invited; (iii) they adapt the process goal by including a new sub goal to verify the identified causes; (iii) it adapts the collaboration tool by providing techniques that can be used by the enlarged group to verify the possible causes.

5 Conclusion

In this paper we introduced the first steps towards the design of a collaboration support system that uses data streams to support collaboration within the product lifecycle. As part of the requirement analysis, we carried out a workshop in the construction industry to identify the potential of using data streams along the product lifecycle. Based on a scenario for maintenance, the paper represents different requirements for collaboration support in a dynamic environment.

We introduced a system model of a collaboration support system that represents the exchange of collaboration data among stakeholders and different types of data streams. The definition of this system model provides a step forward in designing a system that can handle dynamic situations that result from changing time constraints, goals, participants, or resources.

There are still challenges that need to be further investigated. Currently, the paper assumes that the model can automatically trigger collaboration actions based on analysis of the data from data streams. Currently, there is no suitable language that allows a user to define rules to process data and trigger actions. Besides such a language, another challenge is the implementation of the collaboration support system. Such a system has to consider the processing of data streams, the collaboration of a group of experts and the application of collaboration techniques, leading the group based on dynamic goals and outcomes.

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References

Abramovici, M. (2007). Future Trends in Product Lifecycle Management (PLM). In F.-L. Krause (Ed.), *The Future of Product Development* (pp. 665-674). Springer Berlin Heidelberg. Retrieved from http://dx.doi.org/10.1007/978-3-540-69820-3_64

Blanzieri, E., Portinale, L., Ferrario, M., & Smyth, B. (2000). Collaborative Maintenance - A Distributed, Interactive Case-Base Maintenance Strategy. In E. Blanzieri & L. Portinale (Eds.), *Advances in Case-Based Reasoning* (Vol. 1898, pp. 393-405-405). Berlin, Heidelberg: Springer Berlin Heidelberg. doi:10.1007/3-540-44527-7

Boughzala, I., Assar, S., & Romano Jr., N. C. (2010). An E-government Field Study of Process Virtualization Modeling. In G. J. de Vreede (Ed.), *Group Decision and Negotiation 2010* (p. 154).

Dey, A., Abowd, G., & Salber, D. (2001). A Conceptual Framework and a Toolkit for Supporting the Rapid Prototyping of Context-Aware Applications. *Human-Computer Interaction*, *16*(2), 97-166. doi:10.1207/S15327051HCI16234_02

Garcia, E., Guyennet, H., Lapayre, J. C., & Zerhouni, N. (2004). A new industrial cooperative tele-maintenance platform. *Computers & Industrial Engineering*, *46*(4), 851-864. doi:10.1016/j.cie.2004.05.019

Hayes, C. C., Goel, A. K., Tumer, I. Y., Agogino, A. M., & Regli, W. C. (2011). Intelligent Support for Product Design: Looking Backward, Looking Forward. *Journal of Computing and Information Science in Engineering, 11*(2), 9 pages. ASME. doi:10.1115/1.3593410

Hevner, A., March, S. T., Park, J., & Ram, S. (2004). Design Research in Information Systems. *Management Information Systems Quarterly*, *28*(1), 75-105.

Jia, X., Geng, J., & Huang, L. (2011). Research on PLM-Oriented Collaboration Digital Process Planning Technology. *Advanced Materials Research*, *156-157*, 694--699. doi:10.4028/www.scientific.net/AMR.156-157.694

Knoll, S. W., Plumbaum, T., Hoffmann, J. L., & de Luca, E. W. (2010). Collaboration Ontology: Applying Collaboration Knowledge to a Generic Group Support System. In G. J. de Vreede (Ed.), *Proceedings of the Group Decision and Negotiation Meeting 2010 (GDN)* (p. 37).

Kolfschoten, G. L., & de Vreede, G. J. (2009). A design approach for collaboration processes: a multi-method design science study in collaboration engineering. *Journal of management information systems*, *2009*(26 - 1), 225-256.

Kolfschoten, G. L., & de Vreede, G.-J. (2009). A Design Approach for Collaboration Processes: A Multimethod Design Science Study in Collaboration Engineering. *Journal of Management Information Systems, 26*(1), 225-256. Armonk, NY, USA: M. E. Sharpe, Inc. doi:10.2753/mis0742-1222260109

Kolfschoten, G. L., den Hengst, M., & de Vreede, G. J. (2007). Issues in the Design of Facilitated Collaboration Processes. *Group Decision and Negotiation*, *16*(4), 347-361.

Levrat, E., Iung, B., & Crespo. (2008). E-maintenance: review and conceptual framework. *Production Planning & Control*, *19*(4), 408-429. Taylor & Francis. doi:10.1080/09537280802062571

Lukosch, S. G., & Kolfschoten, G. L. (2011). Towards effective collaboration design and engineering. In T. Hussein, S. Lukosch, H. Paulheim, J. Ziegler, & G. Calvary (Eds.), *Proceeding of the IUI workshop on Semantic Models for Adaptive Interactive Systems (SEMAIS)*.

Ming, X. G., Yan, J. Q., Wang, X. H., Li, S. N., Lu, W. F., Peng, Q. J., & Ma, Y.-S. (2008). Collaborative process planning and manufacturing in product lifecycle management. *Computers in Industry*, *59*(2-3), 154-166. doi:10.1016/j.compind.2007.06.012

Nunamaker Jr., J. F., Briggs, R. O., Mittleman, D. D., Vogel, D. R., & Balthazard, P. A. (1996). Lessons from a Dozen Years of Group Support Systems Research: A Discussion of Lab and Field Findings. *Journal of Management Information Systems*, *13*(3), 163-207. Retrieved from http://portal.acm.org/citation.cfm?id=1189548.1189557

Pattberg, J., & Fluegge, M. (2007). Towards an Ontology of Collaboration Patterns. *Proceedings of Challenges in Collaborative Engineering 07*.

Rajsiri, V., Lorré, J.-P., Bénaben, F., & Pingaud, H. (2008). Collaborative Process Definition Using An Ontology-Based Approach. *Pervasive Collaborative Networks*, *283*, 205-212. doi:10.1007/978-0-387-84837-2_21

Romano Jr, N. C., Briggs, R. O., Nunamaker Jr, J. F., & Mittleman, D. D. (1999). Distributed GSS Facilitation and Participation: Field Action Research. *Hawaii International Conference on System Sciences* (Vol. 1). Los Alamitos, CA, USA: IEEE Computer Society. doi:http://doi.ieeecomputersociety.org/10.1109/HICSS.1999.772737

SmartVortex. (2011). SmartVortex. Retrieved from http://www.smartvortex.eu/?q=Project

Stark, J. (2004). *Product Lifecycle Management: 21st century Paradigm for Product Realisation* (p. 400). Springer. Retrieved from http://www.springerlink.com/content/978-1-85233-810-7/

Terveen, L. G. (1995). Overview of human-computer collaboration. *Knowledge-Based Systems, 8*(2-3), 67-81. doi:doi: 10.1016/0950-7051(95)98369-h

Wood, D. J., & Gray, B. (1991). Toward a Comprehensive Theory of Collaboration. *The Journal of Applied Behavioral Science*, *27*(2), 139-162. doi:10.1177/0021886391272001

Yu, R. (2003). A multi-agents based E-maintenance system with case-based reasoning decision support. *Engineering Applications of Artificial Intelligence*, *16*(4), 321-333. doi:10.1016/S0952-1976(03)00079-4

Rethinking Lessons Learned Processes

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Abstract. Lessons learned are one way to retain experience and knowledge in project-based organizations, helping them to prevent reinventing the wheel or to repeat past mistakes. However, there are several challenges that make these lessons learned processes a challenging endeavor. These include capturing knowledge about project management, allowing learning from mistakes, and handling the group processes within the project team. We introduce a novel approach combining elements from storytelling, root cause analysis, and collaboration engineering to address these challenges, and report on first experiences utilizing this approach in a project in the oil and gas industry.

Keywords: Lessons Learned, Root Cause Analysis, Storytelling, Collaboration Engineering, Knowledge Management, Organizational Learning.

1 Introduction

Within project based organizations (i.e. organizations structured around projects) there is some concern over retaining the knowledge and experiences gained in a project. Failure to learn from past projects can lead to repeating errors (Ajmal et al., 2010) or reinventing the wheel. In extreme cases, project based organizations fail to learn from their mistakes for years on end (Ajmal et al., 2010).

Some organizations address this challenge by transferring some of the knowledgeable people, such as engineers or project managers, from one project to the next. These knowledgeable people could carry some of their learning with them. However, the number of projects that can be reached this way is rather limited. In addition, knowledgeable people use their minds. Thus, they own their means of production - when they leave the organization, they take this means of production with them (Stauffer, 1999), depleting the organization of valuable knowledge.

As a result, project based organizations aspire to capture the knowledge and experiences gained in a project. Here, lessons learned are a common strategy to transfer knowledge between projects by gathering lessons and storing these (e.g. in a database) for others to use.

This paper reports on action research, where lessons learned were gathered from a project in the oil and gas industry. The action research strives to address three challenges: capturing knowledge about project management, allowing learning from mistakes, and handling the group processes within the project team. We report on the approach taken to address these challenges, and present some first results.

2 Three Challenges

There are several reasons that make lessons learned gathering a challenging endeavor, see e.g. Newell et al. (2006), Kasi et al. (2008) for an overview. In this paper, we focus on three of these challenges.

First, the knowledge gained in a project covers a wide range of areas. For example, in the construction industry, relevant knowledge can relate to areas such as design, contracting, planning, or operation and maintenance, but also to project management (Tan et al., 2010). Knowledge about project management encompasses e.g. team building, communication and stakeholder management, and risk management (PMI, 2004). Thus, relevant knowledge is not just about technical issues, but also about 'softer' topics such as social interactions and building commitment. Not all of these knowledge areas are regularly covered by lessons learned efforts. Newell et al. (2006) have conducted interviews in several organizations on the effectiveness of their lessons learned efforts. The results of the interviews are telling. While it seems to be possible to capture knowledge about products, technical issues and achievements, softer types of knowledge (i.e. knowledge about the processes that a team had deployed to achieve their goals and why these processes seemed to have worked well or badly) are not retained. One reason for the difficulties in retaining softer types of knowledge/ process knowledge lies in the tacit and situated nature of part of this knowledge (Kasi et al., 2008). It is therefore difficult to capture and transfer (Neuweg, 2006). For organizations relying on the execution of projects this draws a bleak picture. Learning from projects and exchanging both explicit and tacit knowledge beyond the boundaries of a project has been identified as one of the critical success factors for projects (Cooke-Davies, 2002).

Second, learning from mistakes can be a challenge in itself. Here, organizational culture often creates barriers to learning from mistakes. The open and honest productive culture that would facilitate the articulation and analysis of errors is rarely present in most project-based organizations (Ajmal et al., 2010), leading to a lack of psychology safety (Kasi et al., 2008), especially if the project manager plays an important role in how well or badly a project performed. In addition, the process of learning from mistakes can involve re-experiencing the past, thus creating frustration and anger (Kasi et al., 2008).

Both challenges are made more difficult by the fact, that learning and experiences are spread in the project team. With regard to softer types of knowledge, different team members often hold only part of the puzzle. While the project manager might know why something was implemented, and can outline the motivation and actual effects on a high level, others might have detailed knowledge on how something was implemented. Both types of insights are important when it comes to lessons learned. In addition, groups remember more correct information about an incident (see e.g. Hogg, Vaughan, 2008). Overall, groups have a greater amount of knowledge, intelligence and understanding of a problem than any single individual (French et al., 2009). Thus, involving key team members in the lesson learned process *might* lead to better results. However, gathering lessons learned in a group can suffer from well-known group phenomena such as groupthink (see e.g. Hogg, Vaughan, 2008). Thus, handling the group process adequately is a third challenge.

There are only a few studies addressing similar issues in the context of lessons learned. Most studies just state that facilitators should be used and state the method 'discussions' in the group for actually gathering lessons learned (see e.g. Koners (2005), Liebowitz (2008)). Williams (2004) provides more details on his process. He uses a root cause analysis to analyze the management decisions leading to failure. However, he did not consider any group processes. Baas et al. (2010) utilize appreciative enquiry to address the challenge on how to design the lesson learned process in such a way that participants don't see it as such a negative experience. This way they balance reflection on mistakes with more positive experiences, but they do not explain how to actually create good lessons learned from mistakes.

3 Research Case and Approach

This paper reports on gathering lessons learned from a project in the oil and gas industry. The project involved multiple stakeholders, among others a client organization and a contractor handling the management and engineering part of the project. The project team regarded the project as not successful in terms of budget and schedule. Several team members stated that at least one of the project managers played a major role in that situation. Thus, the project presented an opportunity to research how to capture knowledge related to project management (including stakeholder management), and to explore capturing knowledge related to failure.

Using an action research approach, we conducted a series of interviews with key members of the project team and a facilitated workshop to identify, discuss and capture the major lessons learned related to project management.

We recorded all the interviews and the workshop and gathered further data utilizing a questionnaire and debriefing rounds. In particular, we used the questionnaire to assess the perceived effort, and satisfaction with different parts of the process. Debriefing rounds after each step in the workshop and after the workshop as a whole provided feedback as well.

The project managers were involved in how the project was conducted. This made it necessary for an external party to guide the lessons learned effort. In addition, the client organization wanted to improve their lessons learned efforts, thus leading to an opportunity for action research.
Altogether, seven people contributed lessons learned during the process. From the client organization one engineer, two project managers, and one portfolio manager participated. From the contractor's side, there were one project manager and one engineer, as well one person responsible for managing the project manager within their organization.

4 Lessons Learned Process

The lessons learned process employed in this project consists of two major phases: an interview phase and a workshop phase.

The interviews utilized mechanisms from storytelling (see e.g. Lukosch et al., 2011) and root cause analysis (see e.g. Williams, 2004) to gather 'softer' kinds of knowledge about project management. Storytelling is a method to capture experiences, personal perceptions, and insights through stories. In the context of this action research it was embedded in semi-structured interviews and used to gather the personal perception of team members on what went well and what went wrong. The main causes for failure were elicited in the same interviews, asking each team member recursively what they considered the cause for what went wrong ("why"), what they would recommend to address this cause, and whether the recommendation would be able to prevent the ultimate effect. Most of these recommendations had not been tested in this project.

Altogether about 10 hours of interview material were gathered. This interview material was transcribed and analyzed, resulting in a preliminary report. Here, most lessons learned consisted of a description of the problem or situation, and a recommendation on how to handle this problem. The report contained 31 problem descriptions.

In order to bring the separate views together, and to allow the interviewees to refine and reflect upon the gathered lessons learned, a facilitated workshop was conducted. The workshop utilized a group support system in order to allow the participants to work anonymously and in parallel.
The workshop was designed using ThinkLets (see e.g. Briggs, Vreede (2009), Briggs et al. (2006)). ThinkLets are abstracted basic units (steps) of a facilitated group processes, describing the actions of the facilitator and of the group as well as expected outcomes, the purpose, and pitfalls.
As a first step, the participants clarified the problem statements, and were given the opportunity to challenge the recommendations or to add new recommendations (using the LeafHopper ThinkLet with problem statements and recommendations as seeds).

In the next step, they tagged the problems to make it easier to retrieve the lessons learned from the database. An internal framework for describing risk categories was given as an initial set of tags. In addition, the participants could add free tags. On average, each problem description received 2.6 tags.
Third, the group members rated the problems (using the MultiCriteria ThinkLet) on a 5 point scale with regard to their relative importance for their project, the impact should a problem occur in a future project, and probability of a problem occurring in a future projects. The rating criteria impact and probability of (re-) occurring are also used in risk assessment (see e.g. Hillson and Simon, 2007). The results of these ratings give an indication to the reader of a lesson learned, how important this lesson was in the context of the project, and in the context of the organization. Figure 1 shows a scatterplot depicting the problems. The participants consider the problems to be severe and likely to reoccur in other projects. The outliers in the scatterplot can all be explained by some misunderstandings regarding the usage of the voting system.

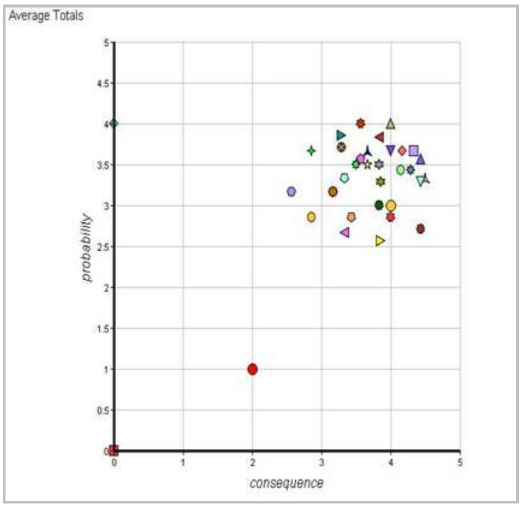

Fig. 1 Probability and Impact of Identified Problems

5 Conclusions

Results from this action research indicate, that the interviews together with an (anonymous) workshop address the complex situation of the project and allow team members to address sensitive issues in the project, such as team building. An initial analysis of the questionnaire revealed that the perceived effort is adequate, and that the participants show a high satisfaction with the process. The debriefings during and after the workshop also showed that the workshop design needs some refinement.

The high ratings regarding impact and probability of reoccurring can be interpreted in two ways. First, they could indicate that during the process an early filtering took place. Consequently, lessons that are considered unimportant are not mentioned at all, thus leaving out important lessons learned. Second, the ratings could indicate that the lessons learned process focused only on lessons learned of high relevance without leaving out other important lessons. This position is supported by the fact that during the workshop no new problems were added. However, to assess whether this explanation actually holds further research is needed.

Another avenue for future research links to risk assessment. The employed lessons learned process already contains elements that are also part of risk assessment. Collier et al. (1996) proposed to use lessons learned as input for risk identification. However, to our knowledge this suggestion has not been taken up. Thus, our lessons learned process could contain first steps in linking lessons learned processes to risk identification.

References

Ajmal, M., Helo, P., Kekäle, T. (2010). Critical factors for knowledge management in project business. *Journal of Knowledge Management*, *14*(1), 156-168.

Baaz, A., Holmberg, L., Nilsson, A., Olsson, H. H., Sandberg, A. B. (2010). Appreciating Lessons Learned. *Software, IEEE*, *27*(4), 72–79. IEEE.

Briggs, R. O., Kolfschoten, G. L., de Vreede, G. J., Dean, D. L. (2006). Defining key concepts for collaboration engineering. In G. I. & rejo R . (Eds.), *Proceedings of the 12th Americas Conference on Information Systems, Acapulco, Mexico* (pp. 121-128).

Briggs, R. O., Vreede, G. J. de. (2009). *ThinkLets: Building Blocks for Concerted Collaboration*. Raleigh, N.C.: Lulu.com.

Buttler, T., Lukosch, S. G., Verbraeck, A. (2011). Frozen Stories - Capturing and Utilizing Frozen Stories for Teaching of Project Managers. In A Verbraeck & M. Helfert (Eds.), *Proceedings of the 3rd International Conference on Computer Supported Education*.

Collier, B., DeMarco, T., Fearey, P. (1996). A defined process for project post mortem review. *Software, IEEE*, *13*(4), 65–72. IEEE.

Cooke-Davies, T. (2002). The real success factors on projects. *International Journal of Project Management*, *20*(3), 185-190.

French, S., Maule, J., Papamichail, N. (2009). *Decision behaviour, analysis and support*. Cambridge: Cambridge Univ. Press.
Hillson, D., Simon, P. (2007). *Practical Project Risk Management: The ATOM Methodology*. Vienna, Virginia: Management Concepts Inc.
Hogg, M. A., Vaughan, G. M. (2008). *Social Psychology* (5th ed.). Financial Times Management.
Kasi, V., Keil, M., Mathiassen, L., & Pedersen, K. (2008). The post mortem paradox: a Delphi study of IT specialist perceptions. *European Journal of Information Systems*, *17*(1), 62-78.
Koners, U. (2005). *Learning from Research & Development Projects: The Role of Post-Project Reviews*. PhD-Thesis. Cranfield School of Management.
Liebowitz, J. (2008). Two forgotten elements of a knowledge management strategy. *Knowledge Management Research Practice*, *6*(3), 239-244. Palgrave Macmillan.
Lukosch, S., Klebl, M., Buttler, T. (2011). Utilizing Verbally Told Stories for Informal Knowledge Management. *Group Decision and Negotiation*, *20*(5), 615-642.
Neuweg, G. H. (2006). *Das Schweigen der Könner*. Linz: Trauner.
Newell, S., Bresnen, M., Edelman, L., Scarbrough, H., Swan, J. (2006). Sharing Knowledge Across Projects: Limits to ICT-led Project Review Practices. *Management Learning*, *37*(2), 167-185.
PMI. (2004). *A Guide to the Project Management Body of Knowledge* (3rd ed.). Project Management Institute.
Stauffer, D. (1999). Why people hoard knowledge. *Across the board*, *36*(8), 16-21.
Tan, H. C., Anumba, C. J., Carrillo, P. M., Bouchlaghem, D., Kamara, J., Udeaja, C. (2010). *Capture and Reuse of Project Knowledge in Construction* (Vol. 1). Oxford: Wiley-Blackwell.
Williams, T. (2004). Identifying the hard lessons from projects – easily. *International Journal of Project Management*, *22*(4), 273-279.

Team Collaboration in Virtual Worlds: Results from a Delphi Study

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Abstract: This study provides a taxonomy of salient opportunities and challenges yielded by collaboration in Virtual Worlds (VWs). A Delphi method is used to gather graduate management students' opinions resulting from a SWOT analysis of team collaboration in VWs. This study produced an ordered list of important adoption and entry issues to consider when collaborating in VWs. Additional factors were identified through a discussion of these issues. Based on our findings, we further discuss the relevance and implications of opportunities and challenges associated with collaboration in VWs.

Keywords: Collaboration, virtual teams, Virtual Worlds, Delphi, exploratory study.

1 Introduction

Virtual Worlds (VWs) provide many opportunities to overcome some issues of traditional collaboration such as scheduling meetings when team members are working in different countries. But team collaboration in these environments can be more effective but also more challenging to manage.

Both researchers in Management Science—specifically the Information Systems field—and in Computer Science—specifically Computer Supported Cooperative Work (CSCW) and Human Computer Interaction communities —have grown increasingly interested in VWs. .Management Science researchers have placed particular focus on studying the emergence and development of virtual organizational settings (e.g., teams, communities, enterprises) (Shaw 1971; Giddens 1984; Armstrong&Hagel 1996; Ahuja&Carley 1999; Boughzala 2007). Such research has focused on the opportunities that VWs, as a form of effective Information and Communication Technology (ICT) provide to enhance business processes. Conversely, computer science researchers have studied the interaction of human beings with VW technology and its capacity to support collaborative work (Yee 2007; Bessière 2009; Ducheneaut et al. 2009). For instance, VWs can influence critical business functions such as internal information sharing, e-commerce, partnerships, organizational learning, value creation, and innovation (Kock 2008). Several researchers have also explored the contribution of VWs as a space for social interaction and a tool to increase, facilitate, and lead team collaboration (Davis et al. 2009). The efficient and effective use of VWs as a platform for team collaboration may yield a variety of benefits to an organization ranging from reducing operating costs (e.g., travel, lost work time due to excessive or untimely meetings), to enhancing productivity (e.g. speed and richness of collaboration, creativity).

Owens and colleagues (2009) argue that VWs can enhance collaboration and VW project management through the unique technology capabilities they provide. That is, when using VW technology capabilities, VW project teams have access to efficient, as well as richer, more engaging environments to help overcome collaboration barriers. However, many organizations are cautious of the unintended consequences of utilizing VW collaboration. Indeed, they consider VWs as surrounded by much hype and uncertainty regarding concrete business value.. Several studies highlighted factors that could negatively impact an organization, such as poor security, and the lack of a clear legal framework and governance

Despite the fact that several research teams have embarked on the study of collaboration in VWs (Davis et al., 2009), there has been limited research into the perceived challenges and opportunities for organizations operating in these environments (Tikkanen et al., 2009). To establish a basic understanding of VW opportunities and weaknesses, many questions need to be answered, including but not limited to: What might be inhibiting or enabling team collaboration in VWs? What might encourage or discourage organizations to invest resources into VWs? What factors optimize the likelihood of successful team collaboration and high quality of outcomes?

To the best of our knowledge, there are few studies that attempted to answer such questions (Kock, 2008; Hendaoui et al., 2008 b; Davis et al., 2009; Owens et al., 2009). Thus, not surprisingly, a taxonomy of salient opportunities and challenges for VW collaboration has not been proposed. As such, we conducted a Delphi study to address this research gap. The Delphi method consisted of an initial brainstorm session, which was followed by a consolidation of key issues and a ranking of these issues. This resulted in a taxonomy of issues relevant to VW collaboration. We then expanded our findings by allowing our panel of experts to openly discuss these issues to ensure the relevance of the initial brainstorming results. Specifically, the current study was exploratory in nature and identified initial barriers and opportunities for VW adoption.

Our findings may help organizations to better prepare their venture into VWs by heightening their awareness of the major challenges of this emergent technology. The relevant issues identified in this study also provide a starting point for better understanding and further researching factors that influence the optimal utilization of VWs to conduct team collaboration. Furthermore, the understanding of several barriers related to the technology will lighten the path to enhance VWs design (Ducheneaut et al., 2009).

The remainder of this paper is structured as follows. The next section presents a literature review. Then we introduce our methodology for identifying the opportunities and challenges associated with team collaboration in VWs. Next, the results of the study are detailed in the fourth section. Section 5 discusses our findings and their implications with the support of a complementary qualitative study through an open discussion with participants. The paper concludes with a summary of the key findings, limitations, and directions for future research.

2 Background

2.1 Virtual Teams (VT)

It is becoming more and more common for individuals to work remotely in cross-distance, cross-domain and cross-organizational VTs (Zolin et al., 2004). That is, organizations are trying to take advantage of the flexibility of technology-enabled work to create distributed VTs and tap into globally dispersed, cross-functional expertise and competences (Huang et al., 2010). At present, electronic communication is evolving towards a 3D era. For the first time, advanced technologies, such as the 3D internet, have made VWs accessible to nearly everyone in an industrialized country (Chen&Chen, 2009). Further, the globalization of business practices and the proliferation of collaboration technologies have catapulted the utility of VWs into the corporate world.

Moreover, VTs have the advantage of incorporating members from different cultures, organizations, countries, etc. These teams are technology-enabled and can improve productivity by reducing operational costs and employing the most adequate human resources for a task (Townsend et al., 1998 b). They can also help organizations distribute risks and costs in an appropriate innovation context (Gassmann and Zedtwitz, 1999).

Despite the potential for VTs to experience great opportunities, efficiency and effectiveness, these teams are not guaranteed to outperform physical world teams. Indeed, VTs face many daunting challenges such as management difficulties, maintaining individual motivation and focus, building commitment, and promoting trust (Huang et al., 2010).

Furthermore, team members may suffer from reduced trust (Bos, 2004) and reduced engagement resulting from excessive multitasking (Mark, 1999). In an effort to ameliorate VTs' meetings difficulties, researchers designed an avatar-based e-meeting support tool named Olympus (Shami, 2010b) to host more personal VT collaborative efforts. Others designed a tool called Porta-Person to enhance the sense of social presence for remote meeting participants (Yankelovich, 2007).

Notably, research cited in this literature review is not exclusive to VWs. However, several aspects of VWs make them more promising than traditional technologies such as e-mail or videoconferencing. For instance, VWs approach the real world and bring a feeling of presence and being together (Franceschi, 2009). They allow object manipulation (Davis et al., 2009) and creation of social and economical interactions (Hendaoui et al., 2008). Consequently, some researchers have pondered whether the use of VWs can mitigate the inefficiencies of distributed meetings (Shami, 2010a).

2.2 Team collaboration in VWs

The introduction of VWs as an innovative technology that can be utilized to enhance collaboration in the workplace has raised promising opportunities and speculation (Rohall, 2008; Shalini, 2009; Srivastava, 2010). Owens and colleagues reported that companies such as IBM and Dell have recognized this potential and began piloting various VW projects. Such projects incorporated work from a variety of issues including but not limited to marketing, healthcare, virtual museum tourism, e-learning, and recruitment. These projects were performed on three types of collaborative platforms within Second Life: Immersive Workspaces, Virtualis and the Alpine Executive Center. Each platform aimed to enhance intra- and inter-organizational work contexts (Owens et al., 2009). The aforementioned platforms provide many communication and work tools and features such as capabilities for editing reports, sharing comments, video conferencing (The ImmersiveSpaces). They allow organizing conferences, social events and brainstorming (Virtualis; Alpine executive center, 2011).

Generally speaking, collaborative platforms in VWs provide the advantage of reducing the need for business travel, which in turn reduces costs and protects the ecological environment. Moreover, in VWs, employees can attend internal conferences and workshops for free from the comfort of their everyday office. This convenience can reduce time wasted on travel and increase productivity during down time. Arguably, VW collaboration may not replace face-to-face collaboration, but it becomes a complementary and supplementary alternative for interpersonal interactions.

Despite the many opportunities for improved collaboration afforded by VWs (Kock, 2008), some researchers have addressed threats and weaknesses inherent to this medium (Bessière, 2009; Owens et al., 2009). For instance, VWs require technical skills (Bessière, 2009) to be used in order to take advantage of the technology’s capabilities. Also, while avatars provide visualization and realism to the electronic communication, the user must be able to effectively maneuver the avatar (Owens et al., 2009). Hence, researchers highlighted a learning curve related to VW technology usage. Also, VWs could face acceptance issues (Bessière, 2009) if users reject the technology, or the idea of changing to new technologies. Furthermore, cross-country VTs still encounter problems with time differentials in VWs. Finally, the Lack of face-to-face could lead to several social problems such as confusion, misunderstandings, interpersonal conflict, intra community conflicts (Cahalane et al, 2010), violation of group norms (Owens et al., 2009), and difficulty building trust between users (Bessier et al., 2006; Yee et al., 2007; Schroeder, 2008).

Some researchers specializing in law, public politics, and economics have raised questions addressing regulation and governance of VWs, and the emerging virtual economy (Lastowka, 2005; Castronova, 2006; MacInnes, 2006; Malaby, 2006). For instance, some authors have addressed the issue of whether “virtual properties” that are bought and sold in VWs should be considered property in the legal sense (Mennecke et al., 2007). Furthermore, some researchers addressed the question of identity theft and fraud in VWs (Lastowka and Hunter, 2004; Roche and Van-Nostrand, 2007). Mennecke and colleagues (2007) argued that more research is needed to understand these issues and to find remedies for them.

In conclusion, researchers have pointed out interesting and salient opportunities and challenges of collaboration in VWs. However, no taxonomy of opportunities and challenges of VWs has been provided. Therefore, our contribution to the literature is to provide the cornerstones—or at least guidance—for such a taxonomy.

3 Method

In order to address the aforementioned research gap, we asked our panel of experts to identify challenges and opportunities organizations may face when using VWs in a collaborative context. We conducted a SWOT analysis from a brainstorming session as a preliminary exploratory study with graduate management students. This SWOT analysis is intended to present possible perceived Strengths, Weaknesses, Opportunities, and Threats of team collaboration in VWs. This study addressed two primary types of factors that influence VW collaboration: 1) internal factors including strengths and weaknesses of VWs, 2) external factors including opportunities and threats. The SWOT analysis generated an organized set of factors which may help organizations to deepen their understanding of the costs and benefits of using VWs for team collaboration. These factors can help inform companies of the advantages to working in VWs, as well as raise their awareness of the prospective threats inherent to VWs. To address these SWOT analysis categories, we considered the following questions:

- Strengths: What factors do you consider as major advantages of VWs?
- Weaknesses: What factors do you consider as major drawbacks of VWs?
- Opportunities: What potential opportunities do VWs offer in a collaborative context?
- Threats: What potential threats do VWs pose in a collaborative context?

To conduct our exploratory study, we used a Delphi approach. Delphi studies are regularly used in information systems studies when a consensus needs to be achieved among domain experts on a topic where ideas generation is required (Keil et al., 2002). We enriched the Delphi process through a thinkLets-based (Briggs et al., 2003) facilitation process. ThinkLets are codified best facilitation practices that create predictable, repeatable patterns of collaboration among people working toward a goal. They are used to streamline collaboration during brainstorming sessions, rapid decision-making, evaluation of strategic objectives, team building, and creativity (Vreede, et al., 2009).

While Delphi studies are normally survey-based (Schmidt et al., 2001), we had the opportunity to use a Group Support System (GSS – here a customized Sphinx Web Reporting application) and a well-structured facilitation process. A GSS is a suite of software tools designed to support collective problem solving, including the generation of ideas, reducing, organizing, and evaluating idea sets (Fjermestad&Hiltz, 1999). These tools facilitate the emergence and sharing of information among participants, and assist the facilitators in the control of the participants' reflection process. Each participant in a GSS session uses a computer to submit ideas and votes to the group, to make selections, to organize ideas, or to write draft texts. Using a GSS, all team members can contribute simultaneously, and may generate and evaluate ideas anonymously, while participating in well-structured deliberation processes (Dennis et al., 2001). The use of a GSS allowed us to collect in a bottom up fashion, extensive and well-organized group collaboration results. It also served for the development of a synthesis report summarizing the results of the process, which was presented and discussed with all participants.

3.1 The Participants

In March 2011, students of a 3D VWs course were invited to participate in a study at the authors' institution. They were asked to do a SWOT analysis of VW collaboration using electronic brainstorming. Demographics of the study participants are provided in Table 1.

Table 1. Delphi study participant demographic data

Study data
• Total Participants: 13
• All participants are Management Graduate students
• Youngest Participant in Age: 21
• Oldest Participant in Age: 26
• Male Participants: 6
• Female Participants: 7
• Web 2.0 & VWs Experience: Very Often

3.2 The Brainstorming Process

The brainstorming process consisted of several activities in which the participants were asked to engage during a 180 minute period. A summarized agenda and research process follows:

- After an introductory presentation on VWs and the scope of the meeting, participants were asked to anonymously generate ideas around the four SWOT themes.
- Participants were then assigned to four subgroups and asked to reduce, clarify and organize collectively generated ideas into unique statements around one of the four themes. Each subgroup was assisted in this task by a facilitator. The goal was to converge on similar ideas, remove non-related ones, and reword those insufficiently clear.
- Participants then rejoined as a single group. Each subgroup facilitator presented and explained to the group which statements were selected for their respective theme.
- Participants were then asked to individually and anonymously rate the relevance of each statement on a 10-point Likert-type scale, with ‘10’ representing a very relevant statement and ‘1’ a least relevant statement relating to each of the four SWOT themes.
- The voting scores were then presented to all participants in a raw format to stimulate a discussion of the results (proposal by proposal), and to allow the reformulation of proposals when necessary, to clarify ratings' standard deviations and so to build a collective consensus.

Finally, we conducted an open discussion for 90 minutes with the same participants about the brainstorming results. We aimed to deepen and clarify their understandings of the statements’ importance and their role to make teamwork in VWs successful. A list of guiding questions addressing these constructs was prepared to facilitate the discussion.

4 Results

The SWOT analysis produced a total of 146 ideas during the initial brainstorming activity aiming to identify opportunities and challenges of VWs. These ideas were reviewed, reclassified, and paraphrased following the process described in the previous section. We reduced them to 32 statements (9 strengths, 7 weaknesses, 9 opportunities, and 7 threats). After data collection, we reviewed and paraphrased the overall results from the SWOT analysis category lists to enhance clarity. Some key questions were asked about the collected data:

- Are the resulting statements possibly misclassified between threats and weaknesses or between opportunities and strengths?
- Are the resulting statements appropriate and within the scope of team collaboration?
- Are the resulting statements specific to a particular VW?

After careful analysis, we organized and put the results in four tables, tables 2 through 5. (SD = Standard Deviation)

Table 2. Strengths: Strengths consolidated from an initial set of 49 ideas and then reviewed, reclassified, and paraphrased.

Strengths	Mean	SD
Universal access	8	1.89
Entertainment	8	2.07
Simulation (object manipulation)	7	1.79
Environment personalization and flexibility	7	1.65
Shaping personality	6	2.78
Pleasant working environment	6	3.17
Cost reducing	6	2.25
Saving energy	6	3.01
Socialization	4	2.36

As a result of the brainstorming activity, participants identified some relevant strengths. First, participants highlighted the universal access to VWs from everywhere and for everyone. This virtual trait is inherited from the Internet and helps to eliminate boundaries and reduces communications' constraints. Secondly, they identified the entertaining environment which may help to make work condition more pleasant. Additionally, they cited the possibility to simulate processes remotely which is more realistic compared to other collaborative environments (i.e. Groupware) where visualization (Hall, 2008) and or co-presence (Schroeder, 2006) are not possible.

Third, they stressed the possibility to personalize the environment and make it better suited to users' demands. In a participant's words "*environment personalization helps to define a suitable environment which improves performance*". Furthermore, the possibility to personalize the avatar seemed to be relevant. Said one participant "*Personalization allows us to be identified with our own profile"*, i.e. to be different from others. So one could be "*identified with his/her character"* or "*getting a desirable image"*, and "*shape his/her personality as desired*". These findings regarding personalization reflect propositions of Ducheneaut and colleagues (2009). Furthermore, users can overcome shyness and interact with people without constraints. Consequently, VWs increase socialization by facilitating the "*connecting with new people"*, and because "*communications are easier and so socialization becomes easier*". Finally, participants declared that VWs help to reduce transportation and accommodations costs. Indeed, like other means of electronic communication, VWs save travel expenses and reduce traffic pollution.

Table 3. Weaknesses: Weaknesses consolidated from an initial set of 48 ideas and then reviewed, reclassified, and paraphrased.

Weaknesses	Mean	SD
Impersonal social communication (desocialization)	9	1.26
Lack of juridical framework	9	1.12
Hacking and fraud	8	1.93
Requiring advanced technical skills	8	1.82
High hidden cost	7	1.76
Loss of touch with reality	7	2.81
Requiring many technical resources	6	2.31

According to the participants, many weaknesses seem to pervade VW collaboration. First, VWs may lead to impersonal social communication. So people will lose important aspects of human contact (desocialization) and "*loss of touch with reality*". That is, VW participant contacts may become virtual contacts only. Moreover, participants are wondering about conflict management in VWs with a lack of juridical framework. One participant said: "*Possibility of conflicts in 3D life, which rules could one apply?"*. Some weaknesses are specific to VWs' technology such as security problems namely hacking and fraud in absence of legislation associated with conflicts in VWs. Furthermore, VWs require advanced technical skills and high hidden cost as well (e.g., subscription fee, software cost). Finally, the use of such technology requires many technical resources such as an advanced graphical card and a powerful processor.

Table 4 Opportunities: Opportunities consolidated from an initial set of 30 ideas and then reviewed, reclassified, and paraphrased.

Opportunities	Mean	SD
Distance reducing	9	1.40
Real time and rapid communication	9	1.44
Time saving	8	1.23
Less discrimination when the visual identity is hidden	8	1.61
Free opinion expression	8	2.36
Personal skills development	6	1.89
Risk reducing with process simulation	5	2.54
Increasing creativity	5	2.86
Easy knowledge sharing	5	2.81

The participants identified many relevant opportunities that may help us to better understand team collaboration in these new environments. First, participants argue that VWs allow people to work remotely from any place—such as their homes. Exchanges between team members may become faster thanks to real time and rapid communication. Consequently, this may "*accelerate project development*" and allow time saving. Second, users are able to hide their visual identity and, in the same time, other team members could know the statue, the identity and competencies of the persons with the hidden visual identity. This may reduce discrimination (e.g., disability, gender, race…) and "*makes discussion in team richer because there is no judgment*". This "*ensures to everybody to express him/herself more easily and freely*". So one may overcome his/her shyness and participate positively in team discussions. Moreover, people can use VWs to develop new skills such as learning languages, attending conferences, and doing process and object simulation. Third, one may reduce project failure risks thanks to remote simulation and a rich tool environment. Furthermore, participants argue that these environments could help to increase creativity through cross organizational and cross cultural collaboration. Finally, VWs make knowledge sharing much easier which is relevant and "*enriching to team collaboration*".

Table 5 Threats: Threats consolidated from an initial set of 19 ideas and then reviewed, reclassified, and paraphrased.

Threats	Mean	SD
Identity theft and hacking	9	0.96
Reduced efficiency	9	1.55
Social loafing	9	1.55
Psychological issues	9	1.19
Perception issues	8	2.2
High dependency on machine reliability	8	1.82
Leadership issues	7	2.33

The last stage of the brainstorming activity was related to threats of VWs when people work in teams. The findings in this section align with the literature review (Lastowka, 2005; Castronova, 2006; MacInnes, 2006; Malaby, 2006; Cahalane et al, 2010; Lastowka and Hunter, 2004; Roche and Van-Nostrand, 2007). In fact, safety issues are strongly highlighted by the majority of participants. They identified some relevant threats such as identity theft, hacking and use of invisible avatars. They also focused on the impact of the use of VWs on team efficacy. They argued that team efficacy may strongly decrease due to the lack of emotion and gesture. Thus, it may be difficult to explain ideas and read body language in VWs, which may lead to more misunderstandings and lower team efficacy. Moreover, the risk of social loafing seems to be noteworthy with the possibility to hide one's visual identity in these environments. That is, social loafing is hard to regulate in this context. One participant said "*no one could know what people do in virtual meetings, are they concentrated, do they listen…*" Another one said, "*People may feel lack of commitment when there is no supervision*". Another one declared that "*social loafing may increase when there is no supervision in team work*" According to the participants' contributions, hiding the visual identity could complicate some leadership issues because it is hard to manage a VT mainly when we do not know or see members. Indeed, when we do not know or see the leader we will not be able to feel his/her charisma and influence. One participant declared that an "*unknown person could not have so strong influence on people*". Another said "*human contact is indispensable for creating leadership in a team*". Furthermore, VWs may lead to some psychological issues such as dependency on these worlds, and social isolation in the physical world. As such, VW participation may have a harmful impact on persons, families and society. Finally, participants highlighted the strong dependency on a machine that may not be always reliable. Indeed, some connection troubles or electricity issues "*could lead us to stop working or cancel a meeting*".

Discussing the strengths, weaknesses, opportunities, and threats of VWs during the brainstorming activity yielded results that appeared to relate to factors are arguably relevant for team collaboration in VWs, such as personalization (Ducheneaut et al., 2009), social loafing (Karau&Williams, 1993), hiding visual identity, object manipulation and simulation (Robinett and Holloway, 1992), knowledge sharing (Cramton, 2001), socialization (Clausen, 1968) and leadership (Chemers, 1997) These are factors which distinctly influence team collaboration. They are neither opportunities nor threats but fundamental constructs that impact team collaboration. Some of them may enhance team collaboration such as knowledge sharing while others may inhibit collaboration in VWs such as social loafing. To further enrich our understanding of the participants' perceptions on these constructs and their role in team work in VWs, we conducted an open discussion focused on enablers or inhibitors of VW collaboration. To this end, a list of open-ended questions was prepared that were used to guide the discussion. These questions and a summary of the participants' responses are presented below.

1. Does it make any difference when you personalize your profile (avatar, space, decor...)?
Participants suggested that personalizing their profiles, including but not limited to their avatars, spaces, and décor, influenced their collaboration experiences in VWs. First and foremost, they indicated that profile personalization helped establish an identity in the VW. Having a unique identity reflected in a personalized profile puts users at ease in a VW because it "*gives you a style, makes you original and helps you feel closer to your avatar and at ease with the environment.*" In fact participants reported that individualizing a VW profile is just as important maintaining a desirable personal image in real life, and some respondents went as far as to suggest that a personalized profile "*is a window to our personality.*" Furthermore, this process of establishing an identity helps users "*interact with others*" by creating a desirable image of a character that fellow users can perceive as a unique person. Participants indicated that being able to customize one's image in a VW can be particularly beneficial because users can control the appropriateness, attractiveness, and aesthetic value of how they appear to others.

2. To what extent would it make a difference when manipulating object in these VWs?
Participants also expanded on how the capability to manipulate objects in VWs influences team collaboration. They explained that object manipulation "*makes us feel closer to reality*" because it gives the perception of touching and interacting with the environment. In addition to making users feel more comfortable in an enriched environment, object manipulation improves collaboration by making idea sharing "*more interactive and illustrative.*" For instance, being able to visualize and ask questions about a project "*decreases project failure risks when processes can be simulated*" for all team members to understand. Moreover, object manipulation is expected to enhance learning in VWs because this function allows users to view a modeled behavior and then practice it.

3. Does it make a difference to hide your visual identity when collaborating with others?
Further probing of the SWOT analysis indicated that the contributions of participants with a hidden visual identity can have a variety of impacts on VW collaborative efforts. Interestingly, about half of the participants heralded the benefits of this kind of participation, whereas the other half suggested that it can be detrimental to collaboration. Those in favor of being able to hide their identity indicated that it "*makes communication easier*" because it reduces evaluation apprehension, and provides "*more freedom to express your opinion.*" Proponents of this method also reported that it increases the richness of debates because judgments focus on the idea rather than the person. Conversely, the other half of the participants warned that visual anonymity makes collaboration "*less comfortable*" and "*feel more distant.*" An argument was made that hidden visual identity decreases spontaneity in that participants are less likely to engage in a rich dialogue. Importantly, it can lead to distrust when participants cannot make judges of credibility, and in some cases this lack of credibility can "*encourage people to be less serious*" about the issue at hand.

4. To what extent you think that hiding your visual identity could increase social loafing?
Moreover, the participants elaborated on how hidden visual identity can increase social loafing. The most common issue that participants identified was that it makes virtual collaboration more crucial. Indeed, it will be more difficult to supervise team members because they can hide behind their computers and nobody knows if they are not contributing to a discussion. The nature of this communication may not be conducive to encouraging participation because those not already committed to the task at hand "*can be more lazy* (by not contributing)," and do not have to worry about defending their reputation. Thus, social loafing is likely to occur unless team members are invested in the goal of a collaborative effort,

5. To what extent you think that hiding your visual identity could influence leadership?
Leadership is critical to effective collaboration and participants explained that hidden visual identity in collaboration can both help and hinder the influence of leadership in VWs. On one hand, it can facilitate leadership because "*Shy people can express themselves more easily and become leaders in the VW.*" it may also encourage the group to share leadership responsibilities. On the other hand, hidden visual identity can be detrimental to leadership efforts when it deteriorates the interpersonal relationship between leaders and followers. For example, if "*everyone considers him/herself equal to the other group*

members, everybody may want to lead the team and nobody would want to take instructions." In this instance, it would make it difficult for the assigned leader to leverage his authority and regulate the group. Further, trust between leaders and followers, is essential to effective collaboration; therefore, hidden visual identity is likely to breed distrust when followers cannot become intimately familiar with their leader. The absence of face-to-face interaction makes trust very difficult to build, especially for newly formed teams.

6. To what extent do you think that socialization could enhance knowledge sharing?

Finally, participants indicated that socialization during VW collaboration efforts could enhance knowledge sharing by means of building bonds and trust that in turn increase the willingness to share and collaborate. Socialization may even lead to collaboration and knowledge sharing outside of the structured collaboration session if people discover they share a common interest. Participants did echo some concerns that socialization in VWs can be a distraction when it takes the focus of collaboration away from accomplishing the task at hand. However, they suggested that socialization is more likely to stir mutual interests and inspire new ideas than it is to overwhelm collaborators with distractions.

5 Discussion and Conclusions

VWs are pervading our daily life and are working their way into our offices. They seem to be an object of diverse opinions, criticisms and support, ranging from the fear of losing human contact to the considerable advantages of distributed team collaboration. From a logistics standpoint, VWs inherited some advantages and opportunities from VTs. For instance, VWs are relatively cheap and easy for anyone to access remotely from everywhere at anytime, they can reduce distances and costs, save time and travel efforts. They allow real time and rapid communications. These findings align with Owens and colleagues (2009) and Davis and colleagues (2009) research. Further, from an interpersonal standpoint, VWs allow an easy knowledge sharing which is one of the bases of virtual team collaboration according to Cramton (2001).

Moreover, VWs have several advantages and opportunities related to the technology. For instance, VWs are customizable environments and have a gaming aspect. As such people will feel more comfortable when working in a pleasant and flexible environment that they can control. Avatar personalization is important because it allows users to express their personality and utilize an avatar to they can relate to. This finding matches with Ducheneaut and colleagues (2009) research as they found that people were more engaged during VW activities when their avatar reflected users' persona. Moreover, the ability to create and manipulate objects in VWs offers the possibility to reduce risks through process simulations, increase the creativity of users, and help users to develop their interpersonal skills. In addition, VWs provide the possibility to hide one's visual identity which may decrease discrimination among team members and allow them to express their opinions more freely. Finally, VWs facilitate more realistic socialization than experienced by traditional VTS, which matches Hendaoui and Limayem's (2008) conclusions.

Basing on these findings, the adoption of VWs into our daily lives and organizations is expected to increase in the future in the age of Web x.0. However many threats or issues remain unresolved. These obstacles could have some negative effects on the adoption and acceptance of VWs by teams due to salient drawbacks and threats. In fact, VWs' lack a juridical framework and provide poor security against hacking, fraud and identity theft as seen in the research of Lastowka and Hunter (2004 ;2005). In addition, several leadership problems have been reported—mainly due to the lack of face-to-face and body language communication. Consequently, team efficiency could drop significantly in VWs. In addition, VWs require advanced technical skills which may inhibit users from adopting them (Bessière, 2009). Finally, VWs could lead to some psychological issues such as isolation (Bos, 2004), addiction, social loafing and loss of touch with the reality.

After data analysis, we noticed a set of constructs that seem to be relevant to effective collaboration in VWs. They are factors may positively or negatively influence team collaboration in VWs, such as social loafing, knowledge sharing, socialization etc.. Some of these factors are essential to effective collaboration, and all have an obvious impact by enabling or inhibiting individuals or teams when collaborating. Enabling factors include opportunities such as knowledge sharing, and others are inhibitors such as social loafing. Some factors can even be both enablers and inhibitors such as the use of hidden visual identity. These understandings/insights are a first step towards an optimal utilization of VWs to conduct team collaboration and a help for better designing of future VWs.

This study is a preliminary exploratory study on the salient barriers and opportunities of collaboration in VWs. It reported the point of view of management students (from the digital generation) on the adoption and use of VWs for team collaboration. The participants produced a list of ideas about their perceptions of team work in VWs. The results provide interesting insights on the various opportunities and challenges organizations face when managing distributed teams in VWs. Nevertheless, this study has several limitations to be taken into account. First of all, it was conducted with a limited number of students from the same class. Second, all participants came from the same geographic location which could lead to a regional bias. Finally, students involved in this study did not actually perform collaborative work tasks for their job in VWs. However they do belong to the digital generation, which tends to be adept at using many Web 2.0 technologies. Further, they are graduate management students who are very sensitive to virtual project management. To address these limitations and as future research directions, we plan to conduct a field study involving experts and managers already using VWs for collaboration.

This exploratory study is an early step in a research program. In future research, we plan to enrich this list of team collaboration factors by conducting a quantitative study examining the relationship between team collaboration factors and performance. It is our hope that this research will address and spawn further research questions surrounding organizations' use of VW. We also hope that this study will aid organizations in deciding they can successfully leverage team collaboration in VWs.

References

Ahuja, M., Carley, K. (1999). Network structure in virtual organizations. *Organization Science*, 10, 741-757.

Alpine executive center. http://www.alpineexecutivecenter.com. *(last accessed on May 2011)*

Armstrong, A., and Hagel, J. (1996). The real value of online communities. *Harvard Business review* 134-141.

Bessier et al., K., Newhagen, J., Robinson, J. Shneiderman, B. (2006). A model for computer frustration: The role of instrumental and dispositional factors on incident, session, and post-session frustration and mood. *Computers in Human Behavior*, 22, 941–951.

Bessière, K., Ellis, J., Kellogg, W. A. (2009). Acquiring a Professional "Second Life:" Problems and Prospects for the Use of Virtual Worlds in Business. *CHI 2009*, April 4 – April 9, 2009, Boston, MA, USA.

Bos, N., Shami, N. S., Olson, J. S., Cheshin, A., Nan, N. (2004). In-group/out-group effects in distributed teams: an experimental simulation. *CSCW 2004, ACM Press* 429-436.

Boughzala, I. (2007). *Ingénierie de la collaboration : Théories, technologies et pratiques*. Paris France, Hermès.

Briggs, R. O., Vreede de, G. J., Nunamaker, Jr., J. F. (2003). Collaboration Engineering with ThinkLets to Pursue Sustained Success with Group Support Systems. *Journal of Management Information Systems*, 19, 31-64.

Cahalane, M., Feller, J., Finnegan, P. (2010). Investigating Collaborative Development Activities in a Virtual World: An Activity Theory Perspective. *ICIS 2010 Proceedings* Paper 84.

Castronova, E. (2006). On the Research Value of Large Games: Natural Experiments in Norrath and Camelot. *Games and Culture*, 1, 163-186.

Chemers, M. M. (1997). *An integrative theory of leadership*, Lawrence Erlbaum Associates.

Chen, T. Y., Chen, Y.M. (2009). Advanced multi-phase trust evaluation model for collaboration between coworkers in dynamic virtual project teams. *Expert Systems with Applications* 29, 11172–11185.

Clausen, J. A. (1968). *Socialization and Society*, Boston: Little Brown and Company.

Cramton, C.D. (2001). The mutual knowledge problem and its consequences for dispersed collaboration. *Organization Science*, 12, 346-371.

Davis, A., Murphy, J., Owens, D., Khazanchi, D., & Zigurs, I. (2009). Avatars, People, and Virtual Worlds: Foundations for Research in Metaverses. *Journal of the Association for Information Systems*, 10(2), 90-117.

De Vreede, G. J., Briggs, R. O. Massey, A. P. (2009). Collaboration Engineering: Foundations and Opportunities. *Journal of the AIS*, 10, 121-137.

Dennis, A.R., Wixom, B.H., Vandenberg, R.J. (2001). Understanding fit and appropriation effects in group support systems via meta-analysis. *MIS Quarterly*, 25, 167--183.

Ducheneaut, N., Wen, M., Yee, N., Alto, P., Wadley, G. (2009). Body and mind: a study of avatar personalization in three virtual worlds. *Proceedings of the 27th international conference on Human factors in computing systems*. Boston, MA, USA

Fjermestad, J., Hiltz, S. R. (1999). An assessment of group support systems experimental research: methodology and results. *Journal of MIS*, 15, 7-150.

Fortune. http://money.cnn.com/magazines/fortune/fortune_archive/2007/02/05/8399120/. *(last accessed on May 2011)*

Franceschi, K., Lee, R. M., Zanakis, S. H., Hinds, D. (2009). Engaging Group E-Learning in Virtual Worlds *Journal of Management Information Systems,* 26, 73-100.

Gassmann, O., Zedtwitz, M.V. (1999). Organizing virtual R&D teams: Towards a contingency approach. *Management of Engineering and Technology*, 1, 198–199.

Giddens, A. (1984). *The Constitution of Society: Outline of the Theory of Structuration*. Polity Press.

Hall, C. M., Mcmullen A.H. S., Hall, D. L., Mcmullen, M. J., Pursel, B. K. (2008). Perspectives on visualization and virtual world technologies for multi-sensor data fusion. *Information Fusion 11th International Conference*

Hendaoui, A., Limayem, M., Thompson, C. W. (2008). 3D Social Virtual Worlds: Research Issues and Challenges. *IEEE Internet Computing*, 12, 88-92.

Huang, R., Kahai, S., Jestice, R., (2010). The contingent effects of leadership on team collaboration in virtual teams. *Computers in Human Behavior*, 26, 1098–1110.

Karau, S., Williams, K.D. (1993). Social loafing: A meta-analytic review and theoretical integration. *Journal of Personality and Social Psychology*, 65, 681-706.

Keil, M., Tiwana, A., Bush, A. A. (2002). Reconciling User and Project Manager Perceptions of IT Project Risk: A Delphi Study. *Information Systems Journal*, 12, 103-119.

Kock, N. (2008). E-Collaboration and E-Commerce In Virtual Worlds: The Potential of Second Life and World of Warcraft. *International Journal of e-Collaboration*, 4, 1-13.

Lastowka, F. G., Hunter, D. (2005). Virtual Crimes. *New York Law School Law Review*, 49, 293.

Lastowka, F. G., Hunter, D. (2004). The Laws of Virtual Worlds. *California Law Review* 92, 1.

MacInnes, I. (2006). Property Rights, Legal Issues, and Business Models in Virtual World Communities. *Electronic Commerce Research*, 6, 39-56.

Malaby, T. (2006). Parlaying value. *Games and Culture*, 1, 141-162.

Mark, G., Grudin, J., Poltrock, S. (1999). Meeting at the desktop: An empirical study of virtually collocated teams. *In Proc of ECSCW*.

Martins, L.L., Gilson, L.L., Maynard, M.T. (2004). Virtual Teams: What do we know and where do we go from here? *Journal of Management*, 30, 805-835.

Mennecke, B. E, Roche E. M, Bray, A. D., Konsynski, B., Rowe, M, Lester, J., Townsend, A. M, (2007). Second Life and other Virtual Worlds: A Roadmap for Research. *International Conference on Information Systems*.

Owens, D., Davis, A., Murphy, J. D., Khazanchi, D., Zigurs, I. (2009). Real-World Opportunities for Virtual- World Project Management. *IT Professional*, 11, 34-41.

Robinett, W., Holloway, R. (1992). Implementation of Flying, Scaling, and Grabbing in Virtual Worlds. *Proceedings of the Symposium on Interactive 3D Graphics***,** 197-208.

Roche&Van-Nostrand (2007). Information Systems, Computer Crime & Criminal Justice. New York., Barraclough Legal Publishing.

Rohall, S., Cheng, L.-T., Patterson, J. (2008). Bluegrass: Lessons for deploying virtual worlds within the enterprise. Workshop on Virtual Worlds, Collaboration, and Workplace Productivity, *CSCW*.

Schmidt, R., Lyytinen, K., Keil, M., Cule, P. (2001). Identifying Software Project Risks: An International Delphi Study. *Journal of MIS*, 17, 5-36.

Schroeder, R. (2006). Being there together and the future of connected presence. *Presence: Teleoperators & Virtual Environments*, 15, 438-454.

Schroeder, R. (2008). The social life of avatars: Presence and interactions in shared virtual environments. *Proceedings of the 11th Annual International Workshop on Presence*. Padova.

Shalini, C., Srivastava, S., Theng, Y. (2009). Role of cognitive absorption and trust for collaboration in virtual world. *PACIS 2009 Proceedings*.

Shami, N. S., Cheng, L., Rohall, S., Sempere, A., Patterson, J. (2010a). Avatars Meet Meetings: Design Issues in Integrating Avatars in Distributed Corporate Meetings. *GROUP'10*. Sanibel Island, Florida, USA.

Shami, N. S., Cheng, L., Rohall, S., Sempere, A., Patterson, J. (2010b). Enhancing distributed corporate meetings with lightweight avatars. *CHI 2010, Proceedings of the 28th of the international conference extended abstracts on Human factors in computing systems.*

Shaw, M. E. (1971). *Group dynamics: the psychology of small group behavior*. NY.

Srivastava, S. C., Shalini, C. (2010). Examining Utilitarian and Hedonic Factors and their Moderators for Virtual World Collaborations. *AMCIS 2010 Proceedings*.

TheImmersiveSpaces. http://riversrunred.com/. *(last accessed on May 2011)*

Tikkanen, H., Hietanen, J., Henttonen, T., Rokka, J. (2009). Exploring Virtual Worlds: Success Factors in Virtual World Marketing. *Management Decision*, 47, 1357-1381.

Townsend, A. M., DeMarie, S. M., Hendrickson, A. R. (1998 b). Virtual teams and the workplace of the future. *Academy of Management Executive*, 12, 17–29.

Virtualis. http://www.virtualiscenter.com/. *(last accessed on May 2011)*

Yankelovich, N., Kaplan, J., Simpson, N., Provino, J. (2007). Porta-Person: Telepresence for the Connected Conference Room. *CHI 2007*. San Jose, California, USA.

Yee, N., Bailenson, J., Urbanek, M., Chang, F., Merget, D. (2007). The unbearable likeness of being digital: The persistence of nonverbal social norms in online virtual environments. *The Journal of CyberPsychology and Behavior* 115-121.

Zolin, R., Hinds, P. J., Fruchter, R., Levitt, R. E. (2004). Interpersonal trust in crossfunctional, geographically distributed work: A longitudinal study. *Information and Organization*, 14, 1–26.

Technology Support for Collaborative Work: A Preliminary Study on a Framework for Studying and Analyzing Group Facilitation

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Abstract: Facilitation has been extensively studied in Group Support Systems (GSS) but under researched in other evolving collaboration technologies. Based on the MAIN+ modeling approach, this paper develops a two-tiered organizing framework on facilitation of technology supported collaboration. Preliminary case situation is used to highlight the dynamic and multi-dimensional nature of facilitation. Contributions include a better understanding of facilitator responsibilities, development of richer facilitation task taxonomies and identification of critical collaboration technology features.

Keywords: Facilitation; Design Science; Modeling; Collaborative Work; Virtual Teams.

1 Introduction

Facilitation has been studied widely in the Group Support Systems (GSS) literature (Fjermestad and Hiltz 1998), but in today's environment, teams choose from a vast array of technologies which can offer varied functionalities and complexities that extend beyond GSS, such as social networking tools and virtual worlds. It is not clear how the role of facilitation changes as teams move into a greater variety of collaborative work situations supported by a myriad of collaboration technologies. Moreover, in practice, facilitators are not always readily available, nor affordable, and the need for automated systems that are capable of effectively supporting some facilitator functions is apparent.

Therefore our objective is to introduce a framework to provide a structured perspective on the role of facilitation to support a team's collaborative activities. Understanding facilitation roles and responsibilities has useful potential for (virtual) project leaders by allowing them to better streamline their process management and apply technologies to support collaborative work situations with increasingly virtual and distributed teams. We therefore aim to develop an organizing framework to better understand the different situations in which teams may use facilitation support to be productive. The research questions we will address are as follows:

RQ 1: What is the role of facilitation in technology supported collaboration?

> **RQ1.1** What are the different collaborative scenarios or situations that can benefit from facilitation support?
>
> **RQ 1.2** What are the different facilitator roles and responsibilities in these different collaborative situations?

The remainder of this paper is structured as follows. In the next sections we discuss the importance of facilitation and its effects on teams and teamwork. This is followed by a description of the MAIN+ modeling approach which we use as a basis to model different collaborative situations and provide examples to better illustrate our proposed framework. We then discuss the utility of this framework in terms of research, practice, and technology design. The paper concludes with a discussion of the framework's limitations and directions for future research.

2 Facilitation

In collaboration research, facilitation is typically considered to be the process by which “a person—whose selection is acceptable to all the members of the group, who is substantively neutral, and who has no substantive decision–making authority—diagnoses and intervenes to help a group improve how it identifies and solves problems and makes decisions, to increase the group’s effectiveness.” (Schwarz, 2002, p.3). Facilitation also functions to guide groups in selecting which collaboration tasks and tools to use, as well as when to use them (Dickson et al., 1993). Such tools can range from simple pen and paper methods to advanced collaboration technologies. As a result, some authors distinguish between two types of facilitation: 1) technical facilitation, and 2) group process facilitation (Clawson et al., 1993). The first form is aimed at assisting participants with the technology, and the second at managing participant interactions. Technical facilitation often is executed by a chauffeur or technographer, who simply listens and operates the collaboration tools, but does not contribute ideas to the discussion (Straus, 2002). Regardless of the form, facilitation is needed to 1) successfully aggregate and build on the strengths and expertise of individual group members, while limiting the challenges of group work; and 2) direct groups in regards to making optimal use of performance enhancing collaboration technologies (de Vreede et al., 2002; Dickson et al., 1993).

2.1 Facilitation Styles, Tasks and Characteristics

Not only does the presence of a facilitator influence technology supported collaborative problem solving efforts matter, but delivery of the facilitation process also impacts collaboration. Thus, we must be able to dissect the role of the facilitator into substantive delivery styles, tasks, and responsibilities. Griffith et al. (1998) and Miranda & Bostrom (1999), indicated that facilitation styles do matter as process facilitation—which provides structure and ensures fair participation—yielded group decision outcomes with higher quality and consensus than that of content facilitation—which allows the facilitator to intervene and contribute ideas to the decision process. Groups experiencing content facilitation were overconfident in the contributions of their facilitators and in response produced fewer of their own ideas. Furthermore, there are two types of process facilitation (Dickson et al., 1996): ‘task interventions’ and ‘interactional interventions’. Task interventions (e.g., guiding the agenda, clarifying issues) are meant to focus the group’s attention on the task. Interactional interventions (managing conflict, soliciting feedback) are aimed at the participants and their relationships. Hostager et al. (2003) found that when process facilitation style (task vs. process interaction) fit the nature of the GSS agenda structure (anonymous, closed-ended activities vs. open-ended discussion), group decision outputs were of higher quality and participants were more satisfied with the outputs and collaboration process. Thus, facilitation does not occur in a vacuum as the behavior of a facilitator and the nature of the collaboration process design has an interactive effect on collaborative decision making outcomes.

In addition to delivery style, the role of the facilitator is also contingent on their tasks. Consequently, Clawson & Bostrom (1996) surveyed expert facilitators to determine what tasks were most salient to the role of a facilitator in GSS supported collaboration. This study yielded a list of the 16 most critical tasks, ranging from planning and designing the meeting to presenting information to the group. Moreover, Niederman et al. (1996) conducted interviews to determine what characteristics a facilitator must have to effectively execute these tasks. Respondents indicated that the two most important qualities are good communication skills and ego-less facilitation, followed by understanding the group and its objectives; flexibility; task focus; and leadership. Understanding the most important tasks and qualities exhibited by facilitator creates a foundation for improving and training for the role of the facilitator.

Moving beyond GSS research, the importance of facilitation is evident in other collaborative endeavors. Presently, organizations are becoming increasingly reliant on Community of Practice (CoP). The CoP lifecycle is typically described in four stages requiring 1) exploration of membership interest; 2) organizing and building of the group 3) activation of the interpersonal communications and activities for purposes of the group; and 4) deactivation of group functioning (Tarmizi & de Vreede, 2005). CoP facilitators have the most intensive role in the group as such members report that on average they spend over 53% of their assigned work time managing the group by means of networking, encouraging participation, and coordination events. Unsurprisingly, the greatest challenges experienced by the facilitator in supporting a CoP are usually specific to the stage in which the CoP resides at the time.

Tarmizi, et al., (2006) indicated that these challenges typically fall within six categories ranging from making a case for the CoP to finding common interesting topics for members to discuss.

In addition to understanding the challenges of facilitating a CoP, the role of the facilitator can be improved by identifying what tasks need to be conducted by a facilitator for the CoP to be productive. For this reason, the aforementioned facilitation taxonomy created by Clawson & Bostrom (1996) was expanded into a CoP specific taxonomy of facilitation tasks by Tarmizi & de Vreede (2005). The CoP taxonomy 33 facilitation tasks that can be categorized as either an internal or external task. Internal tasks involve the functioning of interactions within the community, whereas external tasks concern the functioning of the CoP within the broader organizational environment. More specifically, internal tasks can be subdivided into three facilitator roles: 1) source of information for members of the group; 2) provide inspiration for members to be active in the community; and 3) guide for assisting and advising members. Conversely, external tasks can be subdivided into the following three roles: 1) information source for explaining the CoP to the outside world; 2) public relations manager; and 3) investigator that searches and collects useful information for CoP members. With this understanding of the challenges and task requirements of CoP facilitators, step can be taken to improve facilitator performance and training.

Early research supports that facilitation is of critical importance for a smooth and effective deployment of teams (Kayser, 1994; Rees, 1991; Niederman & Volkema, 1999). Many studies have examined facilitation and leadership in face-to-face teams (see Bass, 2008 for a review of past work in this area), CoPs (Tarmizi & de Vreede, 2010; Tarmizi et al., 2007), and virtual teams (Kahai et al., 2004; Kayworth & Leidner, 2001). For example, Tarmizi and de Vreede (2010) identified five common leadership tasks necessary for facilitators of both CoPs and virtual teams: 1) present information; 2) keep community focus on its purposes; 3) promote the understanding of tools; 4) help community or community members through suggestions; and 5) build members' cooperative relationship. Other studies have examined the challenges of leadership in these realms (Tarmizi et al., 2007).

Yet another line of research has examined the influence of a facilitator's leadership style in CoPs and virtual worlds (Kahai et al., 2004; Kahai et al., 2007). More specifically, when facilitators adopted participatory and directive styles in a collaboration process supported by GSS, participants contributed more ideas to the problem solving effort (Kahai et al., 2004). Further, the more participants contributed, the better they performed, but the less satisfied they felt. Interestingly, when Kahai & Avolio (2008) examined the impact of two common leadership styles—transformational and transactional leadership—on virtual teams, they found that group member participation increased under transactional leadership, especially when contributions were identified (vs. anonymous). Additionally, Carte et al., (2006) found that self-managed virtual teams performed best when leadership emerged in the group that was narrowly focused on performance.

2.4 Organizational Access to and Use of Facilitators

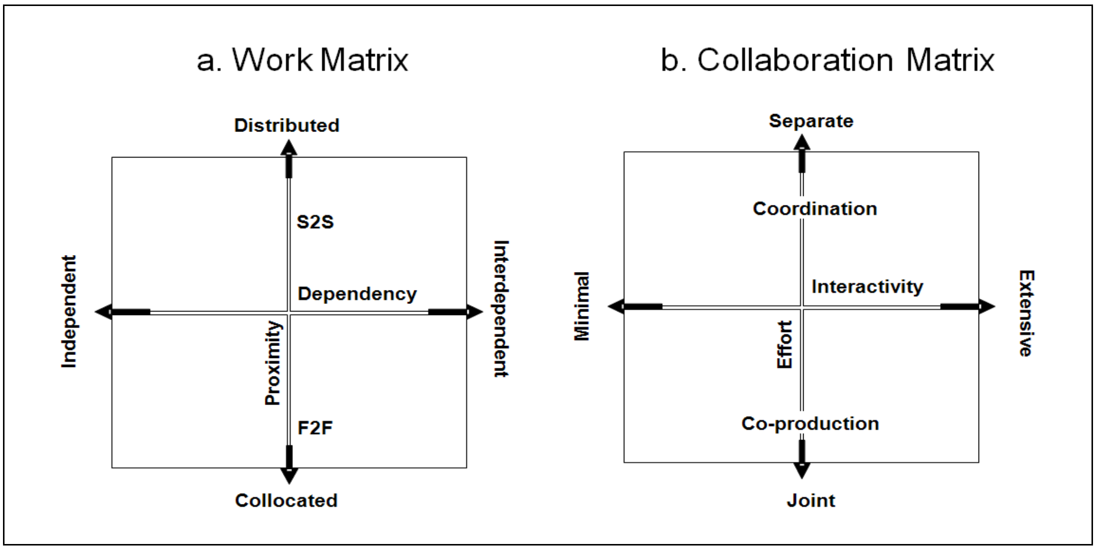
Trained facilitators are invaluable when an organization desires to create sustainable collaborative work practices, successfully adopt such practices, and diffuse collaboration technologies in the workplace (Briggs et al., 2003). In their study Munkvold & Tvedte (2003) found the greatest challenge of GSS implementation was around a lack of facilitators. To determine the likelihood of successfully implementing a collaborative work process supported by collaboration technology into an organization, Briggs et al. (1998) developed the Technology Transition Model (TTM). Generally speaking, the TTM hypothesizes that organizational intention to use a collaboration technology is positively related to how frequently the organization expects to use the technology, and how much value the technology is expected to deliver. Further, these relationships are moderated by organizational certainty that the collaboration technology will work and the perceived net value of the transition to the technology. Behavioral intentions to use the collaboration technology are then expected to be positively related to actual technology use. Two case studies by Agres, et al., (2005) provide support for the TTM. First, a study of GSS use at Rotterdam Port Authority (RPA) indicated that this organization effectively implemented GSS into their daily work. Specifically, RPA followed the TTM as GSS was utilized frequently for disaster relief training (meaningful work). Additionally, cognitive effort for GSS use was minimized through frequent and meaningful training (high certainty of positive results).

3 A Model of Collaborative Work Situations

In this paper, we use the MAIN+ modeling approach as a basis to model different collaborative situations in which teams may use and benefit from facilitation support. MAIN+ is based on business process virtualization modeling in which collaborative situations are analyzed according to the nature of the work (geographical location and work interdependence) and to the form of the collaboration (communication, coordination and co-production) (Boughzala 2001; 2007). The goal of MAIN+ is to support organizations to understand the collaborative nature of the different working situations of their employees and teams and to provide them with collaboration tool recommendations. To this end, MAIN+ provides a structured sequence of analysis steps and a set of modeling techniques to determine the flow and 'virtualizability' of key collaboration processes (Overby, 2008). It also provides for decision aids to determine which type of collaboration technologies would be useful for certain collaborative processes and tasks.

An extensive description of MAIN+ is beyond the scope of this paper. For further details please refer to (Boughzala & Romano, 2011, Boughzala et al., 2010; Levan, 2004). For the development of our organizing framework to discriminate between different types of collaborative activities and situations, we use the MAIN+ techniques from the approach's 'Collaborative Situation Analysis' phase. In this phase, the interactions of actors within each collaborative task are analyzed and identified. Two matrices are used to perform this central analysis in MAIN+: The work matrix and the collaboration matrix (Figure 1)

Figure 1. Work Matrix (a) and Collaboration Matrix (b)
(note: S2S = Screen-to-screen; F2F = Face-to-face)



The Work matrix (Figure 1a) is inspired from the space-time matrix proposed by Johansen et al., (1991) and adapted partially from (Levan 2004). The horizontal axis represents work dependency in terms of work goals and deliverables ranging from independent work (individual work) to interdependent work (collective work) (Malone & Crowston, 1994; Kim, et al., 2002). The vertical axis represents actor proximity ranging from collocated work (Face to Face (F2F) – in the same place) to distributed/remote work (Screen-to-Screen (S2S) – at different places) (Festinger, et al., 1950; DeSanctis & Gallupe 1987; Barkhi, et al., 1999). The Collaboration matrix (Figure 1b) consists of two axes based on collaboration forms: communication, coordination and co-production. The horizontal axis represents the axis of communication interactivity ranging from minimal to extensive (Rafaeli & Sudweeks 1997; Downes & McMillan 2000; Lowry, et al., 2009). The vertical axis represents effort ranging from separate effort to joint effort. Separate effort represents coordination where each actor carries out his/her part of task in consistency with those of the team according to the overall process. It can be in sequence or in parallel with respect to other actors' efforts. Joint effort involves co-production where each actor brings their own knowledge, experience and expertise to solve a common problem simultaneously or to collectively carry out a group task in a synchronous mode (Nunamaker et al. 2001-2002).

Combining the Work and Collaboration matrix yields 16 unique collaborative work situation arch-types. Each collaborative team task can be placed within one of the four quadrants of each matrix to depict their relative collaborative nature. This also forms a starting point to further distinguish between different facilitation tasks and responsibilities. As discussed above, a facilitator may have different responsibilities and involvement levels be it technical, content, or group process facilitation. Building on the previous facilitation research as discussed in the previous section, we identify four distinct facilitator responsibilities: to design, to execute, to evaluate or to train. The facilitator can assume one or more of these responsibilities over the course of a collaborative process:

1. *Design* responsibilities include planning and structuring procedures before the actual execution. The facilitator designs a dynamic process that aims to align and manage relationships, tasks, and technology (Bostrom, et al., 1993). This includes defining key process steps, selecting appropriate collaboration technologies, and preparing instructions for the team members.
2. The *Execution* responsibility includes applying structured procedures and encouraging effective relational behaviors. This involves encouraging broad participation and influence (Hoffman & Maier, 1959), managing conflict constructively (Putman, 1986), emphasizing consensus acceptance through voting (Hall & Watson, 1970), discussing tasks procedures (Hackman & Kaplan, 1974), applying explicit criteria (Hirokawa & Pace, 1983), using and sharing factual information (Hirokawa & Pace, 1983) and maintaining focus on task goals (Dalkay & Halmer, 1963).
3. *Evaluation* responsibilities include the assessment of a collaboration process as it unfolds, generating post meeting assessments, and proposing changes to improve the efficiency and effective of the collaborative practices. When evaluating, the facilitator applies active listening techniques (Bostrom, 1989), discusses interpersonal processes (Hackman & Kaplan, 1974), and acts as a team coach or personal coach.
4. *Training* responsibilities involve teaching collaborative procedures, techniques, and technologies. A facilitator may train group members and/or leaders (Hall & Williams, 1970), provide detailed instructions to group members (Hall &Watson, 1970), or train external facilitators (Anson, 1990; Bostrom, 1989, Hirokawa & Gouran, 1989). A facilitator can also be involved in the transfer of collaborative practices to teams or team leaders. The intention of such training is for the teams to be able to execute the process without any further support from the facilitator (Vreede et al., 2009).

Apart from having different responsibilities, facilitators also experience different levels of involvement in the various collaborative work situations. Depending on their level of involvement, we can classify facilitators as Performers, Conductors, or Choreographers:

1. *Performer*. In this role, someone is involved in all aspects of the team work as both a facilitator and a team member/leader. As a performer (s)he provides support for the technology, moderates and participates in discussions, structures and co-executes tasks, and provides content. His or her presence is critical for successful outcomes of the collaboration process. As a performer the facilitator not only supports the group and encourage multiple perspectives but can provide content from his or her perspective that directly relates to the problem or outcome that is being addressed. This role bears many similarities with that of a meeting chair.
2. *Conductor*. This role is not less involved than that of a Performer. In this role, the facilitator's presence is also critical to the collaborative activity. However, (s)he listens and moderates the discussion, clarifies the process, and collects and integrates information from team members. However, (s)he is not involved in providing actual content to the process like offering solutions to a problem. This role is often considered the traditional role of a facilitator.
3. *Choreographer*. In this role, the focus is on all the pre-planning and design activities that occur before the actual execution of the team process. Their role is like a collaboration engineer who prescribes the way in which a team should execute a collaborative task including the selection of tools that they need to use (Vreede et al. 2009). The involvement of a choreographer encompasses all details related to planning the collaborative work practices, including defining the team's goal, naming and describing team activities, scheduling, identifying required team members, notifying these team members, prescribing working procedures, and defining expected outcomes.

By combining the Work and Collaboration matrix with the different facilitation responsibilities and roles, we create a two-tiered organizing framework. This framework models collaborative work into 16 distinct situations and provides the situational context to explore the different tasks a facilitator may perform to fulfill different responsibilities and roles in each of these situations. In the next section, we use this framework in a case situation in the automotive industry to illustrate different types of facilitation actions and behaviors.

4 Facilitating Technology Supported Collaboration

To better illustrate the framework introduced above, preliminary application was done at a multinational automotive firm. This firm established a new organizational matrix structure, based on the “management by project” principle, after a merger-acquisition between three brands in different countries. This meant greater usage of distributed virtual teams across three different sites. Management by project introduced increased diversity and complexity in terms of actors’ relationships and responsibilities. The company also established several CoPs after a knowledge management audit recommendation. These informal groups focused on several topics related to the company’ specific areas of interest. The CoPs were established as spaces of knowledge sharing, collective reflection/problem solving and innovation. They functioned as think tanks and followed the evolution of the automotive domains. In this context, high quality collaboration between individuals, teams, and sites became increasingly crucial. Indeed, effective collaboration was expected to lead to increased efficiency, higher quality outcomes, and more widely to an overall improved organizational performance. The role of facilitators was considered critical to accomplish desired collaborative productivity, especially since team members’ roles and responsibilities became increasingly diverse and complex due to an assortment of working settings (formal and informal), organizational structure (e.g. project teams, networks, workgroups, CoP) and the prevalence and intensive use of collaboration technologies (e.g. groupware, GSS, and Web 2.0).

To illustrate the different facilitator roles, styles, and responsibilities according to the 16 collaborative situations, we focus on two situational examples within two settings (project mode and community mode) in this automotive firm. The first example relates to a virtual team distributed over two countries (two sites) with different organizational and national cultures, work habits, project management styles (hierarchical vs. consensual management) and decision making styles (reactive vs. proactive behavior). This virtual team was in charge of the “Engine After Treatment System” (EATS) that was part of a larger development project of a new diesel engine (NDE) that took place under the responsibility of a business unit distributed across three countries. This team had three facilitators: The leader of the business unit for the whole project (NDE), the leader of the virtual team (EATS Site 1) and the local coordinator at the other site (EATS Site 2). We refer to these three facilitators as F-A, F-B, and F-C respectively. They assumed different roles and have different styles and responsibilities according to their position in the project: F-A and F-B had a consensual management style and F-C had a hierarchical management style.

The second example is related to a CoP working on “Future Advanced Ecological Systems” (FAES). This CoP is completely virtual and involves several participants from different countries, business units, and sites. Participant involvement in these types of CoPs was voluntary but strongly encouraged by the management. The CoP was facilitated by a group of moderators (referred to as CoP-F1…CoP-Fn) which was related to the different sub-themes and the portfolio of collaboration technologies (Discussion forums, Wikis, blogs, RSS, podcasting, social platform, CMS, etc). The facilitators’ style is this COP was consensual.

Table 1 provides examples of team/CoP member tasks and facilitator tasks according to their different profiles in the 16 standard collaborative work situations. The information for these examples was gathered through observations, interviews with team members and facilitators, and access to session logs on some of the collaborative platforms that were used. For each situation there are two types of task examples. The first is related to the member profile (team member or CoP member) and the second is related to the facilitator profile (team facilitator or CoP facilitator). For each profile, there are two examples according to the two settings (project mode and community mode). The first is related to the virtual team EATS and the second is related to the CoP FAES. For example, for the first collaborative work situation in the EATS team a team member could execute his/her own task in the project according to his/her competence. This work is independent (individual) and distributed. In terms of collaboration, the interactivity between this one and other members is minimal and his/her effort is separate. The same goes for the FAES community when a CoP member posts a message on the discussion forum. In the same situation for EATS, facilitator F-B determines different research tasks and assigning them to project members while the facilitator F-C observes the execution of the task. For the FAES setting, facilitator CoP-F1 checks the messages posted by CoP members on the discussion forum.

Table 1: Task Examples of Members and Facilitators in Project and Community Modes (Automotive Scenario)

Sit#	**Work**				**Collaboration**				**Member Task Examples (Project (EATS) vs. Community mode (FAES))**	**Facilitator Task Examples (Project (EATS) vs. Community mode (FAES))**
	Dependence		Proximity		Interactivity		Effort			
	IN	INTER	DIST	COLL	MIN	EXT	SEP	JOI		
1	**X**		**x**		**x**		**x**		**EATS**: Executing his/her own task in the project according to his/her competence, e.g. collecting recent relevant diesel engine research. **FAES:** Posting a message on the discussion forum.	**EATS:** F-B: Determining relevant areas of research and assigning research tasks to individual project members. F-C: Observing the execution of the research task **FAES:** CoP-F1: Checking the messages posted on the discussion forum (as moderator)
2	**x**		**x**		**x**			**x**	**EATS:** As a trainee, remotely observing group solving a problem or testing a protocol (e.g. Laboratory Engine experiments). **FAES:** Reviewing the flow of a discussion.	**EATS:** F-A: Designing the protocol of an experiment. F-B: Remotely observing a group solving a problem or testing a protocol as evaluator (e.g. Laboratory Engine experiments). **FAES:** CoP-F1: Following the discussion flow or explaining the rules of the discussion protocol.
3	**x**		**x**			**x**	**x**		**EATS:** Writing assigned parts of a specification report and exchanging it with other team members. **FAES:** Sharing knowledge through the CoP's wiki.	**EATS:** F-B: Assigning each member one part of the next version of a specification report. F-C: Checking the progress of everyone towards the deadline. **FAES:** CoP-F1: Evaluating the veracity of the shared knowledge on the CoP's wiki.
4	**x**		**x**			**x**		**x**	**EATS:** Working remotely synchronously with	**EATS:** F-B: Conducting remotely the co-

	x								others on the same artifact making a distinct individual contribution, e.g. the co-design of a mechanical piece with group of engineers with different skills through a shared application. **FAES:** Giving his/her feedback on one issue from his/her viewpoint through Instant Messenger (IM).	design task in group consisting of experts from different areas of expertise. F-C: Training people to use the shared application. **FAES:** CoP-F1: Motivating people to give their personal feedback through IM.
5	x			x	x		x		**EATS:** Executing an individual project task in the presence of others as a demonstration or simulation.	**EATS:** F-C: Evaluating the quality of a demon-stration/simulation of an individual task/process by a project member.
6	x			x	x			x	**EATS:** Reporting as an observer on collocated group problem solving.	**EATS:** F-C: Observing collocated group problem solving.
7	x			x		x	x		**EATS:** Executing an individual project task in the presence of others to get their feedback immediately.	**EATS:** F-C: Evaluating the quality of a demon-stration/simulation of an individual task by a project member. Evaluating the feedback provided by the other members present.
8	x			x		x		x	**EATS:** Working same place same time with others on the same artifact making a distinct individual contribution, e.g. the co-design of a mechanical piece in a team with varied engineering skills.	**EATS:** F-C: Conducting a local co-design task in a group with experts from different areas of expertise.
9		x	x		x		x		**EATS:** Planning tasks and assigning roles to others remotely (i.e. Project Leader/Coordinator) **FAES:** Planning tasks and assigning roles to others remotely (i.e. moderator)	**EATS:** F-A: **:** Assigning roles to others remotely. F-B**:** Planning tasks and assigning roles to others remotely. **FAES:** CoP-F1: Planning tasks and assigning roles to others remotely.
10		x	x		x			x	**EATS:** Taking notes and minutes during a virtual meeting.	**EATS:** F-B: Taking notes during a virtual meeting

									FAES: Taking notes and minutes report during a virtual meeting.	**FAES:** CoP-F1: Taking notes during a virtual meeting
11		x	x			x	x		**EATS:** Voting electronically and remotely on the adoption of a new strategy option through an e-voting system. **FAES:** Voting electronically and remotely on one option through an e-voting system.	**EATS:** F-B: Conducting the e-voting task. **FAES:** CoP-F1: Facilitating the e-voting.
12		x	x			x		x	**EATS:** Remotely discussing new ideas to clarify them or make collective decisions on project options. **FAES:** Discussing ideas to clarify them or taking collective decisions on one CoP's task remotely.	**EATS:** F-B: Moderating the group discussion or the decision making process. **FAES:** CoP-F1: Moderating the group discussion or the decision making process.
13		x		x	x		x		**EATS:** Planning tasks in a F2F mode (i.e. Project Leader/Coordinator).	**EATS:** F-C: Planning tasks in a F2F mode.
14		x		x	x			x	**EATS:** Taking notes and minutes during a F2F meeting.	**EATS:** F-C: Taking notes during a F2F meeting.
15		x		x		x	x		**EATS:** Sharing opinions to prepare and submit a personal evaluation of project options.	**EATS:** F-C: Collecting and processing the submitted evaluations.
16		x		x		x		x	**EATS:** Participating in a creative workshop using a GSS, e.g. to brainstorm solutions to an engineering challenge.	**EATS:** F-C: Moderating the creative brainstorming process.

Table Key:

IN: Independent INTER: Interdependent DIST: Distributed COLL: Collocated

MIN: Minimal EXT: Extensive SEP: Separate JOI: Joint

Let us now take a closer look at two examples situations, 4 and 16, to illustrate the different levels of involvement and responsibilities that facilitators can have in each situation. We focus on these two situations as they present the most collaborative scenarios; they have interdependent work with extensive interactivity and joint effort. The only difference between situations 4 and 16 is that in the team members in situation 4 (for EATS and FAES) are dispersed and have to collaborate virtually, while the team members in situation 16 are collocated. Table 2 shows the roles and responsibilities facilitators in these situations assumed in the automotive firm. (Note that similar examples can be provided for other collaborative situations but are not included due to space restrictions.)

Table 2: Facilitator roles and responsibilities for selected facilitator task examples.

Facilitator Task Examples (Project (EATS) vs. Community mode (FAES))	**Facilitator roles and responsibilities**						
	Role and level of involvement (OR)			Responsibility in the process (AND/OR)			
	Performer	***Conductor***	***Choreographer***	***Designer***	***Executioner***	***Evaluator***	***Trainer***
EATS: F-B: Conducting remotely the co-design task in group consisting of experts from different areas of expertise. **(4)**		x			x	x	
EATS: F-C: Training people to use the shared application for a specific collaborative task. **(4)**			x			x	x
FAES: CoP-F1: Motivating people to give their personal feedback through IM. **(4)**		x		x	x		
EATS: F-C: Moderating the creative brainstorming process. **(16)**		x		x	x	x	x

In situation 4 in the EATS case (table 2), F-B is involved in the process in the role of a Conductor. F-B is not the Designer of the process, since this type of process is a standardized process which is designed at the organizational level. F-B is Executioner of the process and also an Evaluator of the participants. For the same situation, F-C is involved in the process as a Choreographer. His responsibilities include that of Trainer and Evaluator, not of Executioner. In EATS, F-C became a Conductor of the process and hence Executioner of the process for some scenarios as he was learning from F-B. In the FAES case, CoP-F1 was involved in the process as a Conductor and Executioner. CoP-F1 was the Designer of the process but did not act as an Evaluator or Trainer of the participants.

Situation 16 only concerns the EATS case as this was a collocated situation (see table 2). Here, F-C assumed the role of Conductor. His responsibilities included being the Designer and Executioner of the process. In addition, he was the Evaluator for the whole process. Sometimes F-C took the role of trainer for the same process for the new recruits.

5 Discussion and Conclusion

Facilitation is a multi-dimensional process. Its purpose is to make collaboration easier for teams by optimizing interpersonal communication, information processing, and the use collaboration technologies. However, most previous research on the facilitation of technology supported collaboration traditionally has taken a mono-dimensional perspective on a facilitator's tasks, roles, and responsibilities. Many past studies either treat facilitation as a uniform high level concept or analyze facilitation from the perspective of a specific type of collaboration technology, such as GSS or CoP. This paper introduces a two-tiered framework to describe facilitation tasks, roles, and responsibilities in different collaborative work situations. We illustrated the framework through a case example in a multinational automotive firm. A key contribution of this framework is that it initially provides a rich insight into the multi-faceted nature of the roles and responsibilities that are assumed by facilitators in varied collaborative situations. This may not only assist organizations to assign responsibilities and provide organizational and technological support for their team leaders and (virtual) project manager who have to fulfill the facilitator role. It may also assist organizational facilitators themselves to prepare for the various responsibilities they have in assisting technology supported teamwork.

The practical utility of this organizing framework extends further. Organizations can use the framework as a starting point to assess which are the most prevalent collaborative work situations and use this assessment as a map to determine which kind of facilitation needs are most prevalent for the organization. Such insights can, for example, inform organizational training programs for virtual team leaders and project managers. Moreover, organizations may use the framework as a basis for defining facilitator hiring profiles and selecting between candidates, or, as a basis for evaluating the performance of their active facilitators and team leaders. Finally, the framework may serve as a guide for team leaders to more comprehensively understand their responsibilities and subsequently consider which collaboration and project management technologies to adopt for their team.

For researchers, the framework can offer an initial foundation for understanding the situational characteristics of facilitation needs and requirements. This may inform the design of experimental studies where subjects are either assigned facilitation responsibilities or are guided by a facilitator that strives to exhibit consistent behavior within treatments. It may also provide useful as an organizing framework to map past research and determine ‘white spots’ to be addressed in future research. For example, to the best of our knowledge, most facilitation research has been carried out in F2F settings with teams using GSS (Situations 15 and 16). Finally, it may serve as a basis for detailed task analysis research that may result in a rich facilitation task taxonomy. Such taxonomy may consist of a foundational set of tasks that cut across all collaborative work situations augmented with task subsets that relate to a specific work situation(s).

Finally, the framework may also provide utility for designers of collaboration technology. Designers can use the framework to identify critical features that have to be embedded in collaboration technologies to support the facilitator function. The framework can also be used as a starting point to compare and contrast the extent to which facilitation support (such as traceability, feedback capturing, or presence indicators) is embedded in different tools.

There are a number of limitations associated to the work presented in this paper. First, the framework presents a model of collaborative work situations. It discriminates between different situations based on a number of characteristics. In reality, it may not always be possible to distinctly discriminate between these situations as they may blend over the course of a team’s collaboration process (e.g. a team moves between periods of minimal and extensive interactivity). Also, there may be other relevant attributes that characterize collaborative work situations, such as psychological or cultural aspects. Further research needs to be conducted to determine whether these limitations significantly limit the utility of the framework. Second, the framework was single case setting to illustrate different facilitation tasks, roles, and responsibilities. While we did not encounter any situations in this case setting that could not be captured in the framework, further research applying the framework in other case organizations is required to determine the extent to which it can adequately describe different facilitation scenarios that exist in practice.

Other avenues of future research that we plan to explore are threefold. First, we plan to collect additional case study data, second, organize a series of focus group sessions with experts from industry and academia to test the validity and utility of the framework. Third, we intend to investigate how to expand the framework with a selection guide of collaboration tools and capabilities specifically focused on supporting the facilitator role. To this end, the existing collaboration technology selection guidance in MAIN+ provides a promising basis. Finally, we hope that the framework will inspire further research on facilitation of technology supported collaboration.

References

Agres, A., Vreede, G. J. de, Briggs, R. O. (2005). A Tale of Two Cities – Case Studies on GSS Transition. *Group Decision & Negotiation*, 14, 267-284.

Anson, R. (1990) *Improving Meetings Using Computers and Facilitator: A Report to 3M.* Austin, TX: 3M Meeting Management Institute.

Barkhi, R., Jacob, V., S., Pirkul, H. (1999). An Experimental Analysis of Face to Face versus Computer Mediated Communication Channels. *Group Decision and Negotiation*, 8, 325-347.

Bass, B.M. (2008). *The Bass Handbook of Leadership: Theory, Research, and Managerial Applications*. Free Press, New York.

Bostrom, R. (1989). Successful Application of Communication Techniques to Improve the System Development Process. *Information and Management*, 16, 279-295

Bostrom, R.P., Anson, R., Clawson, V.K. (1993). Group Facilitation and Group Support Systems. In: Jessup, L.M. and Valacich, J.S. (eds). *Group Support Systems: New Perspectives*, pp. 146-148. Macmillan, New York.

Boughzala, I. (2001). *Methodological framework for designing inter agent co-operative information system for knowledge management*. Paris, France, EU, Paris 6 University. Ph.D.

Boughzala, I. (2007). *Ingénierie de la Collaboration : Théories, Technologies et Pratiques*, Paris, Hermès Science Publications.

Boughzala I., Assar S., Romano Jr N. (2010). An E-government Field Study of Process Virtualization Modeling, *Group Decision & Negotiation (GDN 2010)*, June 21-24 2010, Delft, The Netherlands.

Boughzala I. and Romano, N. (2011). The MAIN+ Design Science Approach for Process Virtualization Modeling and Collaboration Tool Selection, Group Decision and Negotiation

Briggs, R.O., Adkins, M., Mittleman, D., Kruse, J., Miller, S., Nunamaker, J.F. Jr. (1998). A Technology Transition Model Derived from Field Investigation of GSS Use Aboard the U.S.S. CORONADO. *Journal of MIS*, 15, 151-195.

Briggs, R. O., Vreede, G. J. de, Nunamaker Jr., J. F. (2003). Collaboration Engineering with ThinkLets to Pursue Sustained Success with Group Support Systems," *Journal of Management Information Systems*,19,31-64

Carte, T. A., Chidambaram, L., Becker, A. (2006). Emergent Leadership in Self-Managed Virtual Teams: A Longitudinal Study of Concentrated and Shared Leadership Behaviors. *Group Decision and Negotiation*, 15, 323-343.

Clawson, V.K., Bostrom, R.P. (1996). Research Driven Facilitation Training for Computer Supported Environments". *Group Decision and Negotiation*, 1, 7–29.

Clawson, V.K., Bostrom, R.P., Anson, R. (1993). The Role of the Facilitator in Computer-Supported Meetings. *Small Group Research*,24,547-565.

Dalkey, N.C., Helmer, O. (1963). An Experimental Application of the Delphi Method to the Use of Experts. Management Science, 9, 458-467.

DeSanctis, G., Gallupe, R. B. (1987). A Foundation for the Study of Group Decision Support Systems. *Management Science*, 33, 589-609.

Dickson, G.W., Limayem M., Lee Partridge J.E., DeSanctis , G. (1996). Facilitating Computer Supported Meetings: A Cumulative Analysis In A Multiple Criteria Task Environment. *Group Decision and Negotiation*, 5, 51-72.

Dickson, G.W., Partridge, J.L., Robinson, L.H. (1993). Exploring Modes of Facilitative Support for GDSS Technology. *MIS Quarterly*,7, 173-194.

Downes, E. J. and McMillan, S. (2000). Defining Interactivity: A Qualitative Identification of Key Dimensions. *New Media and Society* 2, 157-179.

Festinger, L., Schachter, S., Back, K. W. (1950). *Social Pressures in Informal Groups: A Study of Human Factors in Housing*. Harper Brothers. New York.

Fjermestad, J., S. R. Hiltz. (1998). An Assessment of Group Support Systems Experimental Research: Methodology and Results. *Journal of Management Information Systems* 15, 7–149.

Griffith, T.L., Fuller M.A., Northcraft G.B. (1998). Facilitator Influence in Group Support Systems: Intended and Unintended Effects. *Information Systems Research*. 9, 20-36.

Hackman, J. R., Kaplan, R. E. (1974). Interventions into Group Process: An Approach to Improving the Effectiveness of Groups. Decision Sciences, 5, 459-480.

Hall, J., Watson, W. (1970). The Effects of a Normative Intervention on Group Decision-Making Performance. Human Relations, 23, 299-317.

Hall, J., Williams, M.S. (1970). Group Dynamics Trainng and Improved Decision Making. Journal of Applied Behavioral Science, 6, 39-68.

Hirokawa, R.Y., Gouran, D. (1989). Facilitation of Group Communication: A Crititique of Prior Research and Agenda for Future Research. *Management Communication Quarterly*, 3, 71-92

Hirokawa, R.Y., Pace, R. A. (1983). A Descriptive Investigation of the Possible Communication- Based Reasons for Effective and Ineffective Group Decision Making. *Communication Monographs*, 50, 363-379

Hostager, T.J., Lester, S.W., Ready, K.J., Bergmann, M. (2003) Matching Facilitator Style and Agenda Structure in Group Support Systems: Effects Participant Satisfaction and Group Output Quality. *Information Resources Management Journal*, 16, 56-62.

Hoffman, L. R., Maier, N. R. F. (1959). The Use of Group Decision to Resolve a Problem of Fairness. *Personnel Psychology*, 12,545–559.

Johansen, R., Sibbet, D., Benson, S., Martin, A., Mittman, R., Saffo, P. (1991). *Leading Business Teams: How Teams Can Use Technology and Group Process Tools to Enhance Performance*. Addison-Wesley, Reading, MA.

Kahai, S. S., Avolio, B. J. (2008). Effects of leadership style and anonymity on the discussion of an ethical issue in an electronic meeting system context. In: S. P. Weisband (Ed.) *Leadership at a Distance: Research in Technologically-Supported Work*, pp. 97-125. Lawrence Erlbaum Associates Publishers, Mahwah, NJ.

Kahai, S., Carroll, E., Jestice, R. (2007). Team Collaboration in Virtual Worlds. *The DATA BASE for Advances in Information Systems*, 38, 61-68.

Kahai, S. S., Sosik, J. J., Avolio, B. J. (2004). Effects of participative and directive leadership in electronic groups, *Group & Organization Management*, 29, 67-105.

Kayser, T. A. (1994). *Building Team Power: How to Unleash the Collaborative Genius of Work Teams*. Irwin, New York.

Kayworth, T.R., Leidner, D. (2001-2). Leadership Effectiveness in Global Virtual Teams. *Journal of Management Information Systems*, 18, 7-40.

Kim, Y., Hiltz, S. R., Turoff, M. (2002). Coordination Structures and System Restrictiveness in Distributed Group Support Systems. *Group Decision and Negotiation*, 11, 379-404.

Levan, S. K. (2004). *Travail Collaboratif sur Internet: Concept, Méthodes et Pratiques des Plateaux Projet*. Paris, France: Vuibert.

Lowry, P. B., Romano, N. C. J., Guthrie, R. (2009). The CMC Interactivity Model: How Interactivity Enhances Communication Quality and Process Satisfaction in Lean-Media Groups. *Journal of Management Information Systems*, 26, 155-195.

Malone, T. W., Crowston, K. (1994). The Interdisciplinary Study of Coordination. *ACM Computing Surveys*, 26, 87–119.

Miranda, S.M., Bostrom, R.P. (1999). Meeting Facilitation: Process Versus Content Interventions. *Journal of Management Information Systems*, 15, 89-114.

Munkvold, E., Tvedte, B. (2003). Implementing a Portfolio of Collaboration Technologies in Statoil," In: E. B. Munkvold (Ed.) Implementing Collaboration Technologies in Industry, pp.81-107. . Springer-Verlag, London, UK

Niederman, F., Volkema, R.J. (1999). The effects of Facilitator Characteristics on Meeting Preparation, Set Up, and Implementation. *Small Group Research*, 30, 330-360.

Niederman, F., Beise , C.M., Beranek, P.M. (1996). Issues and Concerns about Computer-Supported Meetings: The Facilitator's Perspective. *MISQ*, 20, 1-22.

Nunamaker, J. F., Jr., Romano, N. C., Jr., Briggs, R. O. (2001-2002). Increasing Intellectual Bandwidth: Generating Value from Intellectual Capital with Information Technology. *Group Decision and Negotiation*, 11, 69-86.

Putman, L.L. (1994), Productive Conflict: Negotiation as Implicit Coordination. International Journal of Conflict Management, 5, 285-299.

Rafaeli, S. and Sudweeks, F. 1997. "Networked Interactivity." Journal of Computer Mediated Communication (2:4) http://jcmc.indiana.edu/vol2/issue4/rafaeli.sudweeks.html (*last accessed on 10 December 2011*)

Rees, F. (1991). How to lead work teams: Facilitation Skills. Pfeiffer and Company, San Diego, CA.

Schwarz, R. (2002). *The Skilled Facilitator: A Comprehensive Resource for Consultants, Facilitators, Managers, Trainers, and Coaches*. Jossey Bass, New York.

Straus, D. (2002), *How to Make Collaboration Work*. Berrett-Koehler Publishers, Inc., San Francisco.

Tarmizi, H., Vreede, G. J. de. (2005). A Facilitation Task Taxonomy for Communities of Practice. *Proceedings of AMCIS*. Omaha, NE.

Tarmizi, H., Vreede, G. J. de.(2010). Patterns of Facilitation in Online Communities of Practice. In: Yoong, P. (Ed.) *Leadership in the Digital Enterprise: Strategies for Planning and Training*, pp 131-142. IGI Publishing, Hershey, PA.

Tarmizi, H., Vreede, G. J. de, Zigurs, I. (2006). Identifying Challenges in communities of practice facilitation. In: *Proceedings of the 39th Hawaiian International Conference on System Science*s. IEEE Computer Society Press. Los Alamitos.

Tarmizi, H., Vreede, G. J. de, Zigurs, I. (2007). Leadership Challenges in Communities of Practice: Supporting Facilitators Via Design and Technology. *International Journal of e-Collaboration*, 3,18-39.

Vreede, G. J. de, Boonstra, J. A., Niederman, F. (2002). What Is Effective GSS Facilitation? A Qualitative Inquiry Into Participants' Perceptions. In: *Proceedings of the 35th Hawaiian International Conference on System Sciences*, IEEE Computer Society Press. Los Alamitos.

Collaboration Science in the Age of Social Media: A Crowdsourcing View

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Abstract: This paper analyzes the crowdsourcing phenomenon from collaboration science perspectives. We conceptualize the crowdsourcing phenomenon as a social-web, technology-driven collaborative problem-solving model. Collaborative problem solving is an enduring topic in the realm of Group decision and negotiation systems and methods. We provide several insights into how the accumulated body of knowledge from the areas of Collaboration Science and GDSS can frame the study of collaboration in a crowdsourcing context.

Keywords: collaboration science, group decision support systems, Web 2.0, social web technologies, crowdsourcing, closed collaboration, open collaboration.

1 Introduction

Organizations frequently encounter complex problems that no single individual has sufficient expertise, influences, or resources to solve alone. Therefore, management of effective collaboration has been an important feature for every organization. New technology affords opportunities for new ways of collaboration. Especially, the influence of information and communications technologies (ICT) has been sizable in both enhancing human interactions and stretching the tempo-spatial boundary of those interactions. In fact, ICT has begun to reshape organizational forms and structures into socio-technical systems resulting in machine-mediated human collaboration often becoming the norm for organizations.

In academia, the research stream of Group Decision Support Systems (GDSS) studies how ICT can enhance collaboration quality. Indeed, research shows that, under the right conditions, collaboration technologies such as GDSS can help improve the quality of collaborative problem solving (Nunamaker et al. 1989; Vreede 2001) by expanding the limited capabilities of human interaction and facilitating collaboration. A study carried out by IBM reports that the use of electronic meeting systems has improved 55% of collaboration performance on average, and reduced the meeting times and project time up to 90 percent (Aiken et al 1995). Vogel and Vreede's (1999) study on GDSS at IBM and Nationale-Nederlanden, one of the largest insurance companies in Europe, shows that the use of GDSS yield significant timesaving, strong user satisfaction, and high perceived usefulness.

Initially, GDSS were used to facilitate collaboration among teams or groups of employees within the boundary of an organization. Although GDSS stretched the boundary of collaboration and changed the way of communication, it mostly remained focused on co-located teams within a single organization. Therefore, many of the early GDSS studies were carried out at group and organizational levels. Since the emergence of the Internet as a platform for collaboration technologies, GDSS have moved into the virtual meeting space, supporting teams that could not meet at the same tine and/or the same location. However, the majority of research still has focused on co-located teams working at the same time.

Recent years have seen a rapid expansion of new forms of collaboration and collaboration technologies. Social media, dubbed Web 2.0[1], and its derivative socio-technical phenomena such as crowdsourcing raises critical questions for Collaboration Science scholars. As those names (i.e., social media in general and crowdsourcing in particular) imply, these developments affords material ground for large-scale collaboration at a social level beyond the boundary of an organization. As 'social'

[1] We use the terms social web, social media, and Web 2.0 interchangeably in this paper. They are all contemporary terms but we realize that no one term will endure forever due to the rapidly evolving nature of these technologies.

technologies, operating on the material ground of World Wide Web (WWW), they expand the capability of collaborative problem solving into social levels including online crowds of employees, professionals, amateurs, producers and consumer etc. In this sense, virtual spaces opened by social web technologies and new modes of large-scale human interaction demand scholars to reconsider the way and scope of collaboration.

A quick review of a few emergent socio-technical phenomena surrounding Web 2.0 technologies illustrates the emerging mode of collaboration. To name just a few, they include "platform for participation," "mass collaboration" (Tapscott and Williams 2006), "open collaboration," "collective intelligence" (Surowiecki 2005), "crowdsourcing" (Howe 2008), "produsage" (combination of "production" and "usage" to describe user driven content creation through the social web (Bruns 2007)), "co-creation" (the emergent collaborative production mode between firms and consumers through Web 2.0 tools (Kazman and Chen 2009)), and "Pro-Am" (representing the advent of the networked "enthusiast" who is exists on the borderline between professionals and amateurs (Leadbeater and Miller 2004)). Roughly speaking, all these new terms put online users in the center of collaboration processes, which have not been considered as important actors in traditional collaboration models. However, as we will describe in detail in the following sections, it is easy to recognize that Web 2.0 technologies in general and its attendant socio-technical phenomena in particular inherit the spirit of GDSS research, i.e. collaborative problem solving through mediation of technologies. In this sense, traditional studies on GDSS can shed light on framing the study of Web 2.0 collaboration.

In this paper, we present a research framework for social media driven collaboration, in particular crowdsourcing. To do that, we review two dominant definitions of crowdsourcing, and argue that collaborative problem solving is an enduring topic that flows from traditional studies on collaboration science and GDSS to the emerging crowdsourcing phenomena. Through analysis of crowdsourcing websites, we identify two types of collaborative problem solving processes, and show how traditional collaboration science and GDSS studies can contribute to investigate emerging modes of collaboration which are driven by social technologies.

2 Crowdsourcing as a Collaborative Problem Solving Model

The expansion of social web technologies has afforded organizations big and small the ability to diversify collaboration methods in order to solve organizational problems. Social web technologies that are affordable and easy to use have provided access to individuals with innovative ideas and skills around the world, and created a conventional norm that no organization needs to innovate on its own (Pisano and Verganti 2008). Among many, one of the most buzzworthy new collaboration models is crowdsourcing. Crowdsourcing inherits many technological features (e.g., authoring, tagging, sharing, connecting, voting, rating, and commenting) of social media websites such as Facebook, YouTube, Twitter, and Flickr. However, crowdsourcing is distinct from those social media technologies in that organizations actively involve the online community through many collaboration techniques and web enabled control systems. In other words, whereas social media sites focus on the *social* side of online communities, crowdsourcing emphasizes the *management* side of online communities to retrieve and assemble their scattered knowledge and skill sets to solve specific organizational problems (Saxton et al, *forthcoming*).

As of now, there are two common definitions on crowdsourcing, which are useful to consider: crowdsourcing as a sourcing model and crowdsourcing as a problem-solving model. Crowdsourcing as a sourcing model is defined as follows: "*Crowdsourcing is a sourcing model in which organizations use predominantly advanced Internet technologies to harness the efforts of a virtual crowd to perform specific organizational goal*" (Saxton et al. forthcoming, authors emphasis). This definition is a refined version of the crowdsourcing definition which was coined by Jeff Howe (2006): "…*the act of taking a job traditionally performed by a designated agent (usually an employee) and outsourcing it to an undefined, generally large group of people in the form of an open call.*" In a similar vein, the 'crowd of authors' in Wikipedia define crowdsourcing as "*the **act of sourcing tasks** traditionally performed by specific individuals to a group of people or community (crowd) through an open call*" (Crowdsourcing in Wikipedia, 8 December 2011, authors emphasis).

From a slightly different perspective, Brabham (2008) distinguishes crowdsourcing according to applications in the for-profit and not-profit sector, and expands crowdsourcing beyond for-profit applications to "*establish a model that can have profound influence in the way we solve our world's most pressing social environment problems*" (p. 75). He defines crowdsourcing as a problem-solving model as follows: "*Crowdsourcing is a legitimate, complex problem-solving model, more than merely a new format for holding contests and awarding prizes*" (p. 76, authors emphasis).

Although the above perspectives have different focuses, they share a common denominator that crowdsourcing strategically integrates outside, online crowds into collaborative problem solving process by using advanced Internet technologies. However, because the collaboration side of crowdsourcing is simply taken for granted in both definitions, they do not articulate well the fundamental function of *collaboration* embedded in crowdsourcing. As a result, the landscape of crowdsourcing hides the enduring theme of *collaborative problem solving*, which flows from collaboration science and GDSS studies to current crowdsourcing paradigms. However, regardless of focuses manifested in those crowdsourcing definitions, its central argument has been mostly about the new ways of collaborative problem solving through the use of social web technologies (Tapscott and Williams 2006;Surowiecki 2005; Howe 2008; Bruns 2007; Kazman and Chen 2009; Leadbeater and Miller 2004). Therefore, the above definitions of crowdsourcing can be rephrased and blended without changing its essences: *Crowdsourcing is a collaboration model enabled by social web technologies to solve organizational problems in partnership with online communities.* This rephrased definition is advantageous in that it can funnel enduring research questions and accumulated knowledge on *collaborative problem solving* into the emerging field of crowdsourcing. Then, the remaining questions are to understand the structural and procedural patterns of collaboration in crowdsourcing in order to expand previous findings from collaboration science research into this context.

In crowdsourcing, there are two modes of collaboration (closed collaboration versus open collaboration), which have distinctively different collaboration processes. In table 1, while 'closed collaboration' focuses on *finding* the best solution out of many submitted ones, 'open collaboration' focuses on *facilitating collaboration* among undefined large number of online community members to solve problems.

Table 1. Different level of collaboration between online community members of crowdsourcing websites.

	Closed Collaboration	Open Collaboration
Types of problem	• Structured problem. • *Organizations define a problem* and broadcast the defined problem to an online community so that community members can submit solutions to the organization. Exemplary Problem: "A one-part adhesive is required that is activated at room temperature. The adhesive should have a minimum set-strength upon activation for gluing a fixed substrate on metals and synthetics (polymers) which can then be fully cured by other methods…Theoretical proposals (no verified method data) will be considered for a lesser reward."[2]	• Unstructured problem. • Organizations broadcast an unstructured question to an online community so that the community can (1) identify and define specific problems in parallel ("brainstorming"), and (2) clarify and evaluate each problem by commenting or voting to reduce the large number of suggested problems into a selection of the best few ideas worthy of more focused attention ("convergence"). Exemplary Problem: "We've received many suggestions about closing select streets temporarily to create more opportunities for bicycling, walking, and events such as farmers markets and art walks. How often should we close streets for these types of activities?"[3]

[2] This is a real R&D problem broadcast to the InnoCentive online community as a structured question. To protect the copyright and intellectual property of their client, this question is posted by hiding the identity of the client firm. The problem to solve is already defined by the question holding firm who seeks an innovative solution for their R&D question. https://www.innocentive.com/ar/challenge/9932932 (*last accessed on 12th December, 2011*)

[3] This is a real problem broadcasted to an online community in an unstructured question format so that Los Angeles citizens can collectively identify and rank street problems. http://ideas.la2b.org/los-angeles-closing-streets-for-evvents (*last accessed on 12th December, 2011*).

Way of finding solution	The organization *selects* the best solution from a large number of solutions submitted by the online community. Collaboration between online community members is not allowed. Therefore, collaboration features such as voting, commenting, rating, and sharing in the Web interface design are not important.	The organization *facilitates collaboration* between online community members. The organization determines the best solution considering the results of both brainstorming and convergence activities. Therefore, collaboration features such as voting, commenting, rating, and sharing in the Web interface design are important.
Examples	*mTurk.com.com, InnoCentive.com, YourEncore.com, oDesk.com, freeLancer.com*	*Threadless.com, CambrianHouse.com MindMixer.com, CrowdCast.com, BrainReactions.net*

One of the most frequently cited crowdsourcing websites, Amazon's Mechanical Turk, follows the closed collaboration model. Their business process consists of three steps: (1) find, (2) finish, and (3) earn.[4] It means that:

> First, online community users *find* a task posted by solution seeking agent on the web, and make a contract with him/her to complete the task.
> Second, the contracted online community member *finishes* the task.
> Finally, the contracted online community member *earns* monetary gain for their labor.

Although slightly different, another high-profile example of an R&D crowdsourcing firm, *InnoCentive*[5], follows a similar business process. The InnoCentive (IC) problem solving process starts with broadcasting a problem defined by a solution seeking firm along with IC scientific operations staff to the online community as an open call via IC's website with a predefined monetary prize. Then, a large number of online problem solvers *find* and *finish* the task that they can solve, and submit the solution statement directly to IC. The IC staff then screens the solution statements and forward potential solutions to the solution-seeking firm. If the solution-seeking firm finds a submitted solution that meets their requirements, then the problem solver receives a reward. An important distinction is that "IC solvers do not work collectively, through the web site, to solve problems and do not know who else is working on a problem or how many solutions have been submitted" (Jeppersen and Lakhani 2010, p. 1021). It means that, as an IC policy, collaboration among community members is strongly prohibited or is allowed only among agreed team members through confidential team project rooms. This policy serves to protect the solution seeking firm's intellectual property and details on the firm's R&D projects from their competitors[6]. Therefore, focus of closed collaboration lies in *finding* a best solution out of many submissions by strictly controlling collaboration among online users.

The open collaboration model of crowdsourcing *facilitates collaboration* among online community members to solve problems. This model involves two-step collaboration processes with online users, each of which has a different purpose: (1) brainstorming, and (2) convergence. For example, MindMixer[7], a virtual town-hall meeting system starts a collaboration process with a general question posted by a city hall in an unstructured and open-ended question format so that online users can (1) *suggest* as many ideas as possible through online posts, and (2) *evaluate, clarify, and define* each suggested idea by commenting, voting, or rating to reduce large number of suggested ideas into a best few ones worthy of focused attention by the city hall. Then, the city hall compiles the result of online community members' converged ideas into their decision making process to solve municipal problems.

In the for-profit business sector, *Threadless*[8] uses the open collaboration model as the core strategy of their business. As a community driven T-shirt manufacturer, they determine the T-shirt design for print by compiling results of community members' collaboration into their decision making process.

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[4] https://www.mturk.com/mturk/welcome (*last accessed on 8 December 2011*)
[5] https://www.innocentive.com (*last accessed on 8 December 2011*)
[6] More detailed problem solving process of InnoCentive and intellectual property protection measure can be found from Jeppersen and Lakhani (2010). Also refer to https://www.innocentive.com/faq/Seeker (*last accessed on 8 December 2011*).
[7] http://www.mindmixer.com (*last accessed on 12 December 2011*)
[8] http://www.threadless.com (*last accessed on 12 December 2011*)

The collaboration process starts with postings of T-shirt designs on the *Threadless* website by online community members (brainstorming). For each submitted design, community members express their preferences with comments and scores (on a 1-5 scale) (convergence). Then *Threadless* considers the converged results to decide which design to adopt from the many submitted designs.

Be it focused on closed or open collaboration, the strength of both collaboration models is that organizations can receive a large number of solution ideas beyond their internal domain of expertise at low cost. This is a different characteristic from traditional collaboration models, which seek problem-solving ideas from internal organizational groups. Therefore, the key challenges in crowdsourcing are to attract large participation from online communities of diverse domains, and effectively screen a large number of suggested solutions to find the best one. The main difference between closed and open collaboration crowdsourcing is that, while the former focuses on *finding* the best solution out of many submitted ones, the latter makes an effort to *facilitate collaboration* processes of "brainstorming" and "convergence" through interactive system designs of crowdsourcing.

3 Key Issues of Crowdsourcing: Collaboration Perspective

Collaboration research, be it in the context of GDSS or social media, often has the following common underlying assumptions: (1) a larger number of people can solve difficult or complex problems better than a small number of people, and (2) a team or group that has high collective intelligence is more likely to excel in complex problem solving. Compared to traditional settings such as GDSS, a distinctive feature of social media driven collaboration is that it highlights the potential that large online *amateur crowd* can be smarter than a handful *organizational professional experts* in problem solving. Either way, in both cases, it is key is to recognize that (1) *collective intelligence* is not an absolute summation of *individual intelligences*, and (2) *collective intelligence* "emerges from the way group members interact when they are assembled" (Wooley et al. 2011). In other words, collaboration is more about the process of assemblage and emergence rather than a single event.

In fact, Wooley et al. (2011) provide empirical evidence of a general collective intelligence factor. Their study reports that general collective intelligence "is not strongly correlated with the average or maximum individual intelligence of group members but is correlated with the average social sensitivity of group members" (e.g., the equal number of conversational turn-taking and the proportion of females in the group etc.). The implication of this finding is that collective intelligence tends to depend both on the composition of the group and dynamic factors which emerge from the way the team members interact. Furthermore, Wooley et al. suggest that it may be easier to manage and raise group intelligence than individual intelligence. This implies that collective intelligence can be controlled and enhanced by manipulating *the structural* and *the procedural* properties of group. In fact, discovering those properties of collective intelligence at group or online community level has been and will be enduring research questions for collaboration science scholars.

In the social media context, Surowieck (2004) suggests that certain conditions have to be met for online crowds to make wise decisions to solve problems collectively. This is what he refers to as the "wisdom of crowds." To have a "wise" crowd, in Surowiecki's framework, there are four prerequisites: 1) diversity of opinion, by which each individual involved has some private information, even if it is just an eccentric opinion; 2) independence, wherein each person's opinion or decision is not influenced by those around them; 3) decentralization, through which individuals can specialize and tap into local sources of knowledge; and 4) aggregation, which stresses the importance of mechanisms for translating many private opinions or decisions into a collective decision (p. 10). He argues that, when all four conditions are met, we can solve many problems better than a few smart experts by collaborating with a multitude of average people.

These notions are not entirely new. Apart from the fourth condition ('aggregation'), the first three conditions have been repeated research questions in collaboration science research in general (ranging from psychology and management to information systems and industrial engineering) and GDSS research in particular. Although it is still an under-researched area, Collaboration Engineering studies (Briggs and Vreede, 2009; Faieta 2006; Vreede et. al. 2009) have recently begun to pursue the notion of "convergence" which is comparable to Surowiecki's notion of "aggregation". Suggested below are some key concepts that have been repeatedly tested in general collaboration science and GDSS studies. As these concepts are technology independent variables that can be applied to any context of collaboration, we believe that they can fuel a research framework to empirically test the four prerequisites for the "wisdom of crowds".

3.1 Diversity of Opinion

The notion of diversity of opinion in Surowieck (2004)'s four conditions for utilizing wisdom of crowds has been in fact a repeated topic in collaboration science research. It argues that different people can have different interpretations on a common fact or event, and therefore potentially solve problems better in groups than individually. However, whether groups can utilize this advantage depends on the collaboration process that the groups follow to achieve their goals (Steiner, 1972). Various causes of group process loss have been identified in small group research and GDSS literature. For example, Stasser and Titus (1985) found that group members tended to discuss information that seemingly the whole group knew and were reluctant on revealing unique information, which is called the shared information bias phenomenon. Dennis and Williams (2003) summarized five process losses that were popularly cited in the GDSS literature: production blocking, social loafing, evaluation apprehension, cognitive interference and communication speed. As a consequence, the ultimate goal of GDSS research was to overcome these process losses and utilize the diversity of the group. Towards that end, considerable progress has been made in the field, especially in the group brainstorming area. For example, thanks to features such as parallel input and anonymity, electronic brainstorming was claimed to surpass face-to-face brainstorming problems of: (1) evaluation apprehension that group members are not willing to share unique information for fear of being criticized, and (2) production blocking that group member have to wait until all other members finish talk (Nunamaker et. al., 1991, Pinsonneault et. al., 1999). Empirical evidence supported the superiority of electronic brainstorming over face to face group brainstorming, but also showed that it only surpassed nominal group brainstorming i.e. groups in which members do not interact with one another when the group size was large (Pinsonneault et. al., 1999; Dennis and Valacich, 1999).

3.2 Independence

The notion of independence in Surowieck (2004)'s four conditions for utilizing wisdom of crowds is closely related to the concept of anonymity, which has been studied thoroughly in GDSS research. Valacich et. al. (1992) defined the anonymity as the extent group members' contributions were identifiable to the other group members or to others outside the group. Anonymity was considered an important contribution of the GDSS to collaboration process. Groups were found to generate more ideas and comments, and were more critical under anonymous condition than they did under identified conditions (Jessup et. al., 1990; Wilson et. al., 2010). The superiority of anonymity in supporting group tasks were attributed to its effect on removing some of the process losses such as evaluation apprehension and influence of unequal social status (Nunamaker et. al., 1991; Wilson et. al., 2010). However, at the same time, one has to be cautious that anonymity can promote negative group behaviors and effects, such as social loafing (Forsyth, 2009), flaming or uninhibited behaviors (Kiesler, 1984), and the decrease of groups' perceptions of the credibility of the information source (Rains, 2007).

3.3 Decentralization

Surowieck's (2004) idea of utilizing local knowledge of diverse community members with different backgrounds is closely related to the notion of team diversity that has been well studied in group and team research. Compared with a homogeneous team, a diverse team can bring more ideas, and a wider range of knowledge and skills to the team. However, at the same time, it can cause conflicts and reduce team cohesion due to social categorization processes (Forsyth, 2009). Consequently, to maximize the benefits of team diversity, managing conflicts in teams is essential. Some suggestions on the matter have been made in the literature. For example, Salas et al. (2009) proposed that high team psychological safety, (e.g., an environment where team members are willing to raise their voice without fear of being punished, embarrassed, or rejected) could moderate the adverse effect of team diversity on team performance. Moreover, Van Der Vert and Bunderson (2005) also found that in teams with high levels of collective team identification or "the emotional significance that members of a given group attach to their membership in that group" (p. 533), expertise diversity positively related to team performance and team learning while in teams with low level of collective team identification, the relationship was negative.

3.4 Aggregation

Identifying the mechanisms to screen and aggregate the large number of ideas into a small set of collective decision has long been a challenge both in GDSS research (Davis et al. 2007) and crowdsourcing (Pisano and Verganti 2008). A paradox for brainstorming tasks is that, while it is easy to capture hundred of ideas, the process of screening large number of ideas into a few best ones, is a slow and painful process (Chen et. al., 1994; Davis et. al. 2007; Hiltz and Turoff, 1985). This problem gets serious as the scale of collaboration increases and shared understanding among community members becomes weak, as is the case in crowdsourcing. On top of that, as group membership and member involved become more fluid in large online groups, the convergence process must be carried out through (semi)-automated means, such as aggregation algorithms (averaging, counting, subtracting etc).

In collaboration science research, there have been ad-hoc attempts to address the convergence issues. For example, Chen et. al. (1994) suggested using text-mining techniques to automatically classify the content of the brainstorming ideas during the convergent process. Hiltz and Turoff (1985) proposed reducing information load by letting participants to choose the topics they were interested in an electronic conference. In the case of crowdsourcing, one of the most dominant practices of converging on a smaller set of ideas has been to use web tools such as commenting, voting, or rating to collectively determine the quality of posted ideas in terms of relevance, creativity, and practicality.

Apart from these ad-hoc initiatives, the Collaboration Engineering (CE) approach has been suggested to study the convergent process in a more systematic way. The central idea of CE is to systematically combine the distinctively different six collaboration patterns into a repeatable process model. CE suggests six collaboration patterns, generate, reduce, clarify, organize, evaluate, and build commitment. Among these six patterns, the second and third patterns relate to "convergence," which is essentially "moving from many ideas to fewer ideas worthy of more focused attention" (Vreede et. al. 2009). The potential of the CE approach for crowdsourcing study is at least twofold. First, it proposes a seven-layer model of collaboration that defines the various design concerns along six different dimensions of collaborative work practices (Briggs et al., 2009). As this seven staged collaboration design model is technology independent, it can provide a powerful design foundation for social web technology driven collaboration systems and practices. Second, it can provide systematic angle to understand how collaboration processes move from the idea generation stage to the convergence stage, especially in crowdsourcing settings that follow the open collaboration model.

4 Conclusions

Maturing social web technologies and consumer IT devices have dramatically reduced the cost of collaboration. Added to this, the recent crowdsourcing phenomenon has spread the idea that collaboration between organization and online communities is cost-effective and practically feasible (Pisano and Verganti 2008). On the positive side it can be observed that opportunities for collaboration with online users is increasing and collaboration technologies are getting pervasive and cheaper. On the negative side caution is justified as a wealth of free ideas easily may lead to information overload and poverty of solution. Therefore, to take advantage social web technologies for effective collaboration, we need to understand the nature of collaboration itself.

In this paper, we argued that the question of *collaborative problem solving* has endured from general collaboration science and GDSS studies to crowdsourcing. With this recognition, we rephrased currently two dominant definitions of crowdsourcing as a collaborative problem-solving model. After that, we reviewed two typical collaboration models – closed collaboration versus open collaboration – which are manifested in current crowdsourcing phenomena. Also, we illustrated how the accumulated body of knowledge on collaboration science can contribute to set the direction of collaboration studies in a crowdsourcing context.

However, many questions are still untouched. For example, it is noteworthy to mention that crowdsourcing may need very different governance strategies from that of traditional collaboration. While traditional collaboration has normally taken place within organizational boundaries or well-defined inter-organizational contexts, crowdsourcing performs collaboration between organization and online users that have no formal relationship with the organization. That means, while traditional collaboration normally involves team deliberation among employees in the same organization, social media driven collaboration accompanies undefined heterogeneous entities who are temporarily connected around common problems to address. Therefore, compared to collaboration between employees, social media driven collaboration may have weaker shared norms and lower common understandings. Separate from structural and procedural pattern of collaboration, different governance structures (such as rewards, leadership structure, responsibility, and policy on privacy etc.) need to be investigated.

References

Aiken, M., Vanjami, M., and Krosp, J. (Spring 1995), Group Decision Support Systems, *Review of Business*, http://findarticles.com/p/articles/mi_hb6451/ is_n3_v16/ai_n28660020/?tag=content;col1. *(last accessed on 5 December, 2011)*

Badura, V., Read, A. Briggs, R., Vreede, G.J., (2009), Exploring the Effects of a Convergence Intervention on the Artifacts of an Ideation Activity during Sensemaking. In: *Proceedings of CRIWG*. pp.79~93. Peso da Régua, Douro, Portugal.

Briggs, R. O., Kolfschoten, G. L., Vreede, G. J. de, & Dean, D. L. (August 2006), Defining Key Concepts for Collaboration Engineering. In: *Proceedings of the 12th Americas Conference on Information Systems*, pp. 121-128. Acapulco, Mexico.

Briggs, R.O., Kolfschoten, G.L., Vreede, G.J. de, Dean, D.L., & Lukosch, S. (2009), A Seven Layer Model of Collaboration: Good Technology is Not Enough, *30th International Conference on Information Systems*, Phoenix, December 2009.

Briggs, R. O., and Vreede, G. J. de (2009). *ThinkLets: Building Blocks for Concerted Collaboration.*

Briggs, R.O., Vreede, G.J. de, Nunamaker, J.F (2003). Collaboration Engineering With ThinkLets to Pursue Sustained Success With Group Support Systems, *Journal of MIS*, 19:4, pp.31-63.

Bruns, A. (2007). Produsage: Towards a Broader Framework for User-led Content Creation. In: *Proceedings, Creativity and Cognition*, 6, pp. 1-7.

Chen, H., Hsu, P., Orwig, R., Hoopes, L., and Nunamaker, J. F. (1994). Automatic Concept Classification of Text from Electronic Meetings. *Communications of the ACM*, 37, pp. 56-73.

Davis, A., de Vreede, G.-J., and Briggs, R. O. (2007). Designing thinkLets for convergence. Paper presented at the Thirteenth Americas conference on information systems, Keystone, Colorado.

Dennis, A. R., Valacich, J. S. (1999). Electronic brainstorming: Illusions and patterns of productivity. *Information Systems Research*, 10:4, pp. 375–377.

Dennis, A. R., and Williams, M. L. (2003). Electronic brainstorming: Theory, research, and future directions. In P. B. Paulus and B. A. Nijstad (Eds.), *Group creativity: Innovation through collaboration*: 160–178. New York: Oxford University Press.

Faieta B., Huberman, B., and Verhaeghe. (2006), Scalable Online Discussions as Listening Technology, In: *Proceedings of the 39th Hawaii International Conference on Systems Sciences, Hawaii.*

Forsyth, D.R. (2009). *Group Dynamics*. Wadsworth Publishing: Belmont, CA, USA.

Gefen, D. & Carmel, E. (2008). Is the World Really Flat? A Look at Offshoring at an Online Programming Marketplace. *MIS Quarterly*, 32:2, pp. 367-384.

Grohowski, R., McGoff, C., Vogel, D., Martz, B., and Nunamaker, J. (1990), Implementing Electronic Meeting Systems at IBM: Lessons Learned and Success Factors. *MIS Quarterly*, 14:4, pp. 369-384.

Howe, J. (June 2006), The Rise of Crowdsourcing. *Wired*, http://www.wired.com/wired/archive/14.06/crowds.html (*last accessed on 8 December 2011*)

Howe, J. (2008). *Crowdsourcing: Why the Power of Crowd is Driving the Future of Business.* Crown Business, New York.

Jeppersen, L.B. and Lakhani, K.R. (2010). Marginality and Problem-Solving Effectiveness in Broadcast Search. *Organization Science,* 21:5, pp. 1016-1033.

Jessup, L. M., Connolly, T. and Galegher, J. (1990). The Effects of Anonymity on GDSS Group Process with an Idea-generating Task. *MIS Quarterly*, 14:3, pp. 313-321.

Kazman, R., and Chen, H.M. (July 2009). The Metropolis Model: A New Logic for Development of Crowd-Sourced Systems. *Communications of the ACM,* 52:7, pp. 78-84.

Kiesler, S., Siegel, J., and Mcguire, J. W. (1984). Social Psychological Aspects of Computer-Mediated Communication. *American Psychologist*, 39, pp. 1123-1134.

Kim, S.W., and Miranda, S. (December 2011). Seed of Change: Substance and Influence in Brand Communities. In: *Proceedings of International Conference on Information Systems,* Shanghai, China.

Kolfschoten, G. L., and Vreede, G.-J. d. (2006). *The Collaboration Engineering Approach for Designing Collaboration Processes*. Paper presented at the Hawaii International Conference on System Science, Hawaii.

Lacity, M., Khan, S., Yan, A., & Willcocks, L.P. (2010). A review of the IT outsourcing empirical literature and future research directions. *Journal of Information Technology,* 25(4), 395-433.

Leadbeater, C., and Miller, P. (2004). *The Pro-Am Revolution: How Enthusiasts Are Changing Our Economy and Society.* http://www.demos.co.uk/files/proamrevolutionfinal.pdf (*last accessed on 12th December 2011*)

Nunamaker, J.F., Dennis, A.R., Valacich, J.S., Vogel, D.R., and George, J.F. (July 1991). Electronic Meeting Systems to Support Group Work. *Communications of the ACM* , 34:7, pp. 41-60.

Nunamaker, J.F., Vogel, D.R., Heminger A., Martz, B., Grohowski, R., and McGoff, C. (1989). Experiences at IBM with GSS. *Decision Support Systems,* 5:2, pp. 183-196.

Pinsonneault, A., Barki, H., Gallupe, R. B., and Hoppen, N. (1999). Electronic brainstorming: The illusion of productivity. *Information Systems Research*, 10, pp. 110–133.

Pisano, G.P., and Verganti, R. (December 2008). Which Kind of Collaboration Is Right for You? *Harvard Business Review,* pp. 78-86.

Postmes, T, Spears, R, Sakhel, K, and De Groot, D. (2001). Social influence in computer-mediated communication: the effects of anonymity on group behavior. *Personal. Soc. Psychol. Bull,* 27, pp. 1243–1254.

Rain, S. A. (2007). The Impact of Anonymity on Perceptions of Source Credibility and Influence in Computer-Mediated Group Communication: A Test of Two Competing Hypotheses. *Communication Research*, 34:1, pp. 100-125.

Ren, Y., Kiesler, S., and Fussell, S.R. 2008. Multiple Group Coordination in Complex and Dynamic Task Environments: Interruptions, Coping Mechanisms, and Technology Recommendations. *Journal of Management Information Systems,* 25:1, pp. 105-130.

Salas, E., Goodwin, G. F., and Burke C. S. (2009). *Team effectiveness in complex organizations: Cross-disciplinary perspectives and approaches*. Routledge, New York.

Saxton, G., Oh, O., and Kishore, R. (forthcoming). Rule of Crowdsourcing: Models, Issues, and Systems of Control, *Information Systems Management.*

Stasser, G., and Titus, W. (1985). Pooling of unshared information in group decision making: Biased information sampling during discussion. *Journal of Personality and Social Psychology,* 48, pp. 1467-1478.

Steiner, I. D. (1972). *Group process and productivity.* Academic Press, New York.

Surowiecki, J. (2004). *The Wisdom of Crowds*. Doubleday, New York.

Tapscott, D. and Williams, A. (2006). *Wikinomics: How Mass Collaboration Changes Everything.* Penguin Group, New York.

Tilly, C. (2004). *Social Movement, 1768-2004.* Paradigm Publishers, London.

Valacich, J., Jessup, L., Dennis, A., and Nunamaker, J. (1992). A conceptual framework of anonymity in group support. *Group Decision and Negotiation, 1,* 219—241.

Van der Vegt, G.S., and Bunderson, J.S. (2005). Learning and performance in multidisciplinary teams: the importance of collective team identification. *Acad. Manage. J*., 48, pp.532–547.

Vogel, D. and Vreede, G.J. (June 1999). The Organizational Application of GSS: A Comparison Across Time and National Boundaries. In: *Proceedings of the 10th EuroGDSS Workshop,* Copenhagen.

Vreede, G.J. (2001). A Field Study into the Organizational Application of GSS, *Journal of Information Technology Cases & Applications,* 2:4, pp. 27-47.

Vreede, G. J. D., Briggs, R. O., and Massey, A. (2009). Collaboration Engineering: Foundations and Opportunities. *Journal of the Association of Information Systems*, 10:3, pp. 121-137.

Weick, K.E., Sutcliffe, K.M., and Obstfeld, D. (2005). Organizing and the Process of Sensemaking. *Organization Science*, 16:4, pp. 409-421.

Wilson, J.L., Griffin, T.E., and Jessup, L.M. (2010). GSS Anonymity Effects on Small Group Behavior. Academy of Information and Management Sciences, 13: 2, pp. 41:57.

Cognitive Load in Collaboration – Decision Making

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Abstract: Collaboration is inherent to complex participatory systems. Supporting collaboration, and especially decision making is challenging. Decision making, like all knowledge-based collaborative effort, requires mainly cognitive effort. Understanding cognitive load involved in collaborative tasks such as decision making is important, therefore, to the design of decision support techniques and tools. This paper focuses on cognitive load related to decision making, especially the final phase of decision making in which alternative solutions or options are evaluated and the group engages in, e.g., consensus building, negotiation or commitment building to agree on a course of action. This phase is a complex collaborative task that is much less studied than the preceding divergence or brainstorming tasks in which alternatives are created and envisioned. Drawing on an overview of evaluation and consensus building techniques and the broader literature on decision making, this paper presents a framework of cognitive load during the decision processes. The paper ends with a reflection on future work, consisting of validation, use and implications of the framework.

Keywords: Collaboration, Decision making, Cognitive load.

1 Introduction

Collaboration is a sine qua non for innovation and productivity of organizations(Frost & Sullivan, 2007). When groups collaborate they also need to make decisions that represent an agreement in the group. Even when one group member has the power to make decisions alone, it often makes sense to involve others in the decision making process to use their expertise, and more importantly to get buy-in for the results. Thus, while people make decisions alone, group decision making requires consensus building and negotiation to establish trust in buy-in and support. Knowledge intensive collaborative tasks such as decision making often require high cognitive effort to consider alternatives, their implications, their value and personal preferences for these. Further, collaborative decision making requires a team to perform a task jointly, thus requiring interaction and coordination of cognitive effort (Dillenbourg & Betrancourt, 2006). Coordination and support of collaboration can be offered by a group member (leader) or by an external facilitator or mediator, who can help the group to focus cognitive effort and offer tools and techniques to support effective cognitive effort. Furthermore, techniques and tools such as decision and negotiation support systems, and sometimes also training, can offer guidance in collaborative activities (Dennis & Wixom, 2002) and in decision making particularly (Balthazard et al., 1998; Pervan, 1998; Wheeler & Valacich, 1996). Cognitive load is typically higher for collaborative tasks than for individual tasks (Dillenbourg & Betrancourt, 2006) and, therefore, groups often benefit from tools and facilitation to structure their cognitive effort (Niederman et al., 2008).

Cognitive load arises from the cognitive effort made by a person to perform a task (Sweller et al., 1998). Cognitive load theory (CLT) distinguishes various design principles to use cognitive capacity efficiently and effectively in the context of learning (Sweller, et al., 1998). However, in the context of collaboration support, rather little research has been devoted to understanding the cognitive implications of process and technology design. Collaborative problem solving, in particular decision making, does require some form of learning, specifically to create shared understanding about alternatives and their implications; and, therefore, we can learn from this domain to support collaborative effort. In decision making, this cognitive complexity is extensively studied in psychology (Slovic et al., 1977) and in the design of, e.g., expert systems, artificial intelligence (Simon, 1980) and decision support systems (Klein & Hirschheim, 1985). While there exist cognitive models of decision making, these mostly focus on individual decision making rather than group decision making (French, 2007). Also, these models might not consider the different sources of complexity that require cognitive effort, and are triggered in a collaborative decision making process.

To design interventions that improve cognitive efficiency and effectiveness and reduce the demand on our working memory (also called central executive) in collaborative tasks requires an understanding of cognitive activities and processes in collaboration. This paper presents some first steps towards developing a framework for assessment of cognitive load in a collaborative decision making context. Earlier work has focused on the divergence phase in which ideas or solutions are created and shared (Kolfschoten, 2011), and the convergence phase in which the group filters or summarizes the information they shared to analyze it and create structure, shared understanding and an overview of the alternatives they have considered (Kolfschoten & Brazier, 2012). In the decision making phase the group judges the value of the alternatives, compares them, and considers both rational and strategic implications to agree finally on a course of action. Based on the literature and examples of existing collaboration support techniques and tools, the role and design implications of cognitive load in the decision making phase of collaborative problem solving tasks are explored.

2 Cognitive Load

Cognitive load can be defined as *the cognitive effort made by a person to understand and perform his/her task* (Sweller, 1988). Cognitive load has both a *task*-based dimension (mental load) and a *person*-based dimension (mental effort) (Paas & Merrienboer, 1994; Sweller, et al., 1998). We propose that a third dimension of cognitive load can be found in the *mutual coordination* of effort in a group task. Dillenbourg calls this collaboration load (Dillenbourg & Betrancourt, 2006). Task-based cognitive load has a further perceptual and a cognitive dimension, related to the amounts of information presented, and the amount that needs to be processed in working memory to accomplish the task (Fitousi & Wenger, 2011), a similar effect can be considered in collaboration load, where participants consider the actions of others and the 'intentions' or stakes behind those actions to the motivation of their fellow group members, and ultimately to predict their behaviour. The concept of cognitive load in cognitive load theory is associated with 'computer-based' cognitive model in which the main 'processor' is represented by our short-term or working memory, also called central executive, which is limited in capacity (Farrington, 2011; Miller, 1956; Simon, 1974). Problem solving tasks are mainly associated with the prefrontal cortex, which is also used to recall things from memory and to inhibit distraction (Rock, 2009). In this cognitive load theory, the complex cognitive activities of these brain parts are simplified as a limited resource for information processing. While cognitive- and neuropsychologists offer ample debate on the different ways in which cognitive tasks are performed in the brain, they agree that our capacity to process information is limited, and that these limitations are actively experienced in problem solving tasks (Rock, 2009). Furthermore, research in instructional design has provided ample evidence that the manner in which information is offered and structured has significant effects on performance in problem solving (Sweller, 1988).

Problem solving is a complex task, and can benefit from support. Early research from Simon *et al* already indicated that we can learn a lot about problem solving and how to support it, when looking at it from a cognitive perspective (Simon, 1980). CLT assumes people have a short-term or working memory for information processing, and a long-term memory to store information in so called schemata (Sweller, 1988). Information in our long term memory is related, networked or associated through these schemata (Rock, 2009). In a process called automation, also called chunking (Miller, 1956; Simon, 1974), we can process more complex information in our working memory. With limited cognitive capacity, cognitive overload is easily reached in complex cognitive tasks such as the problem solving and decision making considered in this paper. Cognitive overload can impair performance and decision making, create stress, cause difficulty in retrieving knowledge, impede creativity, and cause difficulty in analysing and organizing knowledge, and impede schema building and learning (Eppler & Mengis, 2004). Overload can be handled though structuration, organizing and coordinating, and though the use of information systems that help filter information (Eppler & Mengis, 2004). Cognitive *over*load creates ineffectiveness, but too low cognitive load can also be ineffective as people loose attention for the task. When cognitive load is at a right level, participants can get in a state of flow (Czikszentmihalyi, 1990). The cognitive load of a task differs for each individual, depending on their experience in the domain and skill in the type of problem solving task (Kalyuga et al., 2003; Kolfschoten et al., 2010). Furthermore, people can become distracted while performing a task or use ineffective ways of processing the information due to fatigue or lack of skill (Rock, 2009).

CLT in the context of learning explains how cognitive capacity is used to construct schemata and use them for problem solving tasks. Three types of cognitive load (Sweller, 1988) are distinguished:

- Intrinsic cognitive load is the cognitive load that is inherent to the task, defined by the intrinsic task complexity.
- Extraneous cognitive load is the cognitive load caused by the presentation and transition method of the information. Extraneous load should be reduced as much as possible, as it is ineffective. However, it cannot be completely eliminated. Extraneous load also covers collaboration load, the mental effort required to coordinate effort.
- Germane cognitive load is the cognitive load instrumental to building schemata and storing them in the long term memory. For learning, germane load should be stimulated.

Limiting unproductive mental activity, and focussing collaborators on effective cognitive effort is a critical challenge for information systems design (Bray, 2008), particularly those that support collaboration and collaborative effort. Information systems are socio-technical systems, a combination of technology, people and processes. In these systems, technology and process structuration support decision making by reducing the complexity of information. CLT provides different methods to reduce extraneous (Sweller, et al., 1998), intrinsic cognitive load (2002), and to focus effort on germane load (Paas et al., 2004). With these approaches, CLT has provided new insights in instructional design improving learning efficiency and effectiveness. In collaboration, cognitive load has many sources. It can originate from the information shared among participants through various communication channels, from constructing and thinking up new information, from explaining or arguing positions, from assessing value, implications and effects of decisions, from various procedures, and from distractions. While collaborative problem-solving and decision making is different in many ways from learning tasks, it also bears similarities. We therefore expect that this cognitive perspective will raise new insights in the effectiveness and efficiency of collaborative decision making.

3 Decision Making

When groups collaborate, they often go through a goal oriented problem-solving or design process with roughly three phases.

- First, they brainstorm (also called divergence) to gather, create share or brainstorm information and identify alternatives for decision making.
- Second, they analyze the information available to create meaning and shared understanding (also called convergence).
- Third, they make decisions based on the information analyzed.

This paper focuses on the process of evaluating, comparing and prioritizing alternatives to come to an agreement on a course of action. Divergence, also called generation or brainstorming, (Briggs et al., 2009) often produces a large volume of content of varying relevance, across multiple levels of abstraction and of varying granularity. This knowledge, shared and created by a group, needs to be summarized in a manageable way to create an overview that can be used for further analysis, evaluation or decision making. We acknowledge that decision making often includes the creation and organizing of alternatives. In this paper we focus only on this final phase of decision making, as we have covered brainstorming and convergence in previous work (Kolfschoten, 2011; Kolfschoten & Brazier, 2012). There are many ways to approach decision making, and there are significant differences in the cognitive effort they require, the depth of the analysis of implications of decisions, and the commitment or support of the group and other stakeholders to the agreed on course of action.

Decision making typically can be described along two dimensions; one represents the rational-social choice aspect: the alternatives that have high qualities are not necessarily the ones that most people want given their stakes, personal goals and priorities. The other dimension is the extent to which there is commitment to the decision outcome. Groups can decide to use a very simple decision principle (we choose what the majority wants or judge based on the average score), or they can engage in conflict resolution to unravel their disagreements and find a solution that has full support of all members. In all scenarios, participants need to understand the alternatives, judge alternatives on their value, and consider the impact of the choice on their personal or strategic goals. Depending on how many alternatives are considered and how open the group is toward new alternatives, the complexity of the decision making task will increase. Alternatively, a group can focus more on comparing the value of a few alternatives to maximize value. Furthermore, conflicting objective may need to be traded-off, for instance costs and benefits, or when there is risk or uncertainty related to the alternative. These need be considered and will impact the overall evaluation of ideas and complexity of the decision making task. Decision support can be used to consider these different evaluation criteria and their relative importance to support evaluation and the identification of the source of disagreement.

Several approaches to decision making are compared and merged by Schwenk (Schwenk, 1984). We adapted this approach for Group Decision Making. Note that a very linear view of this process is explained here. In practice the process might iterate and alternate between phases. However, for overview and analysis we use this overview of phases to understand cognitive load in decision making. Figure 1 visualizes this decision making process.

Phase 1: Decision preparation. In this phase two aspects are prepared:

A) the criteria for evaluation, (note that identifying and agreeing on a set of criteria can be a process that takes steps like generating possible criteria, converging to a smaller set and decision making to choose appropriate criteria, as this process covers all three phases of collaboration, we leave this out of the scope for this study and focus only on the decision making phase),

B) the rules for decision making.

(The preparation involves also the choice of decision makers, which can be a decision process in itself. For the cognitive activity involved in decision making we consider this aspect less relevant and exclude it out of the scope.)

Phase 2: Evaluation. This phase is used to assess, value and/or compare alternatives. When all decision makers have shared their assessment and preferences, these need to be combined to get an overview of the group's assessment and preferences, and the level of agreement there is on the evaluation.

Phase 3: Aggregation. In this phase the individual evaluations are aggregated to the group level to compare them. Based on this first overview of evaluation results, disagreements can be explored to see if any of them are based on misunderstanding.

Phase 4: Resolving Misunderstanding. In this phase disagreements based on misunderstanding can be resolved though information sharing, and explanations of differences in perception. When these misunderstandings are resolved, differences in preferences remain.

Phase 5: Negotiation. In this phase, negotiation is used to build support towards the decision that helps to resolve the problem or offer a solution to overcome different perspectives.

Phase 6: Decision making. Finally the phase for determining the final decision is used to confirm results with the group.

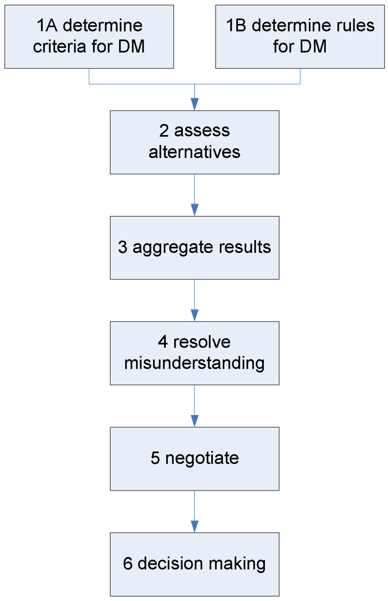

Fig. 1. Decision Making Phases. DM = Decision Making.

4 Cognitive Load in Decision Making

To create an overview of cognitive activities in convergence this paper focuses on eight decision making *thinkLets*. ThinkLets capture best practices in patterns of collaboration (Briggs et al., 2003; Kolfschoten et al., 2006; Vreede et al., 2006). The thinkLets used are CheckMark, StrawPoll, CrowBar, Pin the Tail on the Donkey, Point-Counter-Point, Moodring, and BucketVote as documented in (Briggs & Vreede, 2001). Two of the authors have facilitated over a hundred workshops in education and industry settings based on thinkLets, including those listed above. ThinkLets are documented as scripts and prescribe how to facilitate a collaborative activity. For each thinkLet this paper identifies the cognitive activities required, and listing these in a table. Any overlap of cognitive activities was identified and removed. Next, cognitive activities are grouped in the decision making phases to create a complete list. The resulting set of cognitive activities are compared to the decision making aspects found in the literature described above, to verify completeness of the decision making activities. This completeness check also considers basic cognitive activities; understanding, deciding, recalling (from memory), memorizing (store in memory) and inhibiting (to push away distracting thoughts or stimuli) (Rock, 2009). In this way an overview of the cognitive activities in collaborative decision making is offered, which we will then classify based on their effectiveness.

Effectiveness of decision making has two key factors; objective quality of the decision and subjective support for the decision. Objective quality is about the rigor in comparing alternatives to understand and consider their implications and choose the alternative that best meets the decision criteria. Subjective support is about the accommodation of stakes and preferences and ensuring buy-in and commitment towards the outcome of the decision making process.

The overview of the cognitive processes involved in decision making below is organized in the 6 phases of decision making described above. Cognitive activities and their cognitive implication are listed in the table below, and numbered in the text with numbers between brackets ().

4.1 Cognitive activities in decision making

Phase1: Preparation. In the preparation phase a group receives (listens, reads) a specific decision making task (1), a set of criteria for decision making, and one or more decision making rules, they process these (2-4) for understanding, and memorizing, as they need to be maintained in working memory, especially the objective and criteria. Further, they receive instruction about the tools and methods that will be used for the purpose of decision making (5), observe, study or try it (6) and understand it to infer their personal task (7). Finally, a group needs to make the transition from preparation to the actual decision making activity (8).

Phase 2: Evaluation. In this phase contributions are evaluated based on the criteria presented in the preparation. To enable this evaluation, participants need to explore and understand implications of the alternatives on the systems they affect. Decision support tools and models can be used to assess this impact. This analysis is partly covered in the convergence process described in (Kolfschoten & Brazier, 2012), and will be outside the scope of this paper. Participants need to assess each alternative on each criterion (9), they will consider implications of their score (10) and they will compare scores for alternatives to consider strategic implications (how others will score, how to use the evaluation system to manipulate the outcome) (11) and/or consistency of their scoring with respect to a single criterion (12), and with respect to the relative weight of criteria (13). Finally they mark their evaluation on a ballot either as a score, choice or qualitative evaluation (14).

Phase 3: Aggregation. We assume that results are aggregated according to the decision making rules by a system or though means of shared representation. Depending on the method of evaluation some overview of the results will be presented to the group, including aggregated group scores and rankings of alternatives. Participant will interpret the group results (15) Participants will want to comprehend the aggregation rule (16). They will consider the implications of the group score (17) and compare this with their own evaluations to identify differences (18). Next, participants will want to comprehend the way the ranking is created (19). They will also consider the implications of the ranking of alternatives as a result of the group scores (20), and compare this ranking with their own ranking (21). In case of a qualitative evaluation, some of these aspects will be much more difficult to understand, or they might be absent (e.g. no ranking, or no real group score, ideas that are more or less positively evaluated). However, similar considerations will apply, and some of these aggregations might be created in the next phases rather than directly based on the initial evaluation.

Phase 4: Resolve misunderstanding. Alternatives that receive highly divergent scores can indicate some type of disagreement. Briggs *et al.* (Briggs et al., 2005) distinguish five types of disagreement; different meaning, information asymmetry, different mental models, different goals and different taste. Furthermore, they consider that these disagreements can reflect on the outcome, its implication, and the likelihood of both outcome manifestation and implication manifestation. This diagnostic can be used to understand the source of disagreement; it can be some level of misunderstanding, or there can be a real conflict of stakes behind the disagreement. If the disagreement is mainly rooted in misunderstanding (of meaning, information asymmetry and mental models) it can be 'resolved' by exchanging and explaining different perspectives and understandings of the alternatives. Participants in this process will identify disagreements (22), assess the source of disagreement (23) share/explain their perspective (24), listen to another perspective (25) understand another perspective and the differences between perspectives (26), and reconsider their evaluation (27). In some cases the alternative might be reformulated to reflect shared meaning (28). When misunderstanding is (partly) resolved, participants can mark their new evaluations, looping back to the evaluation phase, or they can brainstorm about reformulation to loop back to the brainstorming phase, which is outside the scope of this paper.

Phase 5: Negotiation. When disagreement is rooted in differences in stakes, a process is initiated that is aimed at either convincing others to change the priorities in their stakes/goals (debate) or to change the alternative to compromise (negotiate). In this process participants argue for a specific evaluation (29), listen to arguments of others (30) and compare arguments with their personal goals/stakes (31). They then make counterarguments, and circle in this process until they consider a compromising proposal (32), they articulate this proposal (33) and then loop to the evaluation process to collect renewed evaluations and/or understand new disagreements. Note that evaluations in these follow-up rounds might be less formal in nature, or could be a complete iteration of the phase.

Phase 6: Decision making. Finally, the group will converge in this process to a group evaluation and ranking of alternatives. In this final stage, participants might reflect on the decision making process to consider if they can accept the outcomes (34), if they find the decision process fair (35) and if they trust that other will commit to the outcome of the decision process (36). Finally, participants might consider the cost-benefits of further evaluation and negotiation (37). To end the decision making process a facilitator or group leader can articulate the decision outcome as a course of action. Participants then understand the decision outcome (38), consider it (34-37), and assert their commitment (yes or no) (39). This process can result in ending the decision process, or reiterating steps.

Distraction: Finally, across phases, participants might be distracted by ideas triggered from considering the alternatives (40), off-task internal distractions (41) and off-task external distractions (42)

Table 1 lists the numbered cognitive activities distinguished from the 8 Evaluation ThinkLets, and our experience with these ThinkLets in practice, we indicate if they are ineffective, extraneous (needed for the process, but not contributing to outcomes) or effective for decision quality or support.

Table 1. Cognitive activities in collaborative decision making.
DQ = Decision Quality, DS = Decision Support, P= Process, IE= Ineffective.

Cognitive Activity	DQ	DS	P	IE
Preparation				
1 receive (listen, read) the decision making task including objective, rules and criteria			x	
2 understand the decision task			x	
3 understand the decision criteria			x	
4 understanding the decision rules			x	
5 listening to the explanation of decision tool & method			x	
6 study/observe/try out the decision tool & method			x	
7 understanding one’s task based on the decision tool & method			x	
8 cognitive effort to make the transition from understanding the decision making task to performing it			x	
Evaluation				
9 assess alternatives based on criteria	x	x		
10 consider implications of individual score		x		
11 compare scores for alternatives to consider strategic implications of ranking		x		
12 compare scores for alternatives to consider consistency of scoring	x			
13 compare scores for alternatives to consider relative weight of criteria	x			
14 mark/capture/write down evaluation or score			x	
Aggregation				
15 understand group results (scores and ranking)		x		
16 understand the aggregation rule (how individual scores are combined into a group			x	
17 consider implications of the group score		x		
18 compare group score with personal score		x		
19 understand the aggregation rule for ranking (how the group scores are combined to become a ranking of alternatives)			x	
20 consider the implications of the ranking		x		
21 compare the group ranking with personal ranking		x		
Resolving misunderstanding				
22 identify group disagreements			x	
23 assess the root cause of disagreement			x	
24 share or explain an evaluation perspective	x	x		
25 listen to other evaluation perspectives	x	x		
26 understand differences between perspectives	x	x		
27 reconsider scores in light of new understanding	x	x		

28 rephrase alternative to capture shared meaning	x	x	
Negotiation			
29 argue for specific evaluation	x	x	
30 listen to other arguments of others	x	x	
31 compare arguments with personal stakes		x	
32 consider compromise	x	x	
33 articulate proposal for compromise	x	x	
Decision making			
34 consider decision outcome acceptance		x	
35 consider decision process fairness		x	
36 consider trust in other stakeholders to commit to the decision outcome		x	
37 consider costs and success chance of further evaluation and negotiation		x	
38 understand final decision outcome	x	x	
39 assert commitment (yes or no)		x	
Distraction			
40 consider new idea sparked by evaluation	x	x	
41 personal distraction			x
42 external distraction			x

5 Discussion and Conclusions

This paper offers a first framework and classification of steps in a decision making process from a cognitive load perspective. In previous work we explored this perspective for divergence (brainstorming) (Kolfschoten, 2011) and convergence (information analysis and structuration) (Kolfschoten & Brazier, 2012). Here we add a cognitive perspective on decision making to understand the cognitive load involved in evaluation and consensus building. The framework needs validation. If validated, it can be used as a basis to design more effective decision support tools, models and processes, taking into account the cognitive effort involved in decision making, and structuring the group decision making effort to support consideration of alternatives and their implications. Validation of cognitive activities is not a straightforward task, as the self-reflection or introspection required as a research approach can impose considerable bias (Ericsson & Simon, 1993; Jack & Roepstorff, 2002). However, we also believe that this perspective on collaboration and decision making can shed a new light on group support tools and techniques, and on designing structure to enable groups to effectively collaborate. In our future work, we will explore methodologies to evaluate and use the framework to understand the cognitive trade-offs in supporting effective decision making.

References

Balthazard, P., Ferrell, W.R., & Aguilar, D.L.: (1998). 'Influence Allocation Methods in Group Decision Support Systems'. Group Decision and Negotiation, 7, 347-362.

Bray, D.A.: 2008. 'Information Pollution, Knowledge Overload, Limited Attention Spans, and Our Responsibilities as IS Professionals'. GITMA World Conference Atlanta

Briggs, R.O., Kolfschoten, G.L., & Vreede, G.J. de: 2005. 'Toward a Theoretical Model of Consensus Building'. Americas Conference on Information Systems, Omaha

Briggs, R.O., Kolfschoten, G.L., Vreede, G.J. de., Albrecht, C.C., Lukosch, S.G., & Dean, D.L.: 2009. 'A Seven-Layer Model of Collaboration: Separation of Concerns For Designers of Collaboration Systems'. International Conference on Information Systems

Briggs, R.O., & Vreede, G.J., de: (2001). 'ThinkLets, Building Blocks for Concerted Collaboration'. Delft: Delft University of Technology.

Briggs, R.O., Vreede, G.J. de, & Nunamaker, J.F. jr: (2003). 'Collaboration Engineering with ThinkLets to Pursue Sustained Success with Group Support Systems'. Journal of Management Information Systems, 19, 31-63.

Czikszentmihalyi, M.: (1990). 'Flow. The psychology of optimal experience.'. New York: Harper Perennial.

Dennis, A.R., & Wixom, B.H.: (2002). 'Investigating the Moderators of the Group Support Systems Use with Meta-Analysis'. Journal of Management Information Systems, 18, 235-257.

Dillenbourg, P., & Betrancourt, M.: (2006). 'Collaboration Load'. In J. Elen & Clark, R. E. (eds.), Handling Complexity in Learning Environments: Research and Theory (pp. 142-163): Pergamon.

Eppler, J.M. , & Mengis, J. : (2004). 'The Concept of Information Overload: a Review of Literature from Organizational Science, Accounting, Marketing, MIS and Related Diciplines'. The Information Society, 20, 325-344.

Ericsson, K.A., & Simon, H.A.: (1993). 'Protocol Analysis: Verbal Reports as Data'. Cambridge: MIT Press.

Farrington, J.: (2011). 'From the Research: Myths Worth Dispelling: Seven Plus or Minus Two'. Performance Improvement Quarterly, 23, 113-116.

Fitousi, D, & Wenger, M.J.: (2011). 'Processing Capacity Under Perceptual and Cognitive Load: A Closer Look at Load Theory'. Journal of Experimental Psychology: Human Perception and Performance, 37, 781-798.

French, S.: (2007). 'Web-enabled Strategic GDSS, e-Democracy and Arrow's theorem: A Bayesian Perspective'. Decision Support Systems, 43, 1476-1484.

Frost, & Sullivan. (2007). Meetings Around the World: The Impact of Collaboration on Business Performance.

Jack, A.I, & Roepstorff, A. : (2002). 'Introspection and Cognitive Brain Mapping: From Stimulus-Response to Script-Report'. TRENDS in Cognitive Sciences, 6, 333-338.

Kalyuga, S., Ayres, P., Chandler, P., & Sweller, J.: (2003). 'The Expertise Reversal Effect'. Educational Psychologist, 38, 23-31.

Klein, H.K., & Hirschheim, R.: (1985). 'Fundamental Issues of Decision Support Systems: A Consequentialist Perspective'. Decision Support Systems, 1, 5-24.

Kolfschoten, G.L.: (2011). 'Cognitive Load in Collaboration - Brainstorming'. Hawaii International Conference on System Science, Kauai, HI, pp. 1-10.

Kolfschoten, G.L., & Brazier, F.: (2012). 'Cognitive Load in Collaboration - Convergence'. Hawaii International Conference on System Science, Maui

Kolfschoten, G.L., Briggs, R.O., Vreede, G.J. de, Jacobs, P.H.M., & Appelman, J.H.: (2006). 'Conceptual Foundation of the ThinkLet Concept for Collaboration Engineering'. International Journal of Human Computer Science, 64, 611-621.

Kolfschoten, G.L., Lukosch, S.G., Verbraeck, A., Valentin, E., & Vreede, G.J.de.: (2010). 'Cognitive Learning Efficiency Through the Use of Design Patterns in Teaching'. Computers and Education, 54, 652-660.

Miller, G.A.: (1956). 'The magical number seven plus or minus two: some limits on our capacity for processing information'. Psychological Review, 63, 81-97.

Niederman, F., Vreede, G.J. de, Briggs, R.O., & Kolfschoten, G.L.: (2008). 'Extending the Contextual and Organizational Elements of Adaptive Structuration Theory in GSS Research.'. Journal of the Association for Information Systems, 9.

Paas, F., Renkl, A. , & Sweller, J.: (2004). 'Cognitive Load Theory: Instructional Implications of the Interaction between Information Structures and Cognitive Architecture'. Instructional Science, 32, 1-8.

Paas, F.G.W.C., & Merrienboer, J.G. van: (1994). 'Variability of Worked Examples and Transfer of Geometrical Problem-Solving Sills: A Cognitive Load Approach'. Journal of Educational Psychology, 86, 122-133.

Pervan, G.P.: (1998). 'A Review of Research in Group Support Systems: Leaders, Approaches and Directions'. Decision Support Systems, 23, 149-159.

Pollock, E., Chandler, P., & Sweller, J.: (2002). 'Assimilating Complex Information'. Learning and Instruction, 12, 61-86.

Rock, D.: (2009). 'Your Brain at Work'. New York: HarperCollins Publishers.

Schwenk, C.R.: (1984). 'Simplification Processes in Strategic Decision-Making'. Strategic Management Journal, 5, 111-128.

Simon, H.A.: (1974). 'How Big is a Chunk?'. Science, 183, 482-488.

Simon, H.A.: (1980). 'Cognitive science: The newest science of the artificial'. Cognitive Science, 4, 33-46.

Slovic, P., Fischhoff, B., & Lichtenstein, S.: (1977). 'Behavioral Decision Theory'. Annual Review of Psychology, 28, 1-39.

Sweller, J.: (1988). 'Cognitive load during problem solving: Effects on learning'. Cognitive Science, 12, 257-285.

Sweller, J., Merrienboer, J.G. van, & Paas, F.G.W.C.: (1998). 'Cognitive Architecture and Instructional Design'. Educational Psychology Review, 10, 251-296.

Vreede, G.J. de, Briggs, R.O., & Kolfschoten, G.L.: (2006). 'ThinkLets: A Pattern Language for Facilitated and Practitioner-Guided Collaboration Processes'. International Journal of Computer Applications in Technology, 25, 140-154.

Wheeler, B.C., & Valacich, J.S.: (1996). 'Facilitation, GSS and Training as Sources of Process Restictiveness and Guidance for Structured Group Decision Making an Empirical Assessment'. Information Systems Research, 7, 429-450.

The LogicalMulticriteriaSort ThinkLet: Logical Navigation for Fair and Fast Convergence in Multicriteria Group Decision Making

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Abstract: Information overload is a key issue in group decision. A heuristics, called "*take-the-best*", has been shown useful to face multicriteria decisions while reducing information overload: when making decisions people often take criteria in a predefined order, the first criterion which discriminates the alternatives at stake is used to make the decision. In order to rationalize group work, Briggs and de Vreede have proposed collaboration design patterns, called thinkLets. This article presents the LogicalMulticriteriaSort thinkLet that can be seen as a generalization of the take-the-best heuristics. It also proposes to consider criteria one at the time but once a criterion has been found discriminating it is kept in a record, and the process is iterated. The thinkLet is supported by a GDSS, based on Logical Information Systems, which gives an instantaneous feedback of each micro decision and keeps tracks of all of the decisions taken so far. The LogicalMulticriteriaSort thinkLet guarantees more fairness and speed than the ChauffeurSort thinkLet. It also avoids the need to give artificial values and weights to the criteria as opposed to the Multicriteria thinkLet. A successful test case is reported.

Keywords: Multicriteria decision, Logical Information Systems, Formal Concept analysis

1 Introduction

At the workplace, collaboration is a key issue, in particular, to make sensitive decisions. Important advantages of a group decision are that the group can share a better understanding of the situation than a single person and that it can be easier to collectively endorse a decision. Experience shows, however, that collaborative work is not always satisfactorily organized. Collaboration design patterns, called thinkLets, have been proposed (Briggs and de Vreede, 2009) to help the person, called the facilitator, in charge of helping a group achieve a common task. "*A thinklet provides a transferable, reusable and predictable building block for the design of a collaboration process*." A major problem faced by people is information overload. ThinkLets for convergence are especially needed in order to reduce the cognitive load (Davis et al. , 2007). As stated by (Lewis, 2010), "*Perhaps the greatest challenge a group will face is how to take a raw list of ideas and discuss, edit, and organize these ideas to create a coherent result*." Consistently, (Vogel and Coombes, 2010) state that, from a cognitive point of view, it is much more difficult for a group to organize ideas than to generate them. In order to minimize the effects of information overload, people tend to employ conscious or even unconscious heuristics (Vogel and Coombes, 2010). The "*gaze heuristics*", reported in (Marewski et al., 2010), is exemplary. In order to catch a ball high up in the air, a player fixates it, starts running and keeps the angle of gaze constant. He does not beforehand calculate a complex differential equation but he will be at the proper place to catch the ball.

A second important issue is the use of multiple criteria. The results of (Vogel and Coombes, 2010) show that "*groups selecting ideas from a multiple criteria task formulation will converge better than groups working on a single criterion formulation*". Another of the heuristics described in (Marewski et al., 2010), called "*take-the-best*", allows to face multicriteria decisions while reducing information overload: when making decisions people often take criteria in a predefined order, the first criterion which discriminates the alternatives at stake is used to make the decision. This heuristics has been shown to be more effective than multiple regression while considering less criteria in a number of cases. Not all criteria are, thus, relevant for a given decision. It is even crucial to discriminate against relevant and irrelevant criteria because, as stated by (Shanteau, 1992), irrelevant criteria can inappropriately influence the judgment of people whatever their expertise level.

The contribution of this article is to propose the LogicalMulticriteriaSort thinkLet with a supporting tool which could be an asset if integrated into existing toolboxes, such as for example the set of simple editors to help non professional facilitators proposed by (Briggs et al. , 2010) or the toolkit for GDSS facilitators proposed by (Adla et al., 2011). The LogicalMulticriteriaSort thinkLet gives a procedure to logically sort candidates into categories according to multiple criteria. It can be seen as a generalization of take-the- best and an implementation of the gaze heuristics. Following take-the-best, it proposes to consider criteria one at the time. There is no predefined order, participants put forward the ones they find the most relevant at a given time. We enhance take-the-best by using a GDSS, based on Logical Information Systems (LIS) (Ferré and Ridoux, 2004). It firstly enables participants to easily navigate in the data. It secondly gives an instantaneous feedback of each micro decision and it thirdly builds a shared knowledge by keeping tracks of all of the decisions taken so far. It thus provides support for the gaze heuristic with no cognitive overload. The LogicalMulticriteriaSort thinkLet has been tested on the debriefing of an academic year validation jury whose results had been controversial. The test case participants were positive about the process and the main result was that they all agreed to use the LogicalMulticriteriaSort thinkLet and the supporting tool for the forthcoming jury at the same level.

The LogicalMulticriteriaSort thinkLet is related to two thinkLets of (Briggs and de Vreede, 2009): ChauffeurSort and Multicriteria. A detailed discussion of these two thinkLets can be found in Section 3. In summary, compared to the ChauffeurSort thinkLet, or Organize of *Meetingworks*™ (Lewis, 2010), the major difference is that, with LogicalMulticriteriaSort, the discussion is led by the criteria and not by the candidates. It ensures both fairness and speed. Indeed, with our approach, it is guaranteed that all the candidates will have been considered along the discussed criteria. Furthermore, the meeting can stop after any criterion analysis if the group decides so. The Multicriteria thinkLet of (Briggs and de Vreede, 2009) also addresses the analysis of problems defined by multiple criteria. The values for the criteria, however, are necessarily numbers; weights are attached to each criterion and a weighted sum is computed. Producing numerical criteria weights is tedious, arbitrary and can lead to dubious results. With our approach, the values can be numerical or symbolic; their analysis is logical. Participants only have to decide if a criterion is relevant or not and define thresholds for the values of the relevant criteria. Mesta (Hiltunen et al., 2009) is a multicriteria decision support tool. For each criterion, participants are asked to propose acceptable thresholds. The graphical display and handling of the thresholds has been proved useful. The approach can be implemented on top of LIS tools. An interface `a la Mesta for the simple cases would be helpful. Our tool, nevertheless, enables to state logical queries that can be much more sophisticated.

In the following, Section 2 briefly introduces Logical Information Systems. Section 3 describes in detail the LogicalMulticriteriaSort thinkLet following the schema of (Briggs and de Vreede, 2009). Section 4 reports about the jury test case, and presents the users' feedbacks collected in two questionnaires, one before and one after the meeting.

2 Logical Information Systems

Logical Information Systems (LIS) (Ferré and Ridoux, 2004) belong to a paradigm of information retrieval that combines querying and navigation. LIS are formally based on Logical Concept Analysis (LCA) (Ferré and Ridoux, 2000), a logical generalization of a mathematical theory, Formal Concept Analysis (FCA) (Ganter and Wille, 1999). In LCA, logical formulas are used to describe objects, as opposed to FCA where only simple symbolic criteria can be used. One advantage of logical formulas is, for instance, to permit numerical and symbolic criteria to be combined. From the descriptions of objects, a data structure, called *concept lattice*, is computed. The concept lattice partially orders both objects and criteria. It serves as the navigation structure. Logical formulas are also used to represent queries and navigation links in the lattice. In the cases addressed by the LogicalMulticriteriaSort thinkLet, the data are so dense that the current FCA tools (see for example (Tilley, 2004)) that graphically display the concept lattices cannot be used. Indeed, the global concept lattice is too large to be managed by hand. On the opposite, and as illustrated by the screen copies in the following, the local views of LIS tools enable users to grasp and manage the relevant information. Local views are obtained by querying the system. There exist three ways to define a query: by formula edition, by navigation (selecting criteria in order to modify the query) or by examples. Query definition is illustrated in Section 4. It is one of the strengths of FCA and LCA systems to be able to focus on the criteria and the objects are then logically sorted. Another important user action provided by LIS tools is annotation. Annotations, navigation and querying can be performed in the same interface. In the following the examples are given using the Camelis tool [1].

3 The LogicalMulticriteriaSort ThinkLet

This section describes the LogicalMulticriteriaSort thinkLet following the schema of (Briggs and de Vreede, 2009). We have added a *Tool and Manpower* field. ThinkLets have been partitioned into 6 pattern categories (Kolfschoten et al., 2010): Generate, Reduce, Clarify, Organize, Evaluate and Consensus Building. The main related pattern and subpattern of LogicalMulticriteriaSort is ***Organize/Categorizing***. People speak of Convergence for the Reduce and Clarify patterns. LogicalMulticriteriaSort can also be considered as a convergence thinkLet because the discussions related to the relevance of criteria and the traces kept by the LIS tool highly contribute to build an explicit shared understanding of the situation. Furthermore, sorting into categories and filtering along the criteria contribute to the reduction aspects. Related thinkLets are discussed in the *Insights on LogicalMulticriteriaSort* field. The descriptions are illustrated using the test case detailed in Section 4, namely a jury to validate students' year, at a technical university. In the following, phrases in italic are taken from thinkLet descriptions of (Briggs and de Vreede, 2009). In that case the name of the thinkLet is given in between parentheses.

Choose this thinkLet...
... when you want to assure that the placement of every item/candidate in a category is carefully considered by the team (ChauffeurSort)
... to evaluate a list of items/candidates against multiple criteria (Multicriteria)
... when it is crucial that the decision process is as fair as possible
... when the important criteria for the decision are not necessarily known
... when creating a shared understanding of the discriminating criteria is crucial
... when the group will have to endorse a sensitive decision
... when meeting time is of the essence

Do not choose this thinkLet...
... when nobody has time to prepare the table associating criteria values to candidates
... if the group has not been prepared to make a decision based on multiple criteria

Overview
The group decides which of the criteria are discriminating for the sort, and what are the required values for those criteria. Candidate sorting is a logical consequence of these decisions. For example, for a jury, the group can decide that in order to pass a student must have had a given grade above a given threshold.

Inputs
1. A set of candidates, for example students for a jury.
2. A set of categories in which the candidates should be sorted. For a jury the categories can be "automatically pass", "let through by jury" and "fail".
3. A set of criteria. For a jury the criteria can be the average grades on different modules, how many credits students have validated, whether they fulfilled the English test requirement.
4. Values of these criteria for most of the candidates. Note that it is not mandatory that all candidates have all criteria filled in.
5. (optional) A set of rules, mandatory or revisable, that automatically sort subsets of the candidates. Mandatory jury rules tell which of the students automatically validate the year according to the rulings of the university. An example of revisable jury rule is that students with a scientific grade average below a given threshold fail. The group is free to revise that threshold, or even remove the rule.

[1] see http://www.irisa.fr/LIS/ferre/camelis/

Outputs

1. Candidates sorted by category.
2. A set of criteria important for that particular decision.
3. A set of rules to explain the sorting. These rules can be used as germs for the next meetings of the same kind.

How to use LogicalMulticriteriaSort

Setup

1. The chauffeur, namely the person in charge of the technical aspects of the hardware and software (Lewis, 2010), collects the data to build the context, basically a table with a line per candidate, filling the criteria slots whenever it is relevant. Note that there are a number of cases where the prerequisite data is not an extra burden because it is done anyway. For example, for juries, grades and additional information must be collected whatever thinkLet is used.
2. The chauffeur or the facilitator integrates the data into the LIS tool.
3. The facilitator investigates the data in order to be able to suggest important criteria, to bootstrap the process if necessary.

Steps The chauffeur uses the tool to display the state of the context. There are two different phases:

1. If there exist mandatory rules, they are “law” and cannot be questioned. The group analyzes the properties of the candidates automatically sorted by these rules, in order to build up references for further discussions.
2. The group iterates through steps 2a to 2f until either all candidates have been sorted and participants are convinced that it is fair enough, or participants cannot find any more criteria on which to discriminate on a consensual way, or time is out.
   - (a) If there are revisable rules, the group investigates what their impacts on the given context. These rules come most likely from a previous meeting of the same kind. They are not necessarily totally relevant for the current context. The group decides to keep them, adjust them or leave them aside.
   - (b) The group takes the list of criteria and decides which ones are relevant for the decision. Note that not all criteria need to be investigated in depth. For a jury the group can decide that the grade for each particular module does not need to be investigated for the time being. Nothing prevents the group from coming to that point later.
   - (c) When a set of criteria have been accepted as being relevant, the group discusses what the characteristic values for these criteria are for each category.
   - (d) Whenever a logical formula has been identified, a rule can be created to keep a trace of each small decision. It provides basic blocks for the global explanation of the final decision. It also enables the group to question each of the small decisions at anytime during the meeting.
   - (e) The group can decide, at any time, that new criteria are relevant. If these criteria were not initially in the context, their values can be filled in on the fly.
   - (f) Regularly, the rules are inspected to check that they still reflect the current state of the group’s understanding and consensus.

Tool and Manpower

As reported in (Ducassé and Ferré, 2008), spreadsheet can be used to support the LogicalMulticriteriaSort thinkLet. Their filters, masks and macros provide part of the necessary functionalities. However, selecting criteria and candidates in the spreadsheet is error prone. It is hard to ensure consistency. Furthermore, adding attributes in the table is tedious and again error prone. Keeping track of the selection process is almost impossible. LIS tools, as shown in the Test Case Section 4, are appropriate tools to sustain this thinkLet. A chauffeur is necessary for a physical meeting, a facilitator is also required. Unless for simple cases, it is advisable that the roles are played by two different persons.

Insights on LogicalMulticriteriaSort

LogicalMulticriteriaSort is related to two thinkLets of (Briggs and de Vreede, 2009): ***ChauffeurSort*** and ***Multicriteria***. ***ChauffeurSort*** investigates the candidates in sequence. Briggs and de Vreede state "*do not use this thinkLet if time is of the essence*". Consistently, (Lewis, 2010) states "*often, the majority of the time will be spent on the first few ideas [candidates] at the top of the list, whether these have the greatest merit or not"*. With LogicalMulticriteriaSort it is the criteria that are investigated following an order prompted by the participants. It ensures both fairness and speed. Going along the candidates without consistency checking mechanisms, the treatment of candidates is not fair, for one candidate participants will talk about some criteria, for another candidate there is no guarantee that the same criteria will be used. With LogicalMulticriteriaSort, even if all the criteria have not been considered, it is guaranteed that all the candidates will have been considered along the discussed criteria. As a consequence, the meeting can stop after any criterion analysis, preferably if the group decides that enough relevant criteria have been considered. If time is out, the criterion analysis is incomplete, the decision is nevertheless guaranteed to be fair to the candidates.

The ***Multicriteria*** thinkLet is based on Multi-Criteria Decision Analysis (see for example (Zopounidis and Pardalos, 2010)). Criteria are given a numerical value and a weight, and then a weighted sum is computed. Briggs and de Vreede state "*do not use this thinkLet as final decision-making process. Odd anomalies can crop up in the results of Multicriteria analysis*". Consistently, (Bana e Costa and Chagas, 2004) emphasize that producing numerical criteria weights is tedious, arbitrary and can lead to dubious results. In order to palliate those problems, they ask users to fully rank the criteria, then according to the actual values of the data they automatically produce weights to insure consistency in the actual context. While this is a significant improvement, our experience is that it is often difficult to reach an agreement about a total ranking of the criteria at a meeting. For example, in the test case of Section 4 there was no obvious convergence in the relative importance of the criteria before the meeting. Even at the end of the meeting there was still disagreement about the importance of a few criteria. With our approach, the values can be numerical but also symbolic, their analysis is logical. Participants only have to decide if a criteria is relevant or not and put conditions, for example thresholds, on the relevant criteria. When the results of LogicalMulticriteriaSort lead to a decision, they explicit in a legible way arguments on which the group agrees, and can be relied upon. When the results do not lead to the final decision they still pave the way for further steps. They, thus, help the group endorse the decision.

4 LogicalMulticriteriaSort Success Stories

An example of success story is a recruitment process, reported in (Ducassé and Ferré, 2008), whose first step had followed the LogicalMulticriteriaSort thinkLet, even if not explicitly said. The overall objective of the meeting was to propose a sorted list of candidates. The first step consisted in sorting the candidates into three categories, "to be considered", "may be", "excluded". For the further steps only the candidates in the first category were actually considered. In the remaining of this section, we describe a successful test case related to a jury at a technical university.

Context of the Jury Test Case

The reported test case is a debriefing of a year validation jury (called the *actual jury* in the following) whose results had been controversial. Such juries, seat at the end of every school year and decide for each student of a class whether s-he passes or fails. In the past, the juries of the concerned institution use to reason almost exclusively on a global weighted average calculated over all the grades of the student for the school year. With the European Bologna process[2], ECTS credits came into the picture. The students must acquire 30 ECTS credits per semester. Yet, compensation between modules is allowed in the French

[2] http://www.europe-education-formation.fr/bologne-ects-doc.php

system[3] and the institution introduced compensation rules for automatic year validation. Jury members are therefore forced to reason on multiple criteria, at least on credits and global average.

The authors were respectively the facilitator and the chauffeur of the meeting. Camelis was used (see Section 2). Beside the facilitator and the chauffeur, there were five participants, all computer science teachers not familiar with the LIS tools. Among the five participants, 4 attended the actual jury; the remaining person had chaired another jury at the same period. Neither the facilitator, nor the chauffeur had attended the actual jury. The whole actual jury, 8 members, had been invited but only the people with responsibilities in the institution came, namely all participants were responsible of a curriculum, including the chair of the actual jury. There were no identified conflicts but there was also no obvious convergence in the relative importance of the criteria. The discussions during the meeting were (audio) recorded.

A spreadsheet file had been prepared for the actual jury by the chair of that jury. It contained 55 lines (one per student under judgment) and 160 columns (one per criteria). Examples of criteria are the grading and the acquired ECTS credits of each module, the average per group of modules, which specialty students took or the ranking in the class. A printed version of this file had been used at the actual jury. The jury chair had sorted it into several sheets. The actual jury members had to browse through 9 printed pages. The facilitator transferred the spreadsheet data into Camelis and structured by hand the criteria so that participants did not have to face the 160 criteria in a first step. Figure 1 shows what participants could see during the meeting (explanations are given in the next section).

Meeting First Phase: Analysis of Automatically Passing Students

The first phase, analyzing the impacts of the mandatory rules, lasted approximately 20 minutes. There was only one rule specifying the students who were automatically passing thanks to the institutional compensation rules. Figure 1 shows a screen shot of Camelis during the first phase. LIS user interfaces give a local view of the concept lattice. The local view is made of three parts: (1) the *query* (top left), (2) the *extent* (bottom right), and (3) the *index* (bottom left). The *query* is a logical formula that typically combines criteria (e.g., `g1_Average`), patterns (e.g., `g1_Average >= 10.`), and Boolean connectors (`and`, `or`, `not`). On the figure, the query area shows the implementation of the institutional automatic passing rule: `g1_Average >= 10. and g2_Average >= 10. and g3_Average >= 10. and g4_Average >= 10. and g5_Average >= 10.` . It means that the selected (passing) students have a grading average of at least 10 (out of 20) for all of the 5 groups of modules.

The *extent* is the set of objects that are matched by the query, according to logical subsumption. Objects correspond to the candidates mentioned in the description of the LogicalMulticriteriaSort thinkLet. The candidates are actually students in this test case. On the figure, one can see part of the identifiers corresponding to the 44 students passing thanks to the institutional automatic passing rule. Note that during the test case participants could see the full name of students.

Finally, the *index* is a set of criteria, taken from a finite subset of the logic, it is restricted to criteria associated to at least one object (student) in the extent. The index plays the role of a summary or inventory of the extent, showing which kinds of objects there are, and how many of each kind there are (e.g., in Figure 1, 3 students in the extent have 10 `compensated_credits`.)

Note that the query had been obtained solely by clicking on criteria of the index. Let us describe how it had been produced. Firstly, opening the `Average ?` criterion, the chauffeur could click to open `g1_Average`. Then clicking on one of the displayed values (here `10.`), then on the `>=` button and then on the `zoom` button produced the `g1_Average >= 10.` part of the query. Repeating the process for all the group averages produced the query.

[3] See for example "Arrêté du 1er août 2011 relatif à la licence NOR: ESRS1119411A"

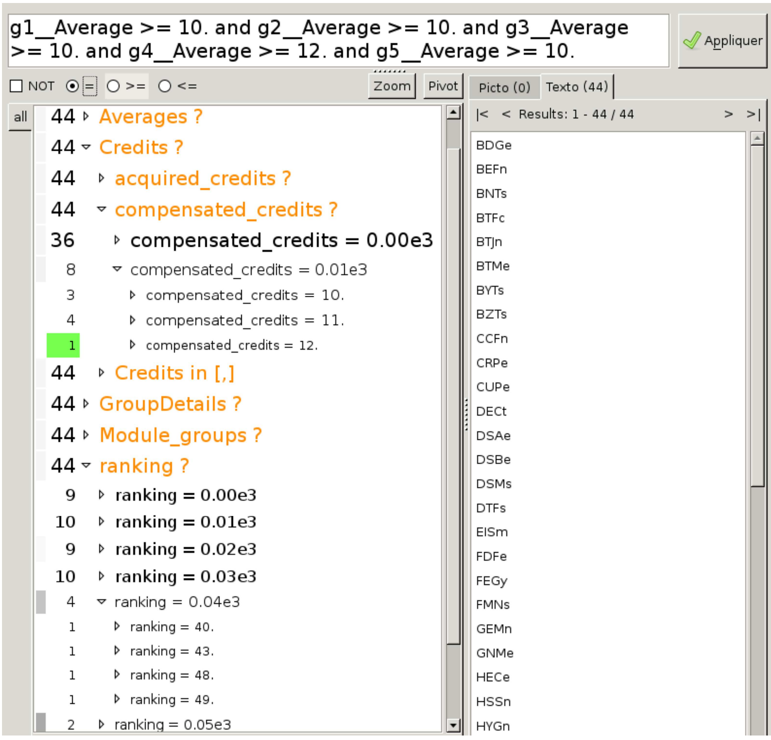

Fig. 1 Screen shot of Camelis with a query specifying a mandatory rule

After some investigations, the group agreed that two interesting facts about the passing students disserved to be noted. Firstly, as can be seen on the figure, 8 out of the 44 passing students had 10 or more `compensated_credits`. Compensated credits come from the institutional compensation rules. The students failed some modules, but because they had grades good enough in some others they gain credits for modules for which they fail. It was very important for the following discussions to note that the maximum number of compensated credits was 12. Secondly, it can also be seen that there are some "holes" in the ranking. `ranking = 0.00e3`[4] means that there are ranking values between 0 and 9, `ranking = 0.01e3` means that there are ranking values between 10 and 19, etc. As mentioned above, the number in front of each criterion tells how many students have the criterion. Here it seems normal that there are 9 students ranked between 1 and 9. It is less normal that there are only 9 students ranked between 20 and 29, and only 4 between 40 and 49 especially as there are two automatically passing students who were ranked after 50. The global ranking, based on the global grade average, used to be the main decision criteria. Here we can immediately see that at least 7 students fall into an unusual case.

Meeting Second Phase: Sorting Out Candidates

The second phase, the actual sorting phase, lasted approximately 50 minutes. In the meeting there were no prior optional rules. To initiate the discussion the facilitator suggested that the number of credits was probably a relevant criterion. After a discussion, the group hinted that it would be unfair to require more credits from the students under discussion than the maximum number acquired without compensation by the automatically passing students, namely 48 credits. Figure 2 shows a screen shot of Camelis where the query selects the students who do not automatically pass and who have acquired at least the required 48 credits. In the extent area one can see that 5 students are concerned. In the index, one can see a number of interesting points. Firstly, all concerned students have a general average above 11 (2 even have an average above 12). They also all have a scientific average above 10. The three students who are below 10

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[4] We acknowledge that this is off putting and we are investigating how to present this in a more accessible way. Note, however, that participants, although initially puzzled, managed very well after they received explanations.

for the average of the g1 group of modules (e.g. `g1_average = 0.00e3`) are the same three students who are above 10 for the average of the g3 group of modules (e.g. `g3_average = 0.01e3`). It can be seen from the coloring of the numbers, an identical color means that the related students are the same. From the above properties, the group decided that for that particular class, it was ok to let through those students. The chauffeur therefore created a rule, saved in the tool, to keep track of the reasons for which these students were let through. At the moment of editing the rule, somebody said that the rule was only acceptable for him because the scientific average was not too weak and wanted that to be recorded in the rule. The rest of the group agreed and the actually saved rule is given in Figure 3. It uses another rule (not shown here) that specifies that if the scientific average is below 10, it is considered too weak and the student fails. Note that the 5 concerned students automatically got a new criterion, namely 'let through cause more acquired credits than some automatically pass students'. This new criterion could then be used in queries. The meeting went on by sorting either from top or bottom. Sorting from top consisted in identifying thresholds above which students could pass (for example with a general average above 12), sorting from bottom consisted in identifying thresholds below which students should fail (for example with not enough acquired credits or a scientific average too weak).

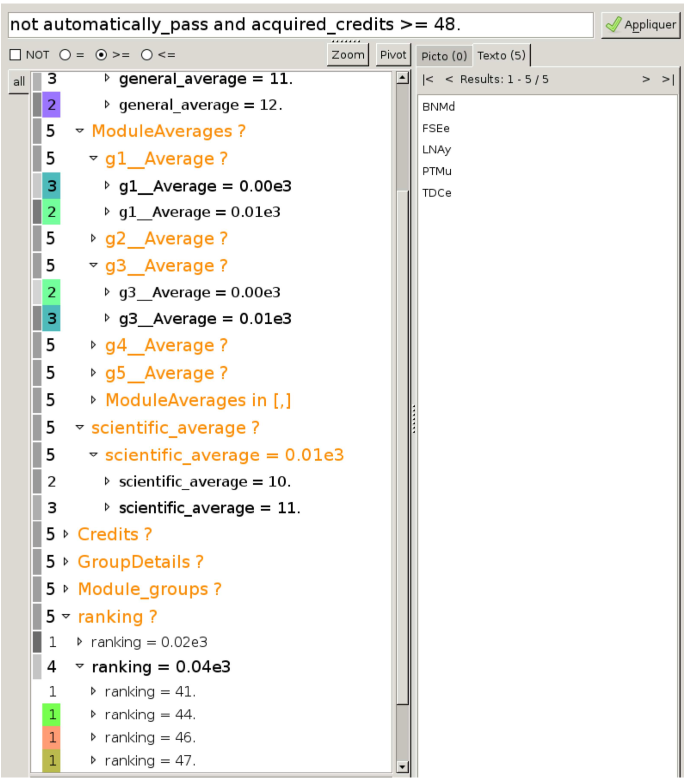

Fig. 2 Screen shot of Camelis when the group had identified a rule

```
'let through cause more acquired credits than some automatically pass
students' :-
              not automatically_pass
      and not 'fail due to scientific average too weak'
      and acquired_credits >= 48.
```

Fig. 3 First rule produced by the jury test case

At the end of the meeting, the context had been enriched by 5 rules which sorted 53 out of the 55 students: (r1) forty four students automatically passed thanks to the institutional mandatory rule, (r2) five students were let through thanks to the rule discussed above, (r3) one student was let through thanks to a good enough general average, (r4) one student failed due to a scientific average too weak, and (r5) 3

students failed due to a lack of credits. One student was concerned by two (consistent) rules and he is therefore counted for each of the rules. Altogether the five produced rules use the three logical connectors “and”, “or” and “not”. They also use 6 different criteria, symbolic and numeric, showing that multi-criteria reasoning and decision are indeed possible at a logical level. Rule r3 concerns one student only. There was a consensus that the student should pass. The facilitator asked whether the student should be simply moved to a “pass” basket. One participant asked that a rule was created to specify explicitly why participants thought he should pass and to keep a trace of the reasons.
At the end of the meeting, there were only two students for whom no consensus could be found, whereas participants reported that the actual jury voted for 6 students.

Users’ Feedbacks

This section reports the results of the two questionnaires filled by participants, one before and one after the meeting. Note that the person who did not attend the actual jury answered only the general questions. The questionnaire and discussions were in French. The quotations of participants have been translated by the authors.

Questionnaires Before the Meeting. All participants reported that at the actual jury there had been no formal step to analyze the results of the students who automatically passed. Two participants mentioned brief discussions about some students while discussing the other students. Three participants acknowledged that analyzing these results with the spreadsheet display is too tedious. The arguments were that the data were too numerous, too complicated and that it takes too much time. One participant thought that reading the 9 pages of spreadsheets was not a problem. Four participants reported having clearly conscience that they were doing a multicriteria decision at the actual jury. Three, out of the four persons who answered, reported being rather unsatisfied of the decision of the actual jury, whereas the 4th one was rather satisfied. Stated reasons for unsatisfaction were: “*we have been unfair against one of the student*”, “*some important arguments had not been explicitly said*”. The two participants who had to deal with the students afterwards were among the unsatisfied participants and reported having difficulties to endorse the decision.

Questionnaires After the Meeting. The two participants who had to endorse the decision reported that after the meeting they endorse it better, even if they were still unsatisfied with the decision. The four participants who answered the question reported that the first phase (analyzing the students that automatically pass) had been useful: “*it has put the light to the importance of the compensated credits*”, “*it has made me realize that we do that but informally*”. All participants validated the produced rules: “*I realize now that they are exactly the ones we used, even if I was not totally aware of it last time*”, “*they could be used at the next jury as a discussion basis*”, “*they will help guarantee consistency in the jury decision*”, “*with the rules it is more rational, the memory effect is interesting*”, “*I appreciate to have clear and stable rules*”. Four participants agreed that the tool had helped the group to express the rules. The person who said having no problem to analyze the printed spreadsheet pages thought that it was rather the opposite. All participants reported having understood all the queries and their effect. Four participants considered that they contributed to the queries (note that a rule is simply a given query which has been given a name). One of them emphasized that it has been a collective contribution. The participants agreed to use the tool for the forthcoming jury of the same level together with the usual material. It should be noted that the two persons who had to endorse the decision were the most positive about the results of the meeting. Moreover, the chair of the actual jury, who was one of those two persons, was the most positive of all.

5 Conclusion

In this article we have proposed the LogicalMulticriteriaSort thinkLet. To address the problems of a multicriteria decision LogicalMulticriteriaSort considers criteria one at the time as the take-the-best heuristics. There is no predefined order between criteria, participants put forward the ones they find the most relevant at a given time. The values can be numerical or symbolic; the analysis on them is logical. It avoids the need to give artificial values and weights to the criteria as opposed to the Multicriteria thinkLet. LogicalMulticriteriaSort guarantees more fairness and speed than the ChauffeurSort thinkLet. In addition, LogicalMulticriteriaSort is supported by a GDSS, based on Logical Information Systems. Thanks to the tool, the group can share a better understanding of the situation and it can be easier to collectively endorse a sensitive decision. In particular the tool keeps tracks of all of the decisions taken so far with a set of rules that explain how candidates have been sorted. It also gives an instantaneous feedback of each current decision. LogicalMulticriteriaSort has been tested on the debriefing of an academic year validation jury whose results had been controversial. The test case participants were positive about the process and they all agreed to use LogicalMulticriteriaSort and the supporting tool for the forthcoming jury at the same level. The two persons who had to endorse the decision were the most positive about the results of the meeting.

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References

Adla, A., Zaraté, P. and Soubie, J.-L. (2011). A Proposal of Toolkit for GDSS Facilitators. Group Decision and Negotiation, 20, 57–77. 10.1007/s10726-010-9204-8.

Bana e Costa, C. A., and Chagas, M. P. (2004). A career choice problem: An example of how to use MACBETH to build a quantitative value model based on qualitative value judgments. European Journal of Operational Research, 153(2), 323–331.

Briggs, R., and de Vreede, G.-J. (2009). ThinkLets: Building Blocks for Concerted Collaboration. Center for Collaboration Science, University of Nebraska at Omaha, USA.

Briggs, R. O., Kolfschoten, G. L., de Vreede, G.-J., Albrecht, C. C., and Lukosch, S. G. (2010). Facilitator in a Box: Computer Assisted Collaboration Engineering and Process Support Systems for Rapid Development of Collaborative Applications for High-Value Tasks. Pages 1–10 of: HICSS. IEEE Computer Society.

Davis, A., de Vreede, G.-J., and Briggs, R. (2007). Designing ThinkLets for Convergence. In: AMCIS 2007 Proceedings.

Ducassé, M., and Ferré, S.. (2008). Fair(er) and (almost) serene committee meetings with Logical and Formal Concept Analysis. In: Eklund, Peter, and Haemmerlé, Ollivier (eds), Proceedings of the International Conference on Conceptual Structures. Springer-Verlag. Lecture Notes in Artificial Intelligence 5113.

Ferré, S., and Ridoux, O. (2000). A Logical Generalization of Formal Concept Analysis. Pages 371–384 of: Mineau, G., and Ganter, B.(eds), International Conference on Conceptual Structures. Lecture Notes in Computer Science, no. 1867. Springer.

Ferré, S., and Ridoux, O. (2004). An Introduction to Logical Information Systems. Information Processing and Management, 40(3), 383–419.

Ganter, B., and Wille, R. (1999). Formal Concept Analysis: Mathematical Foundations. Heidelberg: Springer.

Hiltunen, V., Kurttila, M., Leskinen, P., Pasanen, K., and Pyklinen, J. (2009.) Mesta: An internet-based decision-support application for participatory strategic-level natural resources planning. Forest Policy and Economics, 11, 1–9.

Kilgour, D. M., and Eden, C. (2010). Handbook of Group Decision and Negotiation. Advances in Group Decision and Negotiation, vol. 4. Springer Netherlands.

Kolfschoten, G. L., de Vreede, G.-J., and Briggs, R. O. (2010). Collaboration Engineering. In: (Kilgour and Eden, 2010).

Lewis, L. F. (2010). Group Support Systems: Overview and Guided Tour. In: (Kilgour and Eden, 2010).

Marewski, J. N., Gaissmaier, W. and Gigerenzer, G. (2010). Good judgments do not require complex cognition. Cognitive Processing, 11(2), 103–121.

Shanteau, J. (1992). How much information does an expert use? Is it relevant? Acta Psychologica, 81(1), 75–86.

Tilley, T. (2004). Tool Support for FCA. In: Second International Conference on Formal Concept Analysis. Lecture Notes in Computer Science, vol. 2961. Springer.

Vogel, D., and Coombes, J. (2010.) The Effect Of Structure On Convergence Activities Using Group Support Systems. In: (Kilgour and Eden, 2010).

Zopounidis, C., and Pardalos, P. M. (2010). Handbook of Multicriteria Analysis. Applied Optimization, vol. 103. Springer Berlin Heidelberg.

A Framework for Evaluating Trust Development in Group Collaboration

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Abstract: Trust is referred to as a key facilitator in team collaborations. Evidence shows that different levels of trust will lead to different quality of team collaborations. Trust development in teams presents significant challenges in groups collaborations. In this paper we review factors that affect the establishment of trust in hybrid teams who collaborate virtually as well as face to face. Further we deliver an instrument to validate trust development in teams. Finally we describe preliminary evaluation of the instrument by running experiments with teams of collaborating students.

Keywords: Trust, Trust evaluation, Trust development, Teamwork, Virtual teams

1. Introduction

Increasingly knowledge workers have to work in teams that are global, inter-organizational, inter-cultural, and dispersed in several ways. Therefore, teams increasingly face the challenge of working (partially) virtual. Due to for instance a lack of presence and body language, such teams face problems with respect to trust. Many studies have focused on understanding trust in virtual teams.

Trust plays a pivotal role in reducing complexity, providing “internal security” and determining the internal balance between risk, utility and payback factors that affect decision making ability within our daily lives (Abdul-Rahman & Hailes, 2000). Trust, especially interpersonal trust, is an important concept in psychology and vital to personality development (Erikson, 1963), cooperation institution (Deutsch 1962), and social life (Rotter 1980, Wang & Emurian 2005).

Trust and knowledge sharing play a central role in friendship development. According to what Sharkie (2005) has introduced, “Trust is an important determinant of the predisposition or willingness of individuals to enter into conversations with others as a prerequisite for the sharing of knowledge for the benefit of the organisation”. Consequently, trust represents both an outcome and a process: a degree of trust is necessary for individuals to open up and to confide in each other. Trust is enhanced when another party’s motives are understood, providing these motives are positively oriented.

In this study we’re interested in trust development in teams, particularly in collaborating teams, and the factors that affect trust development over time on effectiveness of collaboration in teams.

2. Types of Trust

The literature identifies various types of trust.

The first of which is “Dispositional trust”. Dispositional or “basic” trust is specific to each individual. Some people are generally more trusting of the world than others. This type of trust is independent of any context (McKnight & Chervany, 1996), and acts as a central ingredient in the ‘‘healthy personality’’ and has a major impact on individual traits (Erikson, 1963), relating to a person’s general faith in human nature, that is, a cross-situational general tendency to trust other people (Rotter, 1980).

‘Interpersonal’ trust is developed from an inter-relationship between two or more persons. It is defined by Rotter (1967 p.651) as, ‘‘an expectancy held by individuals or groups that the word, promise, verbal, or written statement of another can be relied on''. Interpersonal trust is important for maintaining the health of interpersonal relations (Rotter, 1967).

The third category known as 'Situational trust' implies a 'situational decision to trust' in which a person has formed an intention to trust every time a particular situation arises. Trust leads to actions, mostly risk-taking behaviours. The form of the action depends on the situation, and may concern something either tangible or intangible. For instance, a person lends his or her money to a friend because the friend is trusted to pay back the money later (Wang & Emurian, 2005). Others key factors of situational trust identified are: benefit or gain (Lewicki & Bunker; Tan & Thoen, 2003), and the utility of information (Shapiro & Varian, 1998). A situational decision to trust may occur when there is "much to gain from trusting but little attendant risk" (Kee & Knox, 1970:361). An important rider to this is that this trust is context specific such that A might trust B to fix his car, but not to handle his finances (McKnight & Chervany, 1996).

A further category of trust, variously termed 'System' or 'Structural' trust, has particular relevance to this relatively new environment. System trust denotes "an impersonal institutional phenomenon, not founded on any property or state of the trustee, but rather on the perceived properties or reliance on the system or institution within which that trust exists" (Lewis & Weigert 1985, McKnight & Chervany 1996). System Trust might relate to the banking system, or a virtual community system and is therefore context dependent (Coetzee & Eloff 2005). The formal programs and features embedded within so called 'trust-mark' brands (Durkin et al. 2003), such as those used by EBay and Amazon, are often cited as exemplars of trust enabling mechanisms for virtual 'communities of consumption' (Kozinets 1999).

Trust has been variously described as being subjective and as a phenomenon which evolves with time through new experiences and observations (Dimitrakos, 2003), and as assuming different characteristics at varying phases of a relationship as well as in different types of relationship (McKnight & Chervany, 1996). Furthermore, trust is "intransitive", which is explained through the situation whereby Alice trusts Bob and Bob trusts Cathy, but it does not necessarily follow that Alice must trust Cathy, implying that the reputation of an agent (human or systemic) helps us to manage complexity.

3. Trust in Virtual teams

Trust involves vulnerability and is only needed in an environment that is uncertain and risky (Wang & Emurian, 2005). The online environment, with its relative lack of 'media richness', holds a number of inherent risks that can negatively affect the building of trusting relationships (Daft, Lengel, & Trevino, 1987).

Interestingly, the recent dramatic growth in popularity of Internet-based social networking in sites such as Facebook, MySpace and Bebo presents an interesting counterpoint to previous theories relating to people's capacity for online trust. The willingness of large numbers of people to share personal information with others online demonstrates either reduced public levels of apprehension with regard to system trust, or indeed the technical mastery of the tools and techniques for engendering trust. A significant feature of communications in social networking is its informality, and it has been shown to have a significant impact on the development of trust within teams and thus the team's performance (Castelfranchi & Falcone 1998). Castelfranchi, and Falcone also suggest a five-element strategy designed to address problems associated with trust in virtual societies and networked technologies comprising, human-computer (or systems) trust, interpersonal [trust] relationships and dispositional trust, together with risk and attitude, and potential gain. While technology alone provides connectivity between 'micro communities of knowledge' (von Krogh, Kazuo, & Nonaka, 2000), the balance for developing deep trust lies with social factors and the use of 'natural language' between participants (Nolan, Brizland, & Macaulay, 2007). Therefore both social and technical connectivity is required for enabling knowledge exchange and high-level team performance (Kolb, Collins, & Lind, 2008).

According to Friedman et al. (2000, p.36), "People trust people, not technology". Building trust in virtual teams is complicated because time and geographical distance precludes most synchronous communication (Powell et al., 2006). DeLuca and Valacich (2006) report that the same-time-same-place communications, such as face-to-face communications, are highly synchronous. Whereas the different-time-different-place communications, such as e-mail and e-bulletin-boards, are of low synchronicity. Beise et al. (2004) also claim that face-to-face meetings in virtual teams are needed to produce commitment, accountability, and to increase urgency. Drawing on case-based research, Lee-Kelley et al.

(2004) highlight that better performance in virtual teams is achieved through face-to-face meetings for team development.

Dafoulas and Macaulay (2002) have stated that a high level of trust is required in order for virtual teams to perform effectively and avoid any delays and conflicts, which is much higher than in traditional collocated teams. A research on trust development over time on computer-mediated teams by Wilson et al. (2006) has also shown that it takes longer for trust to develop in computer-mediated groups because it requires more time for members of those groups to exchange social information. Researchers have looked for an alternative theoretical lens to understand the interplay of teams and communication media, particularly when attempting to solve business problems with little or no face-to-face communication (Webber, 2002).

4. General Trust factors

According to the definition of trust of Hoy & Tschannen-Moran (1999) and Tschannen-Moran & Hoy (1998, p.334), trust is one party's willingness to be vulnerable to another party based on the confidence that the latter party is (a) benevolent, (b) reliable, (c) competent, (d) honest, and (e) open. A factor-analytic study is also used to reveal the coherent construct of trust (Hoy & Tschannen-Moran 1999).

According to the definitions from the researchers, additionally, as trust is very important between parties, besides the five factors, we also consider the "one party's willingness to be vulnerable to another party based on the confidence" into two factors which are *wiliness to risk vulnerability* and *confidence*. This two factors are also mentioned a lot in Tschannen-Moran and Hoy (2000)'s review of trust literatures. Thus, the general trust factors are considered into the following seven components:

4.1 Willingness to risk vulnerability

It is reported that a necessary condition of trust is interdependence, wherein the interests of one party can not be achieved without reliability upon another (Rousseau et al., 1998). It is stated by Tschannen-Moran and Hoy (2000) that if there is no interdependence, there is no need for trust. The degree of interdependence which brings with it vulnerability may also alter the form trust takes(Tschannen-Moran and Hoy, 2000). Risk is also considered as the perceived probability of loss, as interpreted by the decision maker (Coleman, 1990; Williamson, 1993). Trust is then considered as a willingness to be vulnerable under conditions of risk and interdependence (Rousseau et al., 1998).

4.2 Confidence

It is stated by Tschannen-Moran & Hoy (2000) that one of the early puzzles concerning trust was whether it was an individual's behavior or attitude in a situation of vulnerability. Although this may influence willingness to risk vulnerability, however, it is a significant factor. According to what Kee & Knox has reported four decades ago (1970), a certain amount of confidence is the degree to which the person can be said to trust.

4.3 Benevolence

It is considered that the confidence that one's well-being, or something one cares about, will be protected and not be harmed by the trusted party is considered by many researchers the most common factor of trust in the latter half of the last century (Baier, 1986; Butler & Cantrell, 1984; Bradach & Eccles, 1989; Cummings & Bromily, 1996;Deutsch, 1958; Frost et al. 1978; Gambetta, 1988; Hosmer, 1995; Hoy & Kupersmith, 1985; Hoy & Tschannen-Moran, 1999; Mishra, 1996; Zand, 1971).

4.4 Reliability

At the basic level, trust has to do with predictability, which means it requires consistency of behaviour and knowing what to expect from others (Butler & Cantrell, 1984; Hosmer, 1995). Reliability or dependability combines a sense of predictability with benevolence and there is a sense of confidence that the need will be met. (Tschannen-Moran & Hoy, 2000).

4.5 Competence

Some researchers have stated that when a person is dependent on another but some level of his skill is involved in fulfilling an expectation, and then an individual who means well may not be trusted (Baier, 1986; Butler & Cantrell, 1984;Mishra, 1996).

4.6 Honesty

Honesty, which is from person’s perspective is related with a person's character, integrity, and authenticity (Tschannen-Moran and Hoy , 2000). Rotter (1967, p.651) defined trust as "the expectancy that the word, promise, verbal or written statement of another individual or group can be relied upon".

4.7 Openness

Openness is considered as the extent to which relevant information is not withheld and it is a process by which people make themselves vulnerable to others by sharing their personal information (Butler & Cantrell, 1984; Mishra, 1996). It is also stated by researchers that people who are unwilling to extend trust through openness will end up living in isolated prisons of their own making (Kramer et al.,1996).

All these general factors of trust mentioned above are summarised by researchers from different disciplines during the past half century. These factors are general factors. However, whether they may apply to some certain areas may need to be reconsidered.

5. Measurement Instrument

We will evaluate each of these seven factors both from a self-perspective, and from a group perspective on a weekly basis. We will ask the group if in general, things changed with respect to the trust in the group, and the activities they performed that week. The results will be used to develop a framework of trust development.

In the study we will ask student groups to rate different aspects of trust on a weekly basis during a 7 week project. The student groups are normally composed of five members. They are going to finish their course project. Each week we ask students to rate trust and whether it changed compared to last week. Further, we ask about causes for the change in trust, and overall activities of the team for that week. As this is part of the course, the students are happy to finish all the tasks required.

We considered different criteria to develop the instrument. We asked for the name, age, nationality and group number of each participant and promised confidentiality. We measured trust from an individual trustworthiness and a trust in the group perspective, using the following questions based on the trust factors described above.

1 I didn’t let my group down this week
2 My group didn’t let me down this week
3 I am confident about my performance this week
4 I am confident about the group’s performance this week
5 I have good intentions for my group
6 The group has good intentions for me
7 I did what I promised to do this week
8 The group did what they promised to do this week
9 I am competent to perform my task in this group
10 The group is competent to perform our task
11 I was honest with my group this week
12 The group was honest with me this week
13 I was open to my group about my progress in this task
14 The group was open to me about the progress in this task

Further we asked an open question. By asking the question we were interested in understanding the students’ point of view in terms of why they believe trust has changed in their group.

Finally we asked participants to report the joint activities that they performed that week, and their frequency such as formal meetings, informal meetings, hallway chat, email, skype, IM, chat, phonecall, etc. and asked them to specify and elaborate on their answers.

6. Results Analysis and Discussion

We were only able to gather results from 3 weeks in 3 groups, and the results where quite incomplete, therefore not valid. None the less, we would like to report preliminary results to give an impression of the type of conclusions that could be drawn from this study. Overall we saw a decrease in one group, a slight increase and steady trust level in a second group and an increase in trust in the third group. In the first group, only a formal meeting and occasional email exchange and short chats in the hallway took place. In the second group, we saw a lot of informal contact and email exchange, as well as formal meetings. In the third group, a lot of instant messaging was used to communicate, as well as some meetings. While we cannot draw specific conclusions yet, the potential of the instrument to give insight in the relation between interaction level and mode and trust factors seems relevant.

Based on their answers to the open question, we believe that trust has been established in teams. According to their answers, the more they collaborate in their groups, the more intensive the communication gets the students deliver more positive answer regarding the increasing levels of trust in their teams. During the first week they delivered vague understandings regarding the establishment of trust in their team. They mainly referred to the fact that during the first week they had their initial contacts and therefore could not decide on changes of trust levels in their teams. Each student pointed out his or her own personal opinion about the assignment and not much collaborative understanding about the problem could be achieved. The students indicated trust levels to be low during the first week. As they increased the levels of contacts by the second and third week they presented more promising answers regarding the increasing levels of trust in their teams. They believed the longer time they collaborate the more they understand about the possible approaches they can work in their group and get adapted to it. Therefore they became more motivated to spend more time and effort on the assignments in collaboration with their teams. The students pointed out that by the third week, each student’s task and expectation was well understood by themselves and they each were well aware of what they have to deliver to the other students in teams. By the third week, they could consequently make agreement, reach consensus, become more efficient and eventually increase their level of trust in their teams.

7. Conclusions and Future Research

While the data are yet inconclusive the instrument seems highly promising and further case studies are planned to gather data for first analysis. The instrument allows us to compare the development of trust over time with the different interaction modes and frequencies of the group. This will help us to understand in more detail how different interaction modes affect trust, and how frequency of interaction has impact on trust development. Also, we can map the results with the delivery dates of the projects to get an impression of the impact of performance pressure on trust development.

The work presented in this paper is an ongoing research. In future, further investigation and analysis of trust development in larger number of groups will be considered. Other data collection method such as interviews will be considered. We will also apply the same method to the context of other countries and try to compare the different cases and do cross-case global analysis. Investigating trust development is a significant and a new branch of collaboration research. A longitudinal investigation method to different cases by undertaking experiments is preferred as trust in teams is expected to be dynamic over time. In this field, other future possible work, such as locating the background to global virtual teams, cross-culture teams, and business teams by embedding the latest collaboration and communication technologies and tools during the facilitation and collaboration process is also considered. Compared with other fields of the collaboration engineering research, from the point of view of trust, this research field will also benefit the better understanding of the links between the human behavior and the collaboration system development, business management and theoretical collaboration model building, as well as technology and system enhancement.

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References

Abdul-Rahman, A., and Hailes, S. (2000). Supporting trust in virtual communities, Proceedings of the Hawaii International Conference on System Sciences, 4-7 January, Maui, Hawaii .

Baier, A.C.(1986). Trust and antitrust, Ethics, Vol.96. No.2, pp.28-33

Beise, C.M., Niederman, F. and Mattoerd, H.(2004). IT project managers’ perceptions and use of virtual team technologies, Information Resources Management Journal, Vol. 17, No.4, pp.73-88.

Butler, J.K. and R. S. Cantrell.(1984). A Behavioral Decision Theory Approach to Modeling Dyadic Trust in Superior and Subordinates. Psychological Reports 55: 19-28.

Bradach, J.L. and Robert G.E.(1989). Price, authority, and trust: from ideal types to plural forms. Annual Review of Sociology, Vol.15, No.1, pp98-118.

Castelfranchi, C., & Falcone, R. (1998, 2-8 July). Principles of trust for multi-agent systems: cognitive anatomy, social importance and quantification. Paper presented at the International Conferences on Multi-Agent Systems, Paris.

Coetzee, M., & Eloff, J. H. P. (2005). Autonomous trust for web services. Journal of Internet Research, 15(5), 498-507.

Cummings, L. L., and Bromily, P.(1996). The organizational trust inventory(OTI): development and validation. In R. Kramer & T. Tyler(Eds.), Trust in organizations. Thousand Oaks, CA: Sage, pp.302-330.

Daft, R. L., Lengel, R. H., & Trevino, L. K. (1987). Message equivocality, media selection and manager performance. Management Information Systems Quarterly, 11, 335-368

Dafoulas, G. and Macaulay, L.A.,(2002). Investigating cultural differences in virtual software teams, Electronic Journal on Information Systems in Developing Countries, EJISDC January 2002, Vol.7, No.4, pp.1-14, ISSN 1681 4835.

DeLuca, D. and Valacich, J. S. (2006). Virtual teams in and out of synchronicity, Information Technology and People, Vol.19, No.4, pp.323-334

Deutsch, M. (1958). Trust and suspicion, Journal of Conflict Resolution, Vol2, No.4, pp.265-279.

Dimitrakos, T. (2003). A service-oriented trust management framework In R. Falcone, Barber,S., Korba, L. and Singh, M. (Ed.), Trust Reputation, and Security: Theories and Practice. Berlin: Springer-Verlag, PP. 53-72.

Durkin, P., Durkin, M., & Gillen, J. (2003). Exploring efforts to engender on-line trust. International Journal of Entrepreneurial Behaviour & Research, 9(3), 93-110.

Erikson, E.H. (1963). Childhood and society (2nd ed.). New York: W.W. Norton.

Friedman, B., Kahn, P., Howe, D. (2000), Trust online, Communications of the ACM, Vol, 43 pp.34-40.

Frost, T., Stimpson, D. V., and Maughan, M. R. (1978). Some correlates of trust. Journal of Psychology, vol.99, No.1, pp.103-108.

Gambetta, D (ed)(1988).Trust: making and breaking cooperative relations, Oxford: Basil Blackwell.

Hosmer, L. T. (1995). Trust: the connecting link between organizational theory and philosophical ethics, Academy of Management Review, Vol.20, No.2, pp.379-403.

Hoy, W. K., Kupersmith, W.J.(1985), The meaning and measure of faulty trust, Educational and Psychological Research, Vol.5, No.1, pp.1-10.

Kee, H. W., & Knox, R. E. (1970). Conceptual and methodological considerations in the study of trust and suspicion. Journal of Conflict Resolution, 14(3), 357-366.

Kolb, D. G., Collins, P. D., & Lind, E. A. (2008). Requisite connectivity: Finding flow in a not-so-flat world. Organizational Dynamics(37), 181-189.

Kozinets, R. V. (1999). E-tribalized marketing?: the strategic implications of virtual communities of consumption. European Management Journal, 17(3), 252-264.

Kramer, R. M. (1996). Divergent realityes and convergent disappointments in the hierarchic relation: trust and the intuitive auditor at work. In R. Kramer & T. Tyler (Eds.), Trust in Organizations. Thousand Oaks, CA: Sage. Pp.216-245.

Lee-Kelley, L., Crossman, A. and Cannings, A. (2004), A social interaction approach to managing the ‘invisibles’ of virtual teams, Industrial Management and Data Systems, Vol. 104, No.8, pp.650-657.

Lewicki, R. J., & Bunker, B. B. (Eds.). Developing and Maintaining Trust in Work Relationships. Thousand Oaks, CA.: Sage.

Lewis, J. D., & Weigert, A. J. (1985). Trust as a social reality. Social Forces, 63(4), 967-985.

McKnight, D. H., & Chervany, N. L. (1996). The Meanings of Trust: University of Minnesota.

Mishra, A. K. (1996). Organization responses to crisis: The centrality of trust. In R. Kramer & T. Tyler (Eds.), Trust in Organizations. Thousand Oaks, CA: Sage. Pp.261-287.

Nolan, T., Brizland, R., & Macaulay, L. (2007). Individual Trust and Development of Online Business Communities. Information Technology and People, 20(1), 53-71.

Powell, A., Galvin, J. Galvin, J. and Piccoli, G. (2006). Antecedents to team member commitment from near and far: a comparison between collocated and Virtual teams, Information Technology and People, Vol.19, No.4, pp.299-322.

Rotter, J. B. (1967). A new scale for the measurement of interpersonal trust. Journal of Personality and Social Psychology(35), 651-665.

Rotter, J. B. (1980). Interpersonal trust, trustworthiness, and gullibility. American Psychologist, 35(1), 1-7
Rousseau, D.M., Sitkin, S.M., Burr, R.S., and Camerer, C.(1998). Not so different after all: A cross-discipline view of trust. Academy of Management Review, Vol.23, No.3, pp.393-404.
Shapiro, C., & Varian, H. R. (1998). Information Rules - a strategic guide to the network economy. Harvard Business School Press.
Sharkie, R. (2005). Precariousness under the new psychological contract: the effect on trust and the willingness to converse and share knowledge. Knowledge Management Research & Practice(3), 37-44.
Tan, Y. H., & Thoen, W. (2003). Electronic Contract Drafting Based on Risk and Trust Assessment. International Journal of Electronic Commerce, 7(4), 55-71.
Tschannen-Moran, M., and Hoy, W.K.(2000). A multitidiciplinary analysis of the nature, meaning, and measurement of trust, Journal of Educational Research, Vol.70, No.4, pp.547-593.
von Krogh, G., Kazuo, I., & Nonaka, I. (2000). Enabling Knowledge Creation. New York: Oxford University Press.
Wang, Y. D., & Emurian, H. H. (2005). An overview of online trust: Concepts, elements and implications. Computers in Human Behavior, 105-125.
Webber, R. (2002). Editor's comments, MIS Quarterly, Vol.26 No.1, pp.iii-viii.
Hoy, W. K., & Tshannen-Moran, M. (1999). Five faces of trust: an empirical confirmation in urban elementary schools. Journal of School Learship, Vol.9, No.3, pp.184-208.
Wilson et al., 2006. All in due time: The development of trust in computer-mediated and face-to-face teams. Organizational Behavior and Human Decision Processes. v99. 16-33.
Zand, D.E.(1971). Trsut and managerial problem solving. Administrative Science Quarterly, Vol.17, No.2, pp.229-239.

Negotiation Support Systems

NegoManage - a comprehensive negotiation platform

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Abstract: NegoManage is a comprehensive negotiation platform for supporting bilateral negotiation. It supports all the negotiation phases. In the pre-negotiation phase the preferences elicitation is conducted, which employs the concepts of indifference surfaces and linguistic utility scale. In the communication phase NegoManage allows for exchanging offers and messages, that are rank to built the negotiators' profiles. NegoManage offers also an initial profile construction based on the case base reasoning.

Keywords: negotiation support systems, negotiation analysis, preference analysis, reputation systems, negotiation outcome optimization.

1 Introduction

There are many software solutions that may be used for negotiation support. The most known are the negotiation support systems (NSSs) like: Inspire (Kersten and Noronha, 1999), Negoisst (Schoop et al., 2003) or SmartSettle (Thiessen and Soberg, 2003). They offer the multitude of tools for supporting negotiators' activities within the whole negotiation process, such as the pre-negotiation preparation: preference elicitation, construction of the scoring systems for negotiation offers; actual conduct of negotiation: exchanging the offers and messages, visualization of the negotiation process and its history; and post-negotiation optimization: compromise improvement analysis, construction of the final contract, etc. To support negotiators they applied the formal models, methods and techniques, that require a negotiation process to be previously adequately structured and formalized, and assume that negotiators are able to follow the specific negotiation protocol and handle the supportive tools the systems offer them (i.e. presume the users know the methodology applied, the consequences of its usage and are able to correctly interpret the results they give). For supporting the pre-negotiation phase NSSs usually apply the formal models derived from multiple attribute utility theory (MAUT), mainly the simple additive weighting method (SAW), originally proposed by Keeney and Raiffa (1976). However, some research show that despite its simplicity, SAW is quite often misinterpreted or misused by the negotiators (see Wachowicz and Kersten, 2009; and the results of GRIN project Paradis et al., 2010). NSSs use sometimes the psychometric instruments to determine the negotiators' profiles, the identification of which may be useful in performing the mediation role of NSS. An example of such a tool is Thomas-Kilmann Conflict mode instrument (TKI) (Kilmann and Thomas, 1983) or Myers-Briggs Type Indicator (MBTI) (Myers and McCaulley, 1985). These tools require the users to make series of choices within the questions asked in a predefined questionnaires, that are used later on to calculate the user's final psychological profile. TKI and MBTI are widely used in research and practice. However, there are some drawbacks of using such tools. Some respondents find the forced choice questionnaire to be frustrating, on the other hand reliability of such testing is quite low, since it appears that less than 50 percent of the subjects score the same when asked to answer the questionnaire once again after some weeks (Gardner and Martinko, 1996). Finally, the NSSs provide users with the tools for the post-negotiation analysis, that allows to verify the efficiency of the negotiated agreement and suggest the alternatives that mutually improve the parties' outcomes. Since the negotiation problem is usually well structured and limited to the form of discrete decision problem, such an analysis boils down to the identification of all Pareto-efficient alternatives that dominate the negotiated compromise (see the Inspire's post-negotiation phase protocol). It is possible, however, to conducted a further analysis that would allow to satisfy the pro-active role of NSS and identify the single improvement according to some concepts of the game theoretical barging solutions.

To overcome some limitations of the NSSs based on the formal decision models, usually applied to negotiation support, and extend the scope of negotiation support given by NSSs, a new negotiation support system, called NegoManage (NM), was proposed by the authors. In this paper we give an overall description of NegoManage. First we discuss the general architecture and configuration of the system and then we present its major supportive elements, which are: the preference elicitation module, the communication engine and the profiling subsystem. We discuss the theoretical frameworks of NegoManage modules describing the formal models used, such as linguistic utility scale, the model of indifference surfaces and the notion of negotiation context speech act taxonomy used by the profiling algorithm.

2. NegoManage – the system configuration

From the technical point of view the NSS may be designed and implemented in many different ways. The NSS's architecture and configuration may depend on the type of negotiation, the role NSS is going to play in negotiations and the scope of their support (Stroebel 2003; Kersten and Lai, 2007). While designing the NegoManage system we have chosen a configuration solution in the form of a distributed system with a central unit (NM-CU) deployed on Web and the negotiators' individual units (NM-IUs) installed on the users' desktop computers (see Brzostowski and Wachowicz, 2009). In this configuration the central unit plays a role of a communication centre that allows the negotiating parties to exchange the offers and messages. It also collects the data on the negotiation processes and the negotiators themselves, analyzes and presents it to the negotiators, providing them with the additional information that may be helpful within the actual conduct of negotiation (e.g. visualizes the negotiation progress, depicts the concessions graphs, etc.). The central unit is connected to the domain system, which is an additional simulation, optimization or documentary system, that consists of the independent engines providing the NM-CU and the system's users with the additional facilities (e.g. data analysis engine, that may be used by the system administrators). One of such engines is a tool for post-negotiation optimization, that analyzes the negotiation compromise and suggests the possible improvements by applying some concepts of the cooperative game theory. The negotiation resolution obtained by an iterative exchange of offers can be corrected in order to achieve Pareto efficiency. For this task the post-negotiation optimization unit employs the Gupta-Livne (Gupta and Livne, 1988) bargaining solution. The idea of improvement is based on a shift from the current negotiation resolution towards the Pareto efficiency frontier. NM-CU is also connected to the separate dedicated reputation system (NM-RS), used for the negotiators' profiles analysis. NM-CU presents to the users the negotiation profile information about all registered negotiators, which reduces the negotiation anonymity and allows negotiators to better preparation in the pre-negotiation phase (i.e. to adjust the negotiation strategy to the peculiar characteristics of the potential counterpart). NM-CU is not dependent on any of the negotiators but it can be administrated by a third party in the role of mediator or arbitrator or it can be used for symmetric support of the negotiators in order to look for mutually satisfying compromises.

The NM-IUs are the decision analysis engines used by the negotiators mainly in the pre-negotiation phase to elicit their individual preferences. They allow the negotiators to build scoring systems that are used later on in the actual negotiation phase. While other major NSSs (i.e. Inspire, Negoisst and SmartSettle (Thiessen and Soberg, 2003) employ for the pre-negotiation phase the different variations of Multi-Attribute Utility Theory, NegoManage differs from them by applying a novel technique for preference elicitation. Inspire uses additive scoring system which is corrected by means of the conjoint analysis. Negoisst assumes the linear-additive structure of preferences. SmartSettle uses the similar with additional possibility of modifying the single-attribute utility functions. Compared to these approaches NegoManage completely avoids the issue and option weights assignments by the specification of indifference surfaces instead.

The NM-RS operates within all the negotiation phases and provides NM-CU with the functionalities of identifying the negotiation profile in three possible ways. In the pre-negotiation phase it allows for determining the initial profiles of the new system's users by applying the predefined psychometric tests (TKI questionnaire) or deriving them from the demographic description of the new system user (the case based reasoning algorithm is used to build the rules for proper clustering the negotiators' profiles). During the actual negotiation phase NM-RS analyzes each message that is ranked by the negotiators by specifying the level of importance or the degree of request satisfaction for each message. These ranks are needed for the negotiators' profiles computation performed by the reputation subsystem.

The NegoManage general configuration scheme is shown in Figure 1.

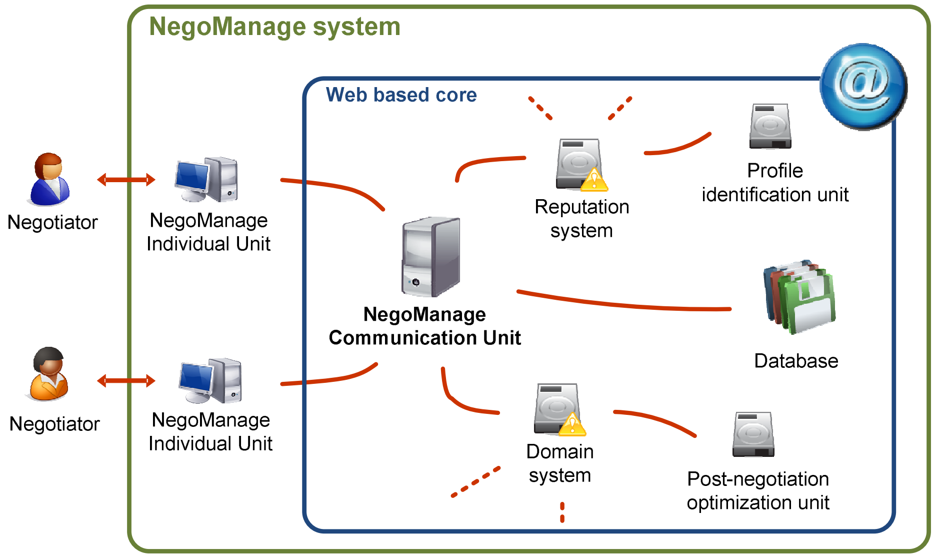

Fig. 1. NegoManage major components.

Such a configuration of NM allows to keep all the sensitive and strategic data (e.g. preferences) solely at the personal computers of the negotiation participants assuring it will not be transferred or revealed to their counterparts. Simultaneously, there are the NM-IUs that conduct all the complicated and time consuming calculations, thus the NM-CU is released from the computational work and ensures the fluent communication support and data visualization.

From the implementation point of view NM-IUs were programmed in Java, while the NM-CU, as well as the additional engines and subsystems that are deployed on Web, were coded in PHP and are connected to the MySQL database.

2 NegoManage Individual Unit's decision support

2.1 Preference analysis

The process of preferences' analysis supported by NM-IUs applies two concepts specific to our preferences model, i.e. the notion of indifference surfaces and the concept of linguistic utility scale (Brzostowski and Wachowicz, 2011). To make this approach applicable the negotiation problem needs to be adequately structured first. Therefore the initial part of preference analysis in NM is the problem definition, which consists of the following steps:

- **Step 1. Calibration of the linguistic utility scale**

  NM operates with double integrated, hierarchical utility scale (Brzostowski and Wachowicz 2011), which needs to be calibrated by the negotiators before applying it to the offers evaluation. This calibration involves the assignment of the numeric utility values to their verbal equivalents. The aim of using linguistic utilities is to increase intuitiveness of preference analysis. The literature indicates (Moshkovich et al., 2005) that the decision-maker is able to cope with the linguistic scale if it does not exceed seven levels. Unfortunately, the seven-level scale lacks precision. Therefore, we propose a compromise between intuitiveness and precision by introducing the hierarchical scale consisting of two seven-level scale. On the first scale the decision-maker can choose a degree of linguistic utility which will be assigned to a particular set of indifferent alternatives. On the second scale the decision-maker chooses the intermediary level located between the two neighboring levels of first scale utility. Such an approach aims at increasing the precision of utility assignment without giving up the seven-level scales.

- **Step 2. Definition of the negotiation space**

The negotiators define the negotiation issues and specify the corresponding ranges of resolution levels for all the issues defined. In the problem definition we assume that the issues have the quantitative character. In the further work the system will be extended to cope with issues of qualitative nature. The negotiators define also the number of indifference surfaces (sets) that they will use to define their preferences. The indifference set is a set of alternatives that are indifferent to the negotiator (consequently all the alternatives in such a set have the same final utility).

Having both the structure of negotiation problem and the utility scale and space defined negotiators start to define their preferences:

- **Step 3. Evaluation of the indifference surfaces**

The negotiators use the double integrated, calibrated verbal utility scale to evaluate the successive indifference surfaces. They identify the surface and use the slider-based surface evaluator to describe the quality of the surface. An example of surface utility definition is given in Figure 2.

Fig. 2. The illustration of double, integrated, hierarchical utility scale for the assessment of an indifference surface.

- **Step 4. Identification of the surfaces' representatives**

The negotiators build the alternatives in a form of complete packages and assign them to the indifferences surfaces. The alternatives need to be defined in form of the complete packages specifying the resolution levels for all issues under consideration. In Figure 3 we presents the main form of the NegoManage preferences' analysis module. On the left part of the form the linguistic and numeric utilities of consecutive indifference surfaces are displayed. In the middle, the chosen surface is displayed with all the alternatives that constitute this surface. To display the alternatives on a plane the system performs multi-dimensional scaling, since the alternatives are multi-dimensional objects, and when mapped onto a plane the distances between alternatives must be retained. The system copes with alternatives in three, four and five dimensions. The smaller form at the right displays the alternative under consideration. The user can set the values of issues by manipulating with sliders that correspond to consecutive issues. The alternative under is visualized using its projections onto two-dimensional subspaces of the alternatives space. Each parallelogram separated by two axes corresponds to a quarter of a plane, and each axis corresponds to one issue.

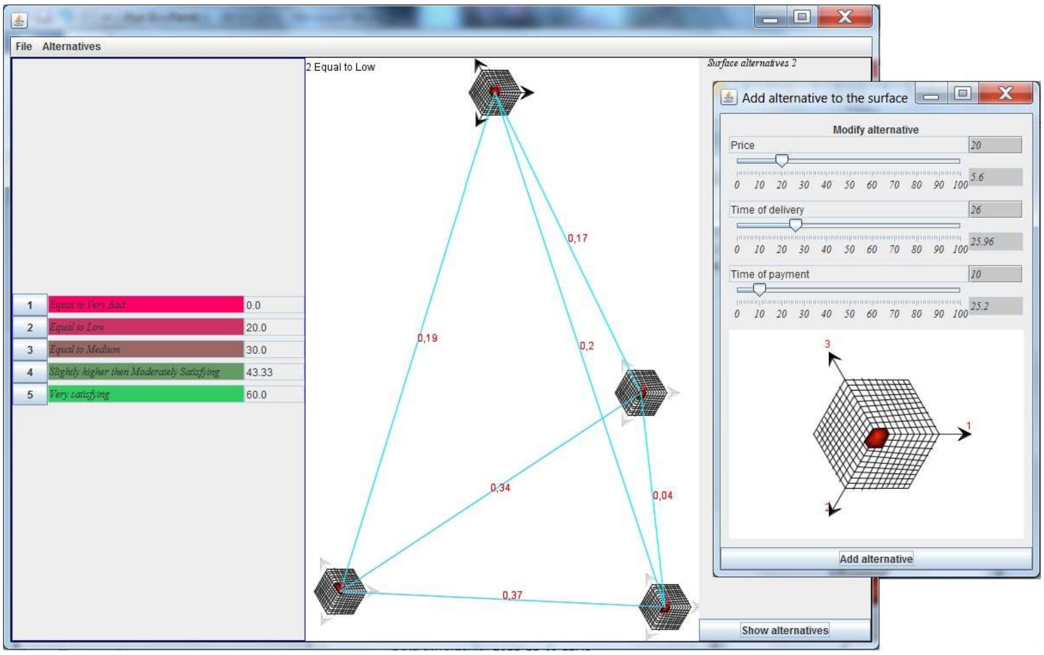

Fig. 3. The illustration of preference analysis by means of offer examples assignment

2.2. Construction of the offers' scoring system

Based on the series of indifference surfaces and series of utility values assigned to these surfaces the NM-IU computes a scoring system that can be used in further phases of the negotiation process: in actual conduct of negotiation – for offers comparison and evaluation of the concessions; in post-negotiation phase – for searching the possible improvements of the negotiated agreement. For deriving the scoring system the preference analysis module computes a probability distribution of each indifference surface. The statistical characteristic of indifference surface is computed by means of the hierarchical clustering (Hartigan, 1975) and kernel density estimation (Parzen, 1962), which was originally proposed by Brzostowski (2011).

Let us consider a reference set specified by the NM user in the following form:

$$RS_i = \{\bar{a}_1, \bar{a}_2, \ldots, \bar{a}_n\} \qquad \textbf{(1)}$$

where every two alternatives belonging to the set are in the relationship of indifference ($\bar{a}_i \approx \bar{a}_j$). These alternatives are described by m criteria, that we denote: $g_1, g_2, \ldots, g_m$. Therefore each alternatives may be represented in the following form:

$$\bar{a} = (g_1(\bar{a}), g_2(\bar{a}), \ldots, g_m(\bar{a})). \qquad \textbf{(2)}$$

We assume that every criterion g_i maps the alternative into numerical scale measuring the degree of satisfaction of this criterion.

Every criterion index allows for mapping the alternative into the corresponding set of criterion values. The indifference set is clustered using *k*-means algorithm:

- **Step 1**.
  Given a split at the current stage of the set RS_i into k disjoint subsets $M_{i1}, M_{i2}, \ldots, M_{ik}$, the means for all subsets (clusters) are computed: $m_{i1}, m_{i2}, \ldots, m_{ik}$.
- **Step 2**.
  Using the means at the current stage the alternatives are reassigned to clusters. Each alternative is assigned to the cluster with the closest mean.

- **Step 3**.
  The two above steps are repeated until the alternatives assignment no longer changes. Such a clustering state is consistent with the convergence condition.
- **Step 4**.
  Having clustered the indifference set, the probability distribution over the such a set can be built. For each M_{ij} (the *j*th cluster of the *i*th indifference set) the multivariate normal distribution is built. Therefore, the we use the probability distribution function of the following form:

$$f_{M_{ij}}(\overline{a}) = \frac{1}{(2\pi)^{k/2}\,|\Sigma|^{1/2}} \exp(\frac{1}{2}(\overline{a}-\overline{m}_{ij})'\Sigma(\overline{a}-\overline{m}_{ij})), \qquad \textbf{(3)}$$

  where Σ is the covariance matrix.
  Let the set M_{ij} be of the form: $M_{ij} = \{\overline{a}_1, \overline{a}_2, \ldots, \overline{a}_n\}$. Thus, for the estimation of the covariance matrix we use the following estimator:

$$\Sigma = \frac{1}{n-1}\sum_{l=1}^{n}(\overline{a}_l - \overline{m}_{ij})(\overline{a}_l - \overline{m}_{ij})'. \qquad \textbf{(4)}$$

- **Step 4**.
  After the distributions for all k clusters have been built they are fused to form the final characteristics of the considered indifference set given by the formula:

$$f_{RS_l}(\overline{a}) = \frac{1}{k}\sum_{j=1}^{k} f_{M_{ij}}(\overline{a}). \qquad \textbf{(5)}$$

The series of probability distributions assigned to the surfaces together with the utility values form a basis for the negotiation offers' scoring system. When the negotiator starts the actual negotiation phase they can evaluate any alternative that occurs within the negotiation process. If the negotiator is interested in the final scoring of a new alternative they can switch to the preferences' analysis module to perform the scoring check. The alternative is inputted to the scoring system and its scoring - in the form of von Neumann-Morgenstern expected utility (von Neumann and Morgenstern, 1944) – is determined. We use this concept since for each indifference surface we can obtain a probability value describing the alternative degree of belonging to a particular surface. Therefore, the system computes the degree of belonging to all indifference surfaces and fuses it with utility values assigned to all surfaces. The sum of products of utility values with probability levels results in a final scoring of an alternative.

3 NegoManageCommunication Unit

The NM-CU is a central part of NegoManage system that coordinates the negotiators activities, allows for an exchange of offers and messages, visualizes the negotiation progress and is an interface for the profiling unit (which is a part of the reputation system). Each message that may be sent via NM-CU contains an offer (the package definition) and a message explaining why this offer is proposed at the current stage of negotiation process (the argumentation). While specifying an offer the negotiator inputs also its private scoring extracted from their NM-IU. They input the offer to the message form, prepare the explaining message and also formalize its elements. If a message is treated as a request they specify the level of importance of this request. If the message is a response to the previous request of their counterpart they evaluate their subjective importance of the counterpart's request. These degrees are further used in negotiator's profile construction (see Section 4).

The NM-CU's form in which the negotiators specify their offers is shown in Figure 4.

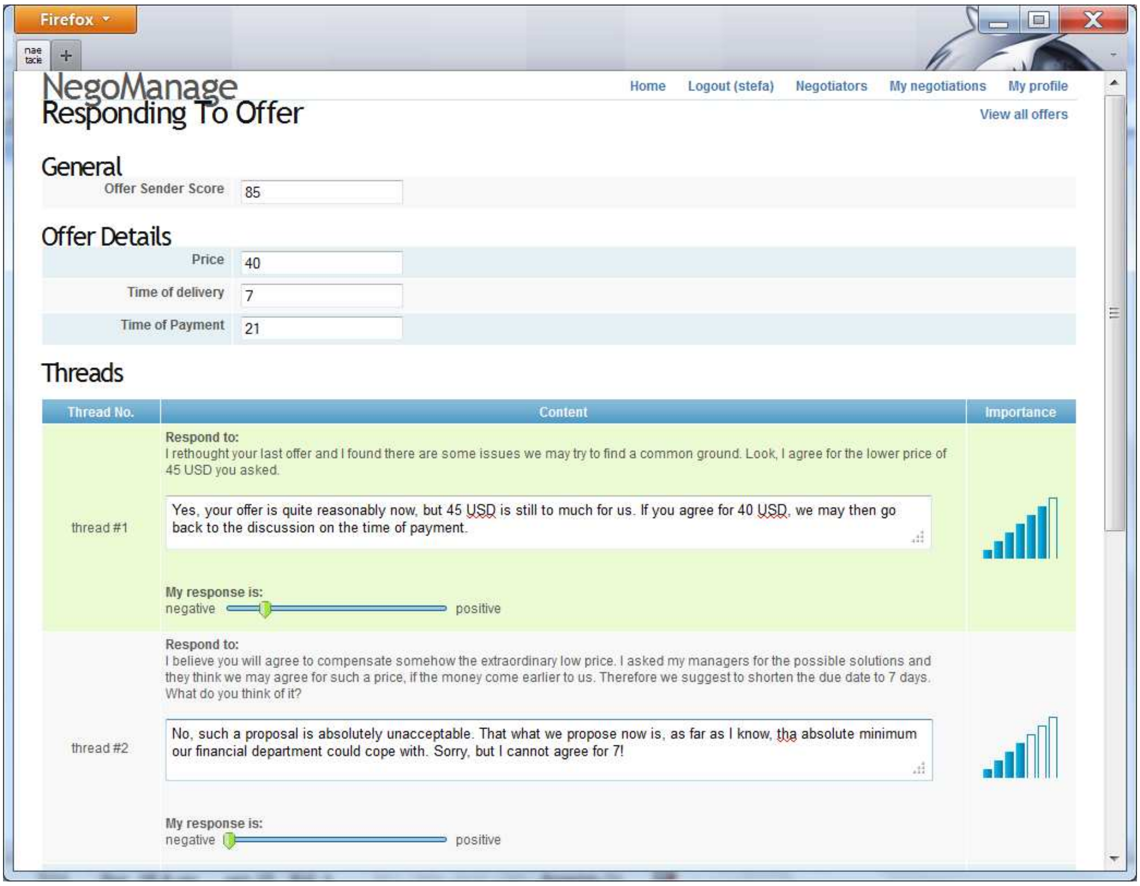

Fig. 4. Offers' construction in NM-CU.

The series of offers and counteroffers are also visualized on the graph using the private scoring assigned to the offers that occurred in the negotiation process. It allows to track the negotiation progress and the scales of the concessions in successive negotiation rounds (see Figure 5).

Within NM-CU the negotiators may also identify their own negotiation profiles by means of TKI questionnaire. But using the data collected and processed by the reputation system, NM-CU presents also the actual negotiation profile of the supported negotiator, built on the basis of negotiation context speech act taxonomy (NCSAT) (Brzostowski and Wachowicz, 2010). It may be confronted with TKI results to analyze negotiator's own bargaining style. NM-CU displays also a list of registered negotiators with the basic information of their profiles determined on the basis on NCSAT, which may help the focal negotiator to prepare an adequate negotiation strategy and the argumentation line that fit their counterpart's potential behavior the most.

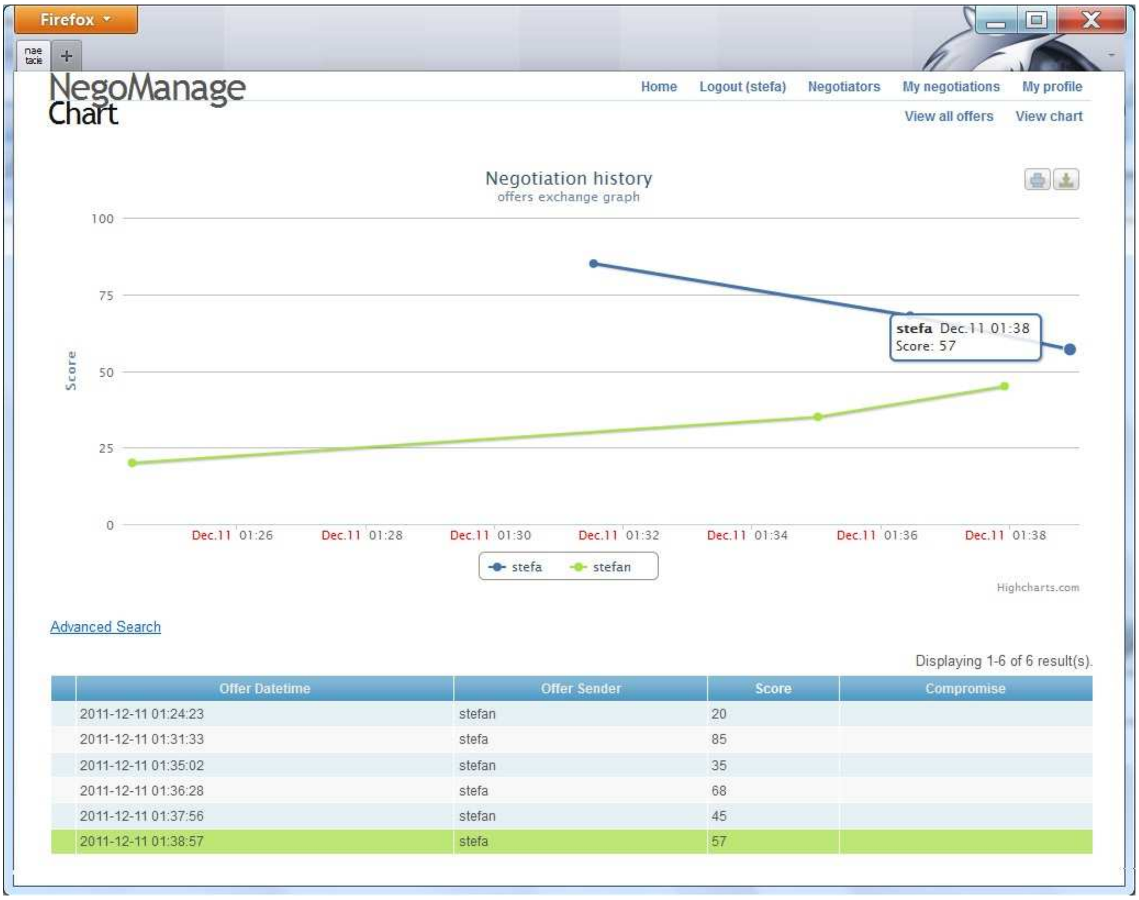

Fig. 5. NM-CU's negotiation history graph and the offers history.

4 NegoManage's reputation system

One of the key problems in electronic negotiations is the lack of knowledge on the counterpart, since the partner is neither seen nor heard. When the actual negotiation phase starts the partner is totally anonymous which can result in a feeling of discomfort for the negotiator. In order to overcome the problem of total anonymity NM introduces a concept of negotiators' profiling. The negotiators' profiles can be created in various ways. Our profile creation mechanism involves the negotiator evaluation in terms of their negotiation style. One of the approaches of deriving the description of negotiation style is Thomas-Kilmann questionnaire (Kilmann and Thomas, 1983). This tool aims at evaluating the negotiator by asking series of questions regarding the reaction types in different conflict situations. Based on the questionnaire the negotiator's style is determined in terms of five possible behaviors, including: Competing, Collaborating, Avoiding, Accommodating and Compromising. These behaviors correspond to two major features of negotiator, namely: cooperativeness and assertiveness.

In NM, a different mechanism is used for measuring the degrees of cooperativeness and assertiveness. The profiling is performed by the analysis of messages exchanged by the negotiators. The negotiator classifies their message based on the negotiation context speech act taxonomy (Brzostowski and Wachowicz, 2010). There are other speech act taxonomies, e.g. the one proposed by Searle (Searle, 1969) and Stiles (Stiles, 1992) that give some insight into speech act theory. However, these taxonomies do not take into consideration the issues important from the viewpoint of negotiation context such as the distinction between forward and backward communication functions. Similarly, as in DAMSL annotation scheme (Core and Allen, 1997) our taxonomy splits the speech act types into forward and backward communicative function. This division is crucial in the negotiation context since the negotiation discourse is a process of exchanging messages where different messages constitute different types of request, and different types of responses to requests.

Thus in NCSAT, if the atomic speech act contained in a message is a for of request, the negotiator's cooperativeness is increased if the response to this message is positive, e.g. the responding message satisfies the request. If the response to a request is negative the cooperativeness degree decreases. In the case of assertiveness feature, the situation is analogous with the difference that the message's sender is assessed. If the sender receives a positive response to their request they assertiveness increases, if negative – the assertiveness decreases. This principle is based on our former postulate that communication leading to positive results means that the sender is assertive (Brzostowski and Wachowicz, 2010). The speech act taxonomy used in NM is presented in Table 1.

Table 1. The negotiation context speech act taxonomy.

Direction of a speech act	**Intention of a speech act**	**The issue of discourse**	**Description**
Forward communicative function	Inform interlocutor	Perform action	**IPA** Informing the partner about performing an action or intending to perform an action
		Give information	**IGI** Informing the partner about facts or beliefs without intention to discuss it.
	Request from interlocutor	Perform action	**RPA** Requesting the partner to perform an action
		Give information	**RGI** Requesting the parnter to give information (Asking question)
		Accept belief	**RAB** Requesting the partner to accept the stated belief
Direction of a speech act	**Intention of a speech act**	**The type of response**	**Description**
Forward communicative function	Respond to IPA	Positive	Thanking the partner for performed action
		negative	Disapproving the action performed by the partner.
		Not understood	Signaling not understanding the speech act
		Ignored	No responding signal
	Respond to IGI	positive	Thanking the partner for given information
		negative	Disapproving the information revelation
		Not understood	Signaling not understanding the speech act
		ignored	No responding signal given
	Respond to RPA	Positive	Informing about performing the requested action
		negative	Refusing to perform the requested action
		Not understood	Signaling not understanding the speech act
		ignored	No responding signal given
	Respond to RGI	positive	Revealing the requested information
		negative	Refusing to reveal the requested information
		Not understood	Signaling not understanding the speech act
		ignored	No responding signal given
	Respond to RAB	positive	Accept the statement presented in the speech act
		negative	Deny the statement and/or give counterargument
		Not understood	Signaling not understanding the speech act
		ignored	No responding signal given

Let us denote by $\bar{a}_{i,j}^{\alpha\to\beta} = \bar{a}^{\alpha\to\beta}(i,j)$ an atomic speech act uttered by the negotiator α to the negotiator β. The number i denotes the number of message in the whole communication thread, while j denotes the number of speech act contained in the message. In NM, each atomic speech act is encoded in the following way

$$\overline{a}_{i,j}^{\alpha\to\beta} = (n_{i,j}, t_{i,j}, d_{i,j}, \overline{r}_{i,j})\,. \qquad \textbf{(6)}$$

where,

- $n_{i,j}$ denotes the intention of the speech act ($n_{i,j} \in \{1,...,7\}$, see Table 1),
- $t_{i,j}$ denotes either the issue of discourse or the type of speech act depending on the intention of speech act ($t_{i,j} \in \{1,...,4\}$, according to the Table 2 there are either 2 possible issues of discourse for the first type of intention and 3 possible issues of discourse for the second type of intention or 4 possible types of response in the case of five remaining types of intentions),
- $d_{i,j}$ is the degree of importance specified by the sender of speech or the degree of response satisfaction specified by the receiver (the value of d can be specified in finite points scale, for instance $d_{i,j} \in \{1,...,7\}$).
- $\overline{r}_{i,j}$ identifies the forward communicative function speech act to which the current $\overline{a}_{i,j}^{\alpha\to\beta}$ speech act is responding. For all forward communicative function speech acts the value of $\overline{r}_{i,j}$ is simple coded as (0,0).

For each pair of speech acts in the form of request ($\overline{a}_{i,j}^{\alpha\to\beta}$) and response to this request ($\overline{a}_{k,l}^{\beta\to\alpha}$) the cooperativeness/assertiveness coefficient of the negotiators is computed as follows. For the positive response a product of request importance degree ($d_{i,j}$) and request satisfaction degree given in the response ($d_{k,l}$) are multiplied and added to the overall scoring. As a result of this operation the cooperativeness degree of the negotiator α increases. In the case of negative response the product of request importance degree and request satisfaction degree are subtracted from the overall scoring of cooperativeness degree.

Formally, the cooperativeness/assertiveness coefficient is determined as follows:

$$\deg_{assertiveness}^{\alpha} = \deg_{cooperativeness}^{\beta} = m(t_{k,l}) \times d_{i,j} \times d_{k,l}\,, \qquad \textbf{(7)}$$

where m is a multiplier, the value of which depends on the type of response the speech act recipient (negotiator β) is giving to its emitter (negotiator α), and $m \in \langle -1;1 \rangle$.

For the assertiveness feature the operation is analogous with the difference that in the case of cooperativeness it is computed for the responding negotiator, and in the case of assertiveness it is computed for the requesting negotiator.

5 Summary

In this work we presented an overview of NegoManage negotiation support system. NegoManage is designed to support bilateral negotiations of different type and context. It was designed in the form of a distributed system and may act as a negotiation platform, on which both the negotiation problems may be defined by the parties and the counterparts may be selected (e.g. basing on the public profiles determined by the reputation system – a supportive subsystem to NM).

To show the major differences between NM and other NSSs working currently on the Web we described the preference analysis system both in terms of methodology used in for deriving the scoring system, and in terms of its usage by human actors. The whole notion of analyzing preferences and building the scoring system that is applied in NM significantly differs form the typical solutions applied in the well known and frequently used in training and practice NSSs such as Inspire, Negoisst or SmartSettle, that usually base on SAW. The solution we proposed does not require the negotiator to assign abstract scores to the issues and options or to weight the issues. Instead, the negotiator define their preferences operating with verbal intuitive evaluation and define the classes of offers of different quality, assigning simultaneously the examples of the offers to this classes. Then the computational algorithm is applied by NM-IUs to build the scoring system adequately to the negotiators preferences, that can be used later on to score any negotiation offer proposed in the actual negotiation phase. Then the NegoManage

Communication Unit was described to show the way the system supports the communication between the negotiators and visualizes the negotiation process.

We also gave a description of a reputation system, an important part of NM used by the system for constructing the negotiators profiles in terms of two features: assertiveness and cooperativeness. This system results in the negotiators' description similar to TKI, but does not require of them to fill in the troublesome and time consuming questionnaire. It bases on the negotiation context speech act taxonomy and the consequent assumptions, which allow to track the messages exchange made by the parties. The negotiators are asked to subjectively evaluate the importance of each message, and depending on the types of answers given by the negotiators, the reputation system calculates the assertiveness/cooperativeness coefficients that are incorporated then in the overall profile description.

Currently the system is being tested by human actors, the students of mathematics and decision science that use NegoMange for negotiation training. These tests will allow to answer the questions on use and usefulness of NM and indicate the potential problems with understanding the supportive methodology we proposed.

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References

Brzostowski, J. (2011). Preference Analysis Approach based on formation of indifference sets for different values of extended linguistic scale, The 21st International Conference on Multiple Criteria Decision Making 2011, June 13-17, Jyvaskyla, Finalnd

Brzostowski, J., Wachowicz, T. (2009), Conceptual Model of eNS For Supporting Preference Elicitation and Counterpart Analysis. In: D.M. Kilgour, Q. Wang (eds.), *Proceedings of GDN 2009: An International Conference on Group Decision and Negotiation*, Wilfried Laurier University: 182-186

Brzostowski, J., Wachowicz, T., (2010), Building Personality Profile Of Negotiator For Electronic Negotiations, In: Tadeusz Trzaskalik and Tomasz Wachowicz (ed.), *Multiple Criteria Decision Making '09*. The Publisher of The University of Economics in Katowice: 31-46

Brzostowski, J., Wachowicz, T. (2011), Preference consistency analysis in the negotiation offers' evaluation system based on the concept of indifference set and extended linguistic scales. In: Tadeusz Trzaskalik and Tomasz Wachowicz (ed.), *Multiple Criteria Decision Making '12*. The Publisher of The University of Economics in Katowice (in press).

Brzostowski, J., Wachowicz, T. (2011), Użycie skal lingwistycznych do opisu użyteczności w procesie analizy preferencji, In: Tadeusz Trzaskalik and Tomasz Wachowicz (ed.), *Modelowanie preferencji a ryzyko '11*. The Publisher of The University of Economics in Katowice

Core, M., Allen J. (1997), Coding dialogs with the DAMSL annotation scheme. In *AAAI Fall Symposium on Communicative Action in Humans and MachinesCambridge*, MA, November 1997: 28–35.

Gardner, W.L., Martinko, M.J. (1996), Using the Myers-Briggs Type Indicator to Study Managers: A Literature Review and Research Agenda. *Journal of Management*, 22(1), 45-83.

Gupta, S., Livne Z. (1988) A. *Resolving a Conflict Situation with a Reference Outcome: An Axiomatic Model*, „Management Science", 34(11), 1303—1314.

Hartigan, J. (1975), *Clustering Algorithms*, Wiley.

Keeney, R., Raiffa, H. (1976), *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*, New York: Cambridge University Press.

Kersten, G.E., Lai, H. (2007). Negotiation Support and E-negotiation Systems: An Overview. *Group Decision and Negotiation*, 16, 553-586.

Kersten, G.E., Noronha, S.J. (1999), WWW-Based Negotiation Support: Design, Implementation And Use. *Decision Support Systems*, 25,135–154.

Kilmann, R., Thomas, K.W. (1983), The Thomas-Kilmann Conflict Mode Instrument. *The Organizational Development Institute*, Cleveland, OH: 57–64.

Moshkovich, H., Mechitov, A., Olson, D. (2005), *Verbal Decision Analysis*. Springer, New York.

Myers, L.B., McCaulley, M.H. (1985), *Manual: A guide to the development and use of the Myers-Briggs Type Indicaror*. Palo Alto, CA: Consulting Psychologists Press.

Neumann, J. von, Morgenstern, O. (1944), *Theory of Games and Economic Behavior*, Princeton Univerosty Press.

Paradis, N., Gettinger, J., Lai, H., Surboeck, M., Wachowicz, T. (2010), E-Negotiations via Inspire 2.0: The System, Users, Management and Projects. In: de Vreede, G.J. (ed.). *Group Decision and Negotiations 2010. Proceedings*. The Center for Collaboration Science, University of Nebraska at Omaha, 155-159.

Parzen, E. (1962), On estimation of a probability density function and mode, *Ann. Math. Stat.* **33**, 1065-1076.

Schoop, M., Jertila, A., List, T. (2003), Negoisst: a negotiation support system for electronic business-to business negotiations in e-commerce. *Data and Knowledge Engineering*, 47, 371–401.

Searle, J.R. (1969), *Speech Acts: An Essay in the Philosophy of Language*. Cambridge University Press.

Stiles, W.B. (1992), *Describing talk: a taxonomy of verbal response modes*. SAGE Publications.

Stroebel, M. (2003), Engineering Electronic Negotiations. Kluwer, New York.

Thiessen, E.M., Soberg, A. (2003), Smartsettle described with the montreal taxonomy. *Group Decision and Negotiation*, 12, 165-170.

Wachowicz, T., Kersten, G.E. (2009), Decisions And Manners Of Electronic Negotiation System Users. In: Kłosiński, K.A., Biela, A. (eds.). *Proceedings of An International Scientific Conference "A Man And His Decisions"*, The Publisher of The John Paul II Catholic University Of Lublin, 63-74.

Developing Notions of Fairness in Negotiation Support Systems

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Abstract: One of the major concerns raised by people using negotiation processes is about the fairness or justice of the process. Individuals undertake negotiation to derive better outcomes than would otherwise occur. This requires them to engage in interest based negotiation. But interest based negotiation focuses upon the interests of the disputants rather than any objective measures of fairness. By the notion of fairness we mean 'legally just' rather than the more commonly accepted negotiation concept of meeting the interests of all parties equally. One example of the need for focusing upon justices arises in the domain of family law, where parents might focus upon their own desires, rather than the needs of the children. Similarly, in employment law, individual bargaining between employers and employees might lead to basic needs (such as recreation leave and sick leave) being whittled away. It is hence vital to investigate how can we develop measures, or at the very least principles, for the construction of *legally just* negotiation support systems? Through an examination of bargaining in the shadow of the law and principled negotiation, we suggest principles which when applied, will encourage fairness and justice in the development of negotiation support systems. Such principles include providing enhanced transparency, supporting bargaining in the shadow of the law and allowing for limited discovery. However, the use of each of this principles also has some negatives, We indicate how some of these principles can be applied in Australian Family Law.

Keywords: On Fairness in Negotiation, Interest Based Negotiation, Bargaining in the Shadow of the Law, Transparency.

1 Introduction

The mantra '*two legs bad, four legs good*', taken from Orwell's Animal Farm (Orwell 1945) is similar to the statement '*negotiation good, conflict bad*'. This latter mantra, often accepted by courts and governments, is that negotiation is preferable to litigation in almost all circumstances. Of course, in Orwell's book, the pigs eventually take over the farm and just like the previous human managers, they too discriminate against the animals. Indeed, in the last paragraph of the book, the pigs begin to take on human physical features.

Knowing when to negotiate and when to refuse to negotiate is vital when trying to ensure negotiations are fair. Mnookin (2003) addresses this issue. For example, on September 30 1938, Neville Chamberlain, the prime minister of the United Kingdom, returned from negotiations in Munich saying '*we have peace for our time*'. Within twelve months, Kristallnacht had occurred[1], the Molotov-Ribbentrop pact was signed[2] and World War Two[3] had commenced.

Even now supporters (or apologists) of Chamberlain rationalise that he was correct, and that his actions in Munich won the United Kingdom vital time to prosecute the war[4]. How can we assess when to

[1] On a single night, November 9-10 1938, more than 2,000 synagogues were destroyed and tens of thousands of Jewish businesses were ransacked. It marked the beginning of the systematic eradication of the Jewish people – the Holocaust.

[2] The pact, signed on August 23 1939, was a non-aggression pact between Germany and the Union of Soviet Socialist Republics that included a secret protocol for dividing the then independent countries of Estonia, Finland, Latvia, Lithuania, Poland and Romania into Nazi and Soviet spheres of influence.

[3] On September 1 1939, when Germany invaded Poland.

[4] As did the former Australian Prime Minister Sir Robert Gordon Menzies in the twenty-second Sir Richard Stawell Oration '*Churchill and his contemporaries'* delivered at the University of Melbourne on 8 October 1955 – see (Is there something missing here?)

negotiate and when it is undesirable to so, especially when knowledge is not transparent? Rather than solely focusing upon resolving conflicts, should we possibly concentrate on just managing the conflict? Condliffe (2008) [5] argues that some conflicts cannot be resolved at all.

Blum (2007) argues that protracted armed rivalries are often better managed rather than solved, because the act of seeking full settlement can invite endless frustration and danger, whilst missing opportunities for more limited but stabilising agreements. She examines in detail enduring rivalries between India and Pakistan, Greece and Turkey and Israel and Lebanon. She notes that in each of these conflicts, neither party is willing to resolve the core contested issues but both may be willing to carve out specific areas of the relationship to be regulated – what she calls *islands of agreement*.

One can adapt Blum's concept to family mediation. In this domain, conflict between parents is viewed as very damaging to children. So it might be beneficial for the children to ensure that minimal conflict or disruption occurs. Eventually, the dispute might be more easily resolved or due to the progress of time, the dispute may no longer exist – this occurs when dependant children become adults.

In the case of condominium disputes, the disputants often need to live in close proximity to each other and hence develop constructive relationships, even whilst engaging in conflict. If condominium disputes are appropriately managed, there may be reduced tensions and no need for a final resolution.

Our interest in justice and negotiation arose because of our research into charge and plea bargaining (Mackenzie et al 2008). In both Australian and United States criminal law jurisdictions, a defendant can appeal a decision if they believe the judicial process was flawed. However, when negotiating about pleas – known as plea bargaining, a participant cannot challenge the decision. The reason for this situation is that unlike in a trial, the defendant has pleaded guilty and thus admitted that he committed the crime. This situation becomes problematic in the admittedly few cases where a person accepts a plea bargain even though they did not commit the crime. The defendant may plead guilty because he was offered a heavily reduced sentence (e.g. no jail time) and he felt the probability that he would be found guilty[6] was reasonably high.

Thus, it is very difficult to undo an '*unfair plea negotiation*'. By fairness, we mean what is legally just, rather than what disputants may want. It is essential that it be possible to reverse unfair decisions.

It is vital that we develop '*fair*' and '*just*' negotiation support systems. One of the barriers to the uptake of Online Dispute Resolution relates to users' concerns about the fairness and consistency of outcomes achieved by any Online Dispute Resolution approach. Pierani (2005), in discussing Online Dispute Resolution in Italy, argues that as with Alternate Dispute Resolution models, Online Dispute Resolution systems need to be impartial, transparent, effective and fair. Ponte (2001) focuses upon cultural barriers to the uptake of Online Dispute Resolution, which includes concerns that users have about the fairness of such systems.

2 Defining Fair and Just Negotiation

The development of '*fair*' and '*just*' negotiation support systems and Online Dispute Resolution environments should lead to an increasing confidence in the use of e-commerce. But there are no accepted norms on how to measure what is '*fair*' and '*just*' negotiation support?

Alexander (1997) has argued that in Australian Family Law, women tend to be more reluctant than men to continue conflict and are more likely to wave their legal rights in a mediation session. McEwen et al (1995) believe family mediators focus upon procedural fairness rather than outcome fairness. Phegan (1995) argues that differences in power between men and women lead to negotiated results that favour men. Field (2004) argues that as victims of domestic violence increasingly find themselves in the mediation context, specific strategies are needed to protect their interests and ensure their safety. In Field (2005) she argues that the Australian Government's New Family Law system, by encouraging mediation without the intervention of lawyers, will potentially endanger many women post-separation and jeopardize the justice of post-separation arrangements for women and children.

www.menziesvirtualmuseum.org.au/transcripts/Speech_is_of_Time/202_ChurchillContemp.html, last accessed 10 May 2011

[5] Chapter One

[6] Often because of poor legal support

As a further example of bargaining imbalances, Alexander argues that because women tend to be more reluctant than men to continue conflict, if their major goal is to be the primary care giver for their children, they may reach a negotiated settlement, which whilst acceptable to them is patently unjust. The wife may for example, give the husband the bulk of the property, in return for her being granted the primary care of the children. Whilst such an arrangement may meet the goals of both parents, it might not meet the paramount interests of the children, who could be deprived of subsequent financial resources[7]. Bargaining imbalances can thus produce *unfair results* unless mediators overcome them. But should mediators try to redress imbalances? How can we determine what are fair results?

Take for example a marriage in Australia where the couple have been married for fifteen years and have three children, one of whom has special needs. Suppose the husband works full-time, whilst the wife is not employed outside the house and is a full-time carer for the husband and children. Suppose they own a house valued at $400,000 with a mortgage of $250,000. Further, the husband earns $45,000 per annum.

Given that this is both a low income and low asset marriage (the common pool is let us say $180,000 - $150,000 from the house and a $20,000 car and limited furniture) the wife might be expected to receive 70% of the common pool. Were she to retain the house and car, she would need to pay the husband $54,000 (otherwise he would receive nothing from the pool. The husband would need to pay Child Support which is mandated by the relevant law[8].

In many circumstances, the fact that the husband has a low income and is paying substantial child support, may mean that he cannot afford to pay rent for himself. He might thus be forced to return to living with his parents. Australian men's groups have vigorously protested at what they perceive as injustices[9].

Are such results fair or just? The answer depends on how we measure fairness. If we measure fairness by meeting the interests or needs of both parents equally, then the answer is clearly no. In Australia, our notion of justice focuses upon meeting the paramount interests of the children. This principle of the paramount interests of the children outweighs other principles of justice[10], including the interests of parents and other concerned parties. Hence the solution suggested above, is eminently fair according to Australian Law.

Australian Family Law is one domain where interest-based notions of mediation can conflict with notions of justice[11]. In such domains, the use of negotiation support systems that attempt to equally satisfy both parties, is limited.

One lesson learned from the evaluation of family law disputes is that suggested compromises might conflict with law and justice. This problem can arise where a fully automated Online Dispute Resolution environment is used in which resolution is based on consensus. Nevertheless, we believe that an Online Dispute Resolution environment may still play a positive role in the family-law setting.

One safeguard for use of Online Dispute Resolution in fields such as family law may be to require a legal professional to certify that the resulting advice is accurate. By doing this, the professional takes the responsibility for the decision, rather than leaving the matter to computer software. A comparable field,

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7 Whilst many, including men's groups, might disagree with Alexander, her views have substantial support.

8 See CHILD SUPPORT (ASSESSMENT) ACT 1989 and the CHILD SUPPORT LEGISLATION AMENDMENT (REFORM OF THE CHILD SUPPORT SCHEME – NEW FORMULA AND OTHER MEASURES) BILL 2006

9 See for example Mens Rights Agency (www.mensrights.com.au) and Fathers4Equality (www.fathers4equality-australia.org) last accessed May 10 2011

10 For example in the United States, biological parents have an implied right to care for their children, when compared to others. In Australia, only the interests of the child are taken into account. So in Australia, an absent father would not have any special rights to custody over an eight year old child, who had been cared for by the mother and her parents (the child's grandparents) for seven years, prior to the mother's death in a car accident.

11 As (Brams and Taylor 1996) do in their work on *Fair Division, from cake cutting to dispute resolution* and (Thiessen snd MacMahon 2000) in their work on developing the SmartSettle system. Both research groups use game theoretic techniques to provide advice about what they claim are *fair* solutions. Their concept of fair negotiation does not coincide with the concept of legally just negotiations that we are considering. Both systems require users to rank and value each issue in dispute. Given these numbers, game theoretic optimisation algorithms are then used to optimise, to an identical extent, each person's desires. These algorithms are fair in the sense that each disputant's desire is equally met. They do not however meet concerns about justice.

where certification is required, is discrimination law where conciliation is used to ensure the principles of the legislation are not compromised by the interests of the parties[12].

3 Bargaining in the Shadow of the Law and Principled Negotiation

Traditional Negotiation Support Systems have focused upon providing users with decision support on how they might best achieve their goals (Raiffa, 1982). Historically, negotiation support systems were not designed to model legal disputes. They focus upon business transactions, where the parties can walk away from failed negotiations without engaging in further communications.

In legal domains, the failure to resolve a dispute, often leads to litigation. A fundamental issue arises when constructing negotiation support systems in legal domains: namely **is the system being developed solely concerned with supporting mediation or do we also need to consider issues of justice?** How can we balance the importance of issues of justice with the need to support mediation? When issues of justice are not reflected in the outcome of the mediation process, bargaining theory has its limitations. Bargaining imbalances can thus produce *unfair results* unless mediators overcome them.

3.1 Bargaining in the Shadow of the Law

Priest and Klein (1984) claim that the potential transaction costs of litigation provide an incentive for nearly all legal suits to settle. Galanter (2004) claims:

In the federal courts, the percentage of civil cases reaching trial has fallen from 11% in 1962 to 1.8% in 2002. In spite of a five-fold increase in case terminations, the absolute number of civil trials was 20% lower in 2002 than it was 40 years earlier.

Two of the reasons for this phenomenon are because average trials are getting longer and more complex and litigants are using alternative forms of Dispute Resolution.

Most negotiations in law are often conducted in the Shadow of the Law i.e. bargaining in legal domains mimics the probable outcome of litigation. Mnookin and Kornhauser (1979) introduced the bargaining in the shadow of the law concept. By examining the case of divorce law[13], they contended that the legal rights of each party could be understood as bargaining chips that can affect settlement outcomes.

Cooter et al (1982) discuss Bargaining in the Shadow of the Law for civil cases. This model now dominates the literature on civil trials. It is also very significant for criminal trials (Bibas 2004).

3.2 Principled Negotiation

Walton and Mckersie (1965) propose that negotiation processes can be classified as distributive or integrative. In distributive approaches, the problems are seen as “zero sum” and resources are imagined as fixed: *divide the pie*. In integrative approaches, problems are seen as having more potential solutions than are immediately obvious and the goal is to *expand the pie* before dividing it. Parties attempt to accommodate as many interests of each of the parties as possible, leading to the so-called *win-win* or *all gain* approach. As (Kersten 2001) notes although Walton and McKersie did not suggest one type of negotiation being superior to the other, over the years, it has become conventional wisdom that the integrative type allows for better compromises, win-win solutions, value creation and expanding the pie.

Traditional negotiation decision support has focused upon providing users with decision support on how they might best obtain their goals. Such advice is often based on Nash’s principles of optimal negotiation or bargaining (Nash 1953). Game theory, as opposed to behavioural and descriptive studies, provides formal and normative approaches to model bargaining. One of the distinctive key features of game theory is the consideration of zero-sum and non-zero-sum games. These concepts were adopted to distinguish between distributive and integrative processes.

Limitations of game theory in providing prescriptive advice sought by disputants and their advisers on one hand, and the developments in multicriteria decision-making and interactive methods on the other, provided the groundwork for negotiation analysis as discussed in (Raiffa 1982). Game theory

[12] Thanks to Peter Condliffe for making this comment
[13] Mnookin and Kornhauser’s research concerned US Family Law circa 1979, which is very different from Australian Family Law which stresses that parents have obligations to children. In the United States, parents have a variety of legal rights.

has been used as the basis for the Adjusted Winner algorithm (Brams and Taylor 1996) and the negotiation support systems: Smartsettle (Thiessen and McMahon 2000) and Family Winner (Bellucci and Zeleznikow 2006).

Most negotiation outside the legal domain law focuses upon interest-based negotiation. Expanding on the notion of integrative or interest-based negotiation, Fisher and Ury (1981) at the Harvard Project on Negotiation [14] developed the notion of principled negotiation.

Principled negotiation promotes deciding issues on their merits rather than through a haggling process focused on what each side says it will and will not do. Amongst the features of principled negotiation are: separating the people from the problem; focusing upon interests rather than positions; insisting upon objective criteria and knowing your *BATNA* (*B*est *A*lternative *T*o a *N*egotiated *A*greement).

The reason you negotiate with someone is to produce better results than would otherwise occur. If you are unaware of what results you could obtain if the negotiations are unsuccessful, you run the risk of:

1) Entering into an agreement that you would be better off rejecting; or
2) Rejecting an agreement you would be better off entering into.

For example, when a person wishes to buy a used car, they will usually refer to a commonly accepted set of approximate automotive prices. Using this initial figure and considering other variables such as new components, the distance travelled by the car and its current condition, the buyer then decides the value they wish to place on a car. If the seller is not willing to sell the car at this price, then you can argue the merits of your valuation, in an attempt to persuade the seller to accept your BATNA. BATNAs can be used to form a basis from which fair agreements can be obtained.

As deVries et al (2005) claim, if negotiators do take account of their options outside a negotiation, they are better protected against agreements that should be rejected. It also helps them to reach agreements that better satisfy their interests. In order to assess whether an offer should be rejected, a party in a dispute has to establish what can be accomplished in alternative procedures to the one currently being conducted. This may include exiting the procedure altogether, or handing over the case to a court. Once the alternatives are known, these can be compared to what one expects to win by accepting an offer in the current procedure. If the proposal is worse than the (best) alternative outside the procedure, it should be rejected; if it is better it should be considered for acceptance. In this respect each party's BATNA serves as a point of reference or a value with which to compare offers Raiffa et al (2002)[15].

Knowing one’s BATNA is important because it influences negotiation power. Parties who are aware of their alternatives will be more confident about trying to negotiate a solution that better serves their interests. For example, when trying to sell one's car to a second hand car dealer, knowing what other car salesmen (or even individuals) offer or have offered for your (or a similar) car, helps in obtaining a reasonable price for your vehicle.

The BATNA concept is a useful metaphor in all dispute resolution procedures where parties have the option to exit the process, such as negotiation and mediation. A BATNA in this sense is a way to put pressure on the other party. If terminating the process has advantages over accepting the other party's offer, it should be an incentive to continue the negotiation, else if the other party is unwilling to reconsider the offer, walking out is a very sensible option.

BATNAs not only serve a purpose in evaluating offers in the dispute, they can also play a role in determining whether or not to accept a certain dispute resolution method. Mnookin (2003) claimed that having an accurate BATNA is part of the armory one should use to evaluate whether or not to agree to enter a negotiation. This holds for many dispute resolution methods, including arbitration and mediation, but also for tools and techniques within these methods, such as (blind) bidding, persuasion dialogues, and final offer arbitration. Comparing the possible (range of) outcomes with alternative options encourages parties to accept methods that are in the interests of disputants and enables them to identify those that are not. It is likely that most parties, to some extent, test the values of their BATNAs when assessing whether or not to opt for a certain dispute resolution method.

[14] See www.pon.harvard.edu. Last accessed 10 May 2011

[15] At p112

4 Principles for developing Fair Negotiation Support Systems

Having examined interest based and principled negotiation and bargaining in the shadow of the law as well as family mediation and bargaining about charges and pleas, we now wish to develop a framework for developing just negotiation support systems.

4.1 Fairness Principle 1 – Developing Transparency

For a negotiation to be fair, it is essential to be able to understand and if necessary replicate the process in which decisions are made. In this way unfair negotiated decisions can be examined, and if necessary, be altered. The same statement holds in family mediation.
van Boven et al (2003) state that:

> *Thompson (1991) has shown that when negotiators have different priorities, negotiators who provide information about their priorities to their partners fare better than those who do not. The* ***illusion of transparency*** *may lead negotiators to hold back information about their priorities in the mistaken belief that one has conveyed too much information already. By leading negotiators to believe that their own preferences are more important than they really are, the illusion of transparency may give rise to the belief that the other side is being less cooperative than they are themselves – which may lead each negotiator to hold back even more. The process can thus spiral in the wrong direction toward greater secrecy.*

The November 2001 declaration of the Fourth Ministerial Conference of the World Trade Organisation , held in Doha, Qatar, developed guidelines for the organization and management of their free trade negotiations. One of their principles (number 49[16]) says:

> *The negotiations shall be conducted in a transparent manner among participants, in order to facilitate the effective participation of all. They shall be conducted with a view to ensuring benefits to all participants and to achieving an overall balance in the outcome of the negotiations.*

Bjurulf and Elgstrom (2004) discuss the importance of transparency in negotiations regarding the European Union directives on public access to European documents. They argue that the development of norms helps facilitate fair negotiations.

Alternate opinions are held by Finel and Lord (1999). They claim that transparency often exacerbates crises in international disputes. They claim that:

a) *The media – a major factor in transmitting information made available by transparency – may have an incentive to pay more attention to belligerent statements than more subtle, conciliatory signals*.

b) *Transparency may actually undermine behind-the-scenes efforts at negotiated settlements - … in the prelude to the war of 1812*[17]*, leaders on both sides felt constrained to limit concessions that might be perceived as giving in to the extremists on the other side.*

c) *A lack of transparency may actually help states to avoid conflict, as in the case of the Chinese-Russian border disputes of 1969. Had the two states, which engaged in belligerent rhetoric, also been transparent, the crisis might have spiraled out of control. In contrast, the onset of World War One was made possible by the fact that neither Russia nor Germany was able to perceive correctly the relatively limited goals of the other side*.

d) *Transparency may make it difficult for observers to determine which groups will contain a given policy decision. In the Suez War of 1956, Nasser may have drawn false conclusions about Israel's willingness to go to war due to the division of opinion in the Israeli government*.

Finel and Lord (1999) suggest the possibility of a curvilinear relationship between transparency and the ability to resolve crises peacefully. They postulate that both a very high transparency – because it accurately signals intentions, and very low transparency - because it prevents the noise of domestic policies from overwhelming diplomatic signals, allows states to defuse crises.
Our focus is upon setting just principles for developing negotiation frameworks. With this goal in mind, we advocate a high transparency model.

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[16] See www.wto.org/english/thewto_e/minist_e/min01_e/mindecl_e.htm#organization last accessed May 10 2011

[17] Between the United Kingdom and the United States

We can in fact also consider two distinct forms of transparency: transparency about the process and transparency of the data in a particular negotiation.

4.2 Fairness Principle 2 – Enabling Discovery

Even when the negotiation process is transparent, it can still be flawed if there is a failure to disclose vital information. Such knowledge might greatly alter the outcome of a negotiation.

Take for example the case of a husband who declares his assets to his ex-wife and offers her eighty per cent of what he claims is the common pool. But suppose that he has hidden from his ex-wife, ninety per cent of his assets[18]. Thus, in reality, he has only offered her eight per cent of the common pool[19].

Discovery, the coming to light of what was previously hidden (Black 2004), is a common pre-trial occurrence. As Cooter and Rubinfield (1994) and Shavell (2003) point out, in litigation, the courts may require that a litigant disclose certain information to the other side; that is, one litigant may enjoy the legal right of *discovery* of information held by the other side. Interestingly enough, Shavell claims that the right of discovery significantly increases the likelihood of settlement, because it reduces differences in parties' information. This benefit is often lost in a negotiation.

The failure to conduct adequate discovery can be a major flaw in negotiation. But how can we conduct sufficient discovery without losing many of the benefits that derive from negotiation?[20]

Cooter and Rubinfield (1994) claim:

> *Trials occur when the parties are relatively optimistic about their outcome, so that each side prefers a trial rather than settlement on terms acceptable to the other side. When the parties are both optimistic (relative to the expected outcome with complete information), at least one of them is uninformed. Revealing information to correct the other side's false optimism creates an advantage in settlement bargaining for the disclosing party. This fact provides a strong incentive to voluntarily disclose facts correcting the other side's false optimism before trial. Consequently, discovery increases settlements and decreases trials by organizing the voluntary exchange of information.*

This benefit is often lost in a negotiation, especially if important information is not disclosed, or even worse, hidden. Relationships Australia claims to be child focused, but in providing evaluative mediation advice, does little discovery on determining what is in the best interests of the child. In many family disputes, information about marital property or child abuse might not be disclosed. Given the failure to disclose, how can we ensure negotiations are fair?

Requiring specified aspects of disclosure in a negotiation might help enhance the fairness of the negotiation process.

4.3 Fairness Principle 3 – Bargaining in the Shadow of the Law and the Use of BATNAs

As discussed in section 3.2, most negotiations in law are conducted in the shadow of the law i.e. bargaining in legal domains mimics the probable outcome of litigation. These probable outcomes of litigation provide beacons or norms for the commencement of any negotiations (in effect BATNAs). Bargaining in the Shadow of the Law thus provides us with standards for adhering to *legally just* and *fair* norms. By providing disputants with advice about BATNAs and Bargaining in the Shadow of the Law and incorporating such advice in negotiation support systems, we can help support fairness in such systems.

For example, in the AssetDivider system, interest based negotiation is constrained by incorporating the paramount interests of the child[21]. By using Bargaining in the Shadow of the Law, we can use evaluative mediation (as in Family Mediator) to ensure that the mediation is fair

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[18] In trusts and other property.

[19] 0.8 x 0.1 = .08 or 8% of the pool.

[20] Whilst conducting sufficient discovery can have a positive impact on negotiation - the party who conducts sufficient discovery and uncovers information is better informed to negotiate. In relation to the above example, if the ex-wife conducts discovery, she might be able to find some additional assets (not necessarily the 90% hidden assets but part of these) and thus be better informed. She would then not readily accept what the husband has supposedly stated as being his assets. However the process of discovery is expensive and can greatly extend the time required to reach an agreement – lead to a negotiation that more closely simulates the litigation process.

The Split_Up system models how Australian Family Court judges make decisions about the distribution of Australian marital property following divorce. By providing BATNAs it provides suitable advice for commencing fair negotiations.

The BEST-project (*B*ATNA *E*stablishment using *S*emantic web *T*echnology), based at the Free University of Amsterdam aims to explore the intelligent disclosure of Dutch case law using semantic web technology[22]. They use ontology-based search and navigation. The goal is to support negotiation by developing each party's BATNA.

We have outlined the benefits of promoting transparency and bargaining in the shadow of the law to support fair negotiation. There is however a certain danger in promoting transparency and Bargaining in the Shadow of the Law for negotiation support.

a) Disputants might be reluctant to be frank – one of the benefits of negotiation (as opposed to litigation) is that outcomes are often kept secret. Thus the resulting negotiation does not act as a precedent for future litigation. If this benefit is lost, then parties23 might be more reluctant to negotiate. This desire to keep negotiated decisions secret, has led to Edwards (1985) claiming that such negotiated decisions are not just.

b) **Mediators might be seen to be biased** (such as in evaluative mediation) – Honeyman (1985) indicates that there can be three groups of biases in mediation – personal, situational and structural. If mediators need to offer advice about transparency and bargaining in the shadow of the law, then both the disputants and other interested parties might be reluctant to engage in the negotiation[24].

c) The difficulty and dangers of incorporating discovery into negotiation support systems – discovering appropriate information is complex, costly and time consuming. As previously noted, Katsh and Rifkin (2001) state that compared to litigation, Alternative Dispute Resolution includes advantages of lower cost; greater speed and a less adversarial process. By insisting upon certain basic levels of discovery, we might lose these benefits. Hence we are left with the dilemma as to whether certain basic levels of discovery (that would ensure fairness which is one of the concerns of the users) be sacrificed because of the higher cost, less speed and more adversarial process that discovery brings about?

d) **The inability to realise the repercussions of a negotiation** — often disputants focus upon resolving the dispute at hand. They fail to realise that the resolution or indeed the means used to achieve the resolution. may involve larger scale repercussions.

In 2005, the Australian Competition and Consumer Commission (ACCC) convened a number of examinations of VISY executives (whose chairman is Richard Pratt) over allegations that VISY entered illegal price-fixing and market-sharing arrangements with arch-rival Amcor. Initially VISY denied any wrongdoing[25]. In October 2007, Pratt secured an early negotiated settlement with the Australian Competition and Consumer Commission, avoiding months of potentially damaging publicity for Mr. Pratt and Amcor. But his changed evidence led, in June 2008, to the Australian Competition and Consumer Commission beginning criminal proceedings in the Federal Court against Mr Pratt for allegedly providing false or misleading evidence in the course of an investigation. Despite receiving expensive legal advice, Mr. Pratt did not realise that his negotiated civil plea

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[21] In this case, Relationships Australia (Queensland) input into the system what percentage of the Common Pool both the husband and the wife will receive.

[22] See http://www.best-project.nl/index.shtml Last accessed May 10 2011

[23] Such as defendants in tobacco litigation disputes will only settle if the outcome is kept secret. If outcomes are published the tobacco companies are less likely to settle the cases.

[24] The issue of whether mediator bias is undesirable is considered by Kydd (1993). He claims: *mediators are often thought to be more effective if they are unbiased or have no preferences over the issue in dispute. This article presents a game theoretic model of mediation … which highlights a contrary logic. Conflict arises in bargaining games because of uncertainty about the resolve of the parties. A mediator can reduce the likelihood of conflict by providing information on this score. For a mediator to be effective, however, the parties must believe that the mediator is telling the truth, especially if the mediator counsels one side to make a concession because their opponent has a high resolve and will fight. An unbiased mediator, who is simply interested in minimizing the probability of conflict will have a strong incentive to make such statements even if they are not true, hence the parties will not find the mediator credible. Only mediators who are effectively* ***on your side*** *will be believed if they counsel restraint.*

[25] See Cameron Stewart, *Richard Pratt to admit breaking law*, Australian 6 October 2007.

negotiation with the Australian Competition and Consumer Commission could lead to later criminal proceedings against him[26].

Thus, our proposed principles for developing fair negotiation support systems also have some drawbacks.

5 Conclusion

We have seen that one of the major concerns from disputants using alternative dispute resolution is about the fairness of the process and of the outcomes when confronted with a superordinate ideal of fairness (such as the paramount ideal in Australian Family law being the best interest of the children). Without negotiation procedures being seen as fair and just, there will always remain legitimate criticisms of the process. But how can we measure the fairness of alternative dispute resolution procedures?

Meeting disputants' interests is a vital part of the negotiation process. Howeever adhering to principles of justice is also important, and it is vital to incorporate principles of justice into negotiation support systems[27].

Through an examination of the relevant literature in a variety of domains – including international conflicts, family law and sentencing and plea bargaining – and an in depth discussion of negotiation support tools in Australian Family Law, we have developed a set of important factors that should be incorporated into 'fair' negotiation support processes and tools. These factors include:

* Transparency;
* Bargaining in the Shadow of the Law and BATNAs; and
* Limited Discovery.

Incorporating these factors does, however, have some drawbacks for the development of negotiation support systems.

References

Alexander, R. (1997). Family mediation: Friend or Foe for Women. 10:1 *Australasian Dispute Resolution Journal* 8(4):255.

Bellucci, E., Zeleznikow, J. (2006). Developing Negotiation Decision Support Systems that support mediators: a case study of the Family_Winner system, *Journal of Artificial Intelligence and Law*, 13(2), 233-271.

Bjurulf, B., Elgstrom O. (2004). Negotiating Transperency in Elgstrom, Ole and Jonsson, Christer (eds.), *European Union Negotiations: Processes, Networks and Institutions*, Routledge, UK. ISBN: 978-0-415—34 124-0

Bibas, S. (2004). Plea bargaining outside the shadow of the trial, *Harvard Law Review*, 117:2464-2547..

Black's Law Dictionary (2004). (8th ed). West Publishing Company, St. Paul, Minnesota.

Blum, G. (2007). *Islands of Agreement: Managing Enduring Armed Rivalries*, Harvard University Press, Cambridge MA.

Brams, S., Taylor, A. (1996). *Fair Division, from cake cutting to dispute resolution*. Cambridge University Press, Cambridge, UK.

Van Boven, L., Gilovich, T. & Medvec, V. (2003). The Illusion of Transparency in Negotiations, *Negotiation Journal*, 19(2): 117-131.

Condliffe, P. (2008). *Conflict Management: A Practical Guide*, 3rd ed, Lexis Nexis, Sydney

Cooter, R., Marks, S. & Mnookin, R. (1982). Bargaining in the shadow of the law: a testable model of strategic behavior. The Journal of Legal Studies, 11(2): 225-251.

Cooter, R. & Rubinfeld, D. (1994). An Economic Model of Legal Discovery. *Journal of Legal Studies* 23:435-63.

Edwards, Harry 1985. Alternative Dispute Resolution: Panacea or Anathema? *Harvard Law Review*, 99:668-684.

Field, R. (2004). A feminist Model of Mediation that centralizes the role of lawyers as advocates for participants who are victims of domestic violence, *The Australian Feminist Law Journal*, 20:65-91.

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[26] This issue is now moot, since in April 2009, Mr. Pratt was diagnosed with prostate cancer. Given this information, the criminal charges against him for giving misleading and false information to the Australian Competition and Consumer Commission were dropped. Mr. Pratt passed away on April 28 2009.

[27] We are not claiming that disputants generally ignore principles of justice when engaging in interest based negotiation. Indeed many, if not most, parents focus exclusively upon the intests of the children during their divorce proceedings. However, we do claim principles of justice should be incorporated into the relevant negotiation support systems to ensure disputants focus upon fairness as well as interests.

Field, R. (2005). Federal Family Law Reform in 2005: The problems and pitfalls for women and children of an increased emphasis on post-separation informal dispute resolution, *QUT Law and Justice Journal*, 5(1):28.

Finel, B., Lord, K. (1999). The Surprising Logic of Transparency, *International Studies Quarterly*, 43:315-339.

Fisher, R., Ury, W. (1981). *Getting to YES: Negotiating Agreement Without Giving In*, Boston: Haughton Mifflin

Galanter, M. (2004). The Vanishing Trial: An Examination of Trials and Related Matters in State and Federal Courts, *Journal of Empirical Legal Studies* 1(3): 459-570.

Honeyman, C. *(*1985). Patterns of bias in mediation. *Missouri Journal of Dispute Resolution*, 1985: 141-150.

Katsh, E., Rifkin, J. (2001). *Online Dispute Resolution: Resolving Conflicts in Cyberspace*. Jossey-Bass, San Francisco Ca.

Kydd, A. (1993). Which Side Are You On? Bias, Credibility and Mediation. *American Journal of Political Science*, 47(4):597-611.

Kersten, G. (2001). Modeling Distributive and Integrative Negotiations. Review and Revised Characterization. *Group Decision and Negotiation*. 10(6), 493-514.

Mackenzie, G., Vincent, A. & Zeleznikow, J. (2008). Negotiating about charges and pleas – balancing interests and justice, Proceedings of *Group Decision and Negotiation 2008*, Proceedings – Full Papers, J. Climaco, G. Kersten and J. P. Costa (eds.) INESC Coimbra, Portugal, ISBN: 978-989-95055-2-0, 167-180.

McEwen, C., Rogers, N. & Maiman, R. (1995). Bring in the Lawyers: Challenging the Dominant Approaches to Ensuring Fairness in Divorce Mediation, *Minnesota Law Review* 79: 1317-1412.

Mnookin, R. (2003). When Not to Negotiate, *University of Colorado Law Review, 74,* 1077-1107.

Mnookin, R., Kornhauser, L. (1979). Bargaining in the shadow of the law: The case of divorce, *Yale Law Journal*, 88: 950-997.

Nash, J. (1953). *Two Person Cooperative Games*, 21 Econometrica 128-140.

Orwell, G. (1945). *Animal Farm*, Secker and Warburg, London, UK.

Phegan, R. (1995). The Family Mediation System: An Art of Distributions *McGill Law.Journal* 40: 365.

Pierani, M. (2005). ODR Developments under a consumer perspective: The Italian Case. *Proceedings of Second International ODR Workshop,* Wolf Legal Publishers, Nijmjegen, Netherlands. 43-45.

Ponte, L. (2001). BOOSTING CONSUMER CONFIDENCE IN EBUSINESS: RECOMMENDATIONS FOR ESTABLISHING FAIR AND EFFECTIVE DISPUTE RESOLUTION PROGRAMS FOR B2C ONLINE TRANSACTIONS, *Albany. Law Journal of Science. & Technology*, 12: 441-492

Priest, G., Klein, B. (1984). The Selection of Disputes for Litigation, *Journal of Legal Studies*, 13:1-55.

Raiffa, H. (1982). *The Art and Science of Negotiation: How to Resolve Conflicts and Get the Best Out of Bargaining*, Cambridge, Massachusetts: The Belknap Press.

Raiffa, H., Richardson, J. & Metcalfe, D. (2002). *Negotiation Analysis: The Science and Art of Collaborative Decision Making*, Cambridge, Massachusetts: The Belknap Press.

Shavell, S. (2003). *ECONOMIC ANALYSIS OF LITIGATION AND THE LEGAL PROCESS*, Discussion Paper No. 404, JOHN M. OLIN CENTER FOR LAW, ECONOMICS, AND BUSINESS, Harvard University, Cambridge, Ma. ISSN 1045-6333

Thiessen, E. McMahon, J. (2000). Beyond Win-Win in Cyberspace. *Ohio State Journal on Dispute Resolution*, 15, 643

Thompson, L. (1991). Information Exchange in negotiation. *Journal of Experimental Social Psychology*, 27: 161-179.

De Vries, B., Leenes, R. & Zeleznikow, J. (2005). Fundamentals of Providing Negotiation Advice Online: the Need for Developing BATNAs. *Proceedings of Second International ODR Workshop,* Wolf Legal Publishers, Nijmjegen, Netherlands. 59-67.

Walton, R., Mckersie, R. (1965). *A Behavioral Theory of Labor Negotiations*, McGraw - Hill, New York.

Systems for Logistics Services e-Procurement: Design and Performance

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Abstract: The paper addresses the topic of e-procurement of logistics services and examines how the system that companies adopt to support this task affects the process performance, evaluated in terms of objective outcome (i.e. the profit that logistics providers gain) and other performances related to behavioral issues. Specifically, the considered system is characterized by the exchange mechanism that rules the transaction (multi-attribute auction vs. negotiation) and the level of complexity by which the service is described. The analysis, conducted via a laboratory experiment, shows that both the exchange mechanism and the complexity of representation affect performance. Practical implications are derived, which could help companies design effective e-procurement systems.

Keywords: auctions, negotiations, logistics services, e-procurement, laboratory experiments.

1. Introduction

Most of the peculiarities of logistics services procurement arise from the different nature of a service from that of a physical good. Lovelock (1983) explains the nature of the service concept by means of several features: services are intangible, heterogeneous (i.e. they cannot be standardized), they need simultaneous production and consumption, and are perishable (i.e. cannot be stored). These characteristics may be behind the firms' belief that defining, measuring, and controlling performances is more difficult for services than goods. This may lead to inefficiencies and lack of control, as it has been raised in the case of procurement (Fitzsimmons et al., 1998; Smeltzer and Ogden, 2002).

Often, a major quota of firms expenditures for services is for logistics services. In addition to the above characteristics, these are also highly complex and affected by uncertainty. Complexity increases when buyers demand advanced services, including bundles of multiple services or value-adding logistics solutions (e.g. integrated transportation and warehouse management, supply chain inventory management, and reverse logistics), thus requiring a high degree of customization (Andersson and Norrman, 2002).

Innovation in logistics services and the growing impact of logistics on competitive advantage is one of the reasons for the ongoing changes in the relationship between buyers and suppliers, which are moving from competitive to collaborative approaches. In the former, which are typically limited to purchase basic services, the focus of the relationship is transaction efficiency, thus price is considered the main leverage. Conversely, the procurement of logistics solutions involves collaboration, information and data sharing, risks and rewards sharing, and joint investments in facilities and equipments, namely third-party logistics relationships (Berglund et al., 1999; Skjoett-Larsen, 2000).

The above changes impact on the design of the system for the logistics services procurement (Bellantuono et al., 2008), in particular when such a process is supported via information and communication technology (e-procurement). This paper focuses on the choice of specific key features of such systems: the exchange mechanism (e.g. auction vs. negotiation) and the level of complexity adopted to describe the service itself. Both features impact on the outcome achieved by the e-procurement process. Exchange mechanisms are sets of rules, which specify the functioning of the market and permissible behavior of its participants. The three standard mechanisms are: (i) catalogues, where requests and offers are posted; (ii) auctions, where one side automates the process during which participants from the other side compete against each other; and (iii) negotiations, where the participants bargain over the conditions of an exchange. One or more of these mechanisms are implemented in every e-marketplace. This research focuses on auctions and negotiations.

Auctions are well-structured and can be described completely and unequivocally using a set of rules and formulae. Negotiations belong to a rich and ill-defined family of processes used for exchanging goods or services among buyers and sellers, and for resolving inter-personal and inter-organizational conflicts. Negotiations involve an exchange of information comprised of offers, counter-offers, and arguments with the purpose of reaching a consensus (Bichler et al., 2003).

In addition to the mechanism selection, a key issue concerns the criterion or criteria according to which the e-procurement decision is made. A survey by Ferrin and Plank (2002) found that over 90% of purchasing managers based their decisions on both price and non-price variables (e.g. durability, service, lead-time, and trust). As most e-procurement decision problems are multi-attribute, companies need guidelines to properly identify e-procurement systems able to handle several decision criteria. In particular the performance offered by multi-attribute auctions as well as multi-attribute negotiations, when applied to e-procurement of logistics services should be investigated. However, the most recent survey on experimental auction research (Kagel and Levin, 2012) does not include any multi-attribute auction experiment. Furthermore, some scholars (Chen-Ritzo et al., 2005) found that the higher complexity of a multi-attribute auction mechanism consumes some of the efficiency gains over price-only auctions. Similar considerations could apply to multi-attribute negotiation. As a result, there is a need for investigating the trade-off between the description accuracy of the procured service (number of utilized criteria and associated complexity of the multi-attribute mechanism) and the e-procurement process performance.

This paper investigates how the process performance in logistics service e-procurement is affected by the features of the system that is adopted to support this task. In particular, the considered system handles multiple decision criteria to select the logistics provider and is characterized by the exchange mechanism (multi-attribute auction vs. negotiation) and the level of complexity adopted to describe the logistics service (i.e. number of attributes). The process performance is analyzed in terms of objective and substantive outcome, trust, satisfaction with dealing, and perception of opportunism.

The remaining of the paper is organized as follows: Section 2 provides a short literature review to illustrate the constructs that define process performance, and states research hypotheses. Section 3 presents research methodology, in particular the protocol adopted to conduct the laboratory experiment as well as the measurement of constructs and their validation. Results are summarized in Section 4 and discussed in Section 5.

2. Literature review and research hypotheses

2.1. Constructs

The constructs taken into account along this study are introduced and described below with respect to the extant literature.

Objective and substantive outcomes. Following Oliver et al. (1994), we define negotiation outcomes as the products of a given bargaining episode and distinguish economic and social-psychological outcomes. The former refers to the objective allocations of negotiated resources that result from the bargain and are typically thought of in terms of revenue or profit claimed by individuals as well as in terms of the joint payoff for both parties. The latter are the subjective social perceptions held by negotiating parties following the encounter. Apparently, both kinds of outcomes directly affect satisfaction, albeit in a measure that depends on the specific bargain context (Oliver, 1993).

In this study, both objective and substantive outcomes are treated as dependent variables (DVs), whereas the exchange mechanism and number of attributes are the independent variables (IVs). Objective outcomes are directly measured in terms of supplier's profit and revenue, whereas substantive outcomes are obtained from a questionnaire by means of the following items:

- I am satisfied with the results that I achieved.
- I achieved more than what I had expected.
- The outcome is better for the buyer than it is for the provider.

- The results I obtained are not favorable for my company.

Trust. The literature on procurement and supply chain management, while stressing the importance of trust in building effective buyer–supplier relationships (Kumar, 1996; Zaheer et al., 1998), states that developing the intended partner's trust is an important concern in partnership management (Johnston et al., 2004). However, such a concept lacks of a definition that is univocal and generally accepted (Gattiker et al., 2007): for instance, according to Doney and Cannon (1997), trust is a combination of perceived credibility and perceived benevolence. Cummings and Bromiley (1996), instead, provide a more complex definition, which invokes the expectation that another group or individual (i) is honest, (ii) behaves accordingly to explicit or implicit commitments, and (iii) renounces to take gain when there is a chance to do it at the counterpart's expense. It has been also stressed that the level of trust between two persons or organizations is affected by the experience that they have achieved from past mutual relationships (Kim et al., 2008).

The above definitions help us to investigate trust by means of items, each focusing on it from a different perspective. In particular, the items that we considered to test the construct are the following, adapted from Doney and Cannon (1997):

- I think that the buyer will keep the promises it makes to my company in the future.
- When making important decisions, the buyer considers my company's welfare as well as its own.
- My company trusts the buyer to keep our best interests in mind.

Satisfaction with dealing. An element to assess the success of an exchange relationship is the satisfaction that actors involved in that relationship perceive (Wong, 2000). Such a satisfaction requires that in buyer-supplier relationships the so-called arm's length arrangements are forsaken and replaced with strategies able to build strong relationships among partners (Gadde and Snehoda, 2000; Liu et al., 2010). Research on antecedents of satisfaction has shown that this may be affected by specific actions and behaviors that parties repeatedly adopt in dealing with their counterparts. This result holds as for both buyer's (Humphreys et al., 2004) and supplier's satisfaction (Goffin et al., 2006; Ghijsen et al., 2010).

In the perspective of the supplier, satisfaction has been defined by Benton and Maloni (2005) as "the feeling of equity with the relationship no matter what power imbalances exists". The survey conducted by Ghijsen et al. (2010) within the automotive industry provides evidence of the role that influence strategies – such as recommendations, information exchanges, threats or legalistic pleas – play in building supplier's satisfaction, assessed by means of measures adapted from previous literature on the topic (Benton and Maloni, 2005; Ping, 1997). In this research, we adopt the following items, based on (Ghijsen et al., 2010):

- Dealing with this buyer benefits my company.
- This buyer is a good company to do business with.

Perception of opportunism. Williamson (1975) defines opportunism as "self-interest seeking with guile", i.e. with "lying, stealing, cheating, and calculated efforts to mislead, distort, disguise, obfuscate, or otherwise confuse" (Williamson, 1985). Somewhat similarly, Macneil (1981) defines guile as "taking advantage of opportunities with little regard for principles or consequences".

Following Jap (2003), we claim that "opportunism is not merely a form of distrust. Trust is a broad meta-construct with many facets and levels (Rousseau *et al.*, 1998). Opportunism is more delimited and behavioral in nature; it is observable by the supplier and grounded in specific actions and should create reduced attributions of trust".

The concept of opportunism has been widely discussed in the field of buyer-supplier relationships (Brown et al., 2000). Indeed, although both parties would make a profit, in fact they pursue different conflicting objectives: buyers aim at reducing price, increasing quality and charging their counterpart for risks due, for instance, to units unsold or late deliveries. At the opposite, suppliers wish to maximize sales, irrespective of buyers' actual requirements, obtain assurances on minimum purchases, transfer increases in labor or row materials costs, and so on. These conditions breed discord and suspicion, and make parties agree on complex coordination schemes so as to reduce their vulnerability toward counterpart's opportunistic behavior. Unfortunately, contracts cannot include rules to manage all possible cases, thus parties have to cope with opportunism and hold-up problems (Kim and Mahoney, 2010).

In this paper we focus on the supplier's perception of opportunism, namely the suspicion that the buyer behaves opportunistically at his expense. The items used to test this construct are the same as in Carter and Stevens (2007):

- In future interactions, I believe that the buyer would be unwilling to accept responsibility for its mistakes.
- In future interactions, I believe that the buyer would try to "nickel and dime" my company.

2.2. Research hypotheses

Our research goal is to identify guidelines for companies that need to select or design systems for logistics services e-procurement. We then propose several research hypotheses, which concern the impact that specific design parameters (the exchange mechanism chosen for the logistics service procurement and the level of complexity adopted to describe the service) have on certain performance (objective and substantive outcome, trust, satisfaction with dealing, and perception of opportunism). The possible impacts of two independent (design parameters) on five dependent (performance) variables result in ten hypotheses.

Hypotheses H1 to H5 assume the exchange mechanism to be an independent variable. Ivanova-Stenzel and Kroger (2005) found that bidders' satisfaction is higher in auctions than in negotiations, due to a higher transparency of their set of rules. On the other hand, Gattiker et al. (2005) show that, at different levels of procurement complexity, if the buyer adopts e-auctions instead of negotiations, the seller's trust may decrease. Similar results have been obtained by Beall et al. (2003). Also the relationship between the adoption of a specific exchange mechanism and the perceived opportunism has been widely discussed in literature, however results are to some extent controversial. For instance, Beall et al. (2003) gives empirical evidence that the bidders' suspicions of opportunism is lowered in e-auctions, due to the intrinsic transparency of this mechanism, Other scholars affirm that suppliers believe that the buyers opportunism leads them to: (i) adopt reverse auctions instead of other mechanisms (Carter *et al.*, 2004; Jap, 2003; Smeltzer and Carr, 2003), (ii) select specific kinds of auctions (Jap, 2003), or (iii) admit a higher number of participants (Carter and Stevens, 2007).

In hypotheses H6 to H10 we assume the complexity of service description to be an independent variable, and operationalize it in terms of the number of service attributes to be dealt with during transactions. We assume that a transaction based on three attributes, compared with one based on two attributes, is less easy to manage and requires more attention and carefulness.
Below are ten hypotheses:

H1. Auctions will generate lower objective outcome than negotiations.
H2. Auctions will generate a higher substantive outcome than negotiations.
H3. Auctions will generate a lower level of trust than negotiations.
H4. Auctions will generate a lower satisfaction with dealing than negotiations.
H5. Auctions will generate a lower perception of opportunism than negotiations.
H6. Transactions with high complexity of representation will generate lower revenue for providers than transactions with low complexity of representation.
H7. Transactions with high complexity of representation will generate a lower substantive outcome than transactions with low complexity of representation.
H8. Transactions with high complexity of representation will generate a lower level of trust than transactions with low complexity of representation.
H9. Transactions with high complexity of representation will generate a lower satisfaction with dealing than transactions with low complexity of representation.
H10. Transactions with high complexity of representation will generate a higher perception of opportunism than transactions with low complexity of representation.

The conceptual model is depicted in Figure 1.

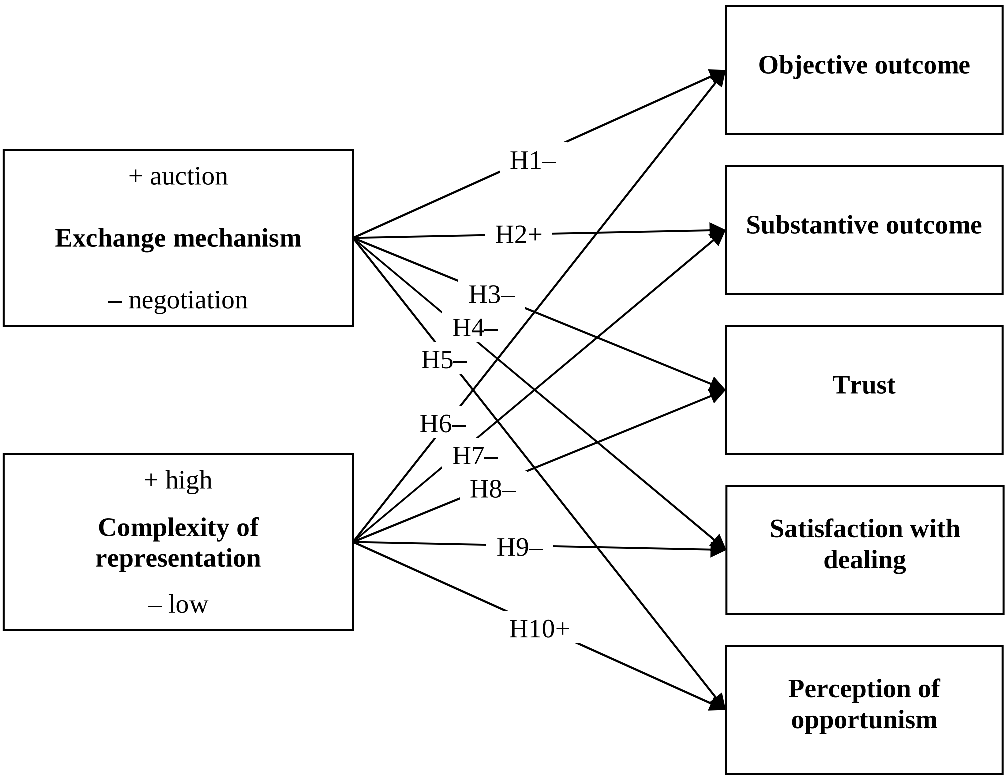

Fig. 1. Conceptual model.

3. Methodology

Our research utilized laboratory experiments, which are a specialized form of field experiment that usually involves students acting in an environment created for research purposes (Colquitt, 2008). By suitable grants, participants are induced to adopt “smart” decisions, namely to maximize their own payoff, thus optimizing their behavior. This increases their compliance with the experiment aim, and reduces the risk of bias. The use of students instead of experienced suppliers is common in experimental design (Naquin and Paulson, 2003; Gattiker et al., 2007) and assures that results cannot be explained through participants’ work experience with e-procurement (Carter and Stevens, 2007).

3.1. Participants

The sample consisted of students enrolled in courses at an Italian University. In both auctions and negotiations, the role of bidders was played by second and third-year undergraduate students in Management Engineering. There were 200 participants. Two participants were not taken into consideration because their records were incomplete. Of the 198 remaining participants, 51% were female and 98.5% Italian citizens. Age of 83.3% participants was between 21 and 25 years, while 14.6% participants were under 21 years. Students’ participation was voluntary, but awarded extra credit. To motivate conscientious behavior during the experiment, participants were also informed that the best 25% of performers would double their extra credit.

Buyers for negotiations were selected from graduate students and junior researchers in Management Engineering. They received detailed instructions regarding their behavior, so as to make their tactics similar during the experiment. Auctions did not require buyers.

3.2. Design

Our hypotheses were tested by adopting a 2×2 research design, whose experimental factors were the exchange mechanism and the level of complexity in describing the service. For both the factors – considered as independent variables – we took into account two values, namely auction and negotiation for the former, and two and three service attributes for the latter. All variables were completely crossed, thus resulting in four experimental conditions.

Differently from auctions, wherein the system works automatically, in negotiations buyers played an active role: to assure a tight control on the resulting possible confounding factors, every experimental condition that recurs to negotiations includes 14 transactions (equally divided into two groups, based on the buyer's strategy – competitive vs. cooperative). On the other hand, every experimental condition that recurs to auction includes 11 transactions. On the whole, 50 independent transactions were considered.

3.3. Procedure

Transactions were entirely performed on a web-based platform named *InterNeg Virtual Integrated Transaction Environment* (INVITE), hosting a system for conducting auctions (*InterNeg Multi-Attribute Reverse Auction System* - IMARAS) and another for conducting negotiations (*InterNeg Multi-Bilateral Negotiation System* – IMBINS). The above transaction environment and the two systems are detailed in Strecker et al. (2006) and Kersten et al. (2012).

Transactions were conducted in a computer laboratory, in consecutive sessions, and they lasted two hours each, including the preparation time. Participants at the bidder-side were randomly matched up in group of four and their identities rested unknown to each other. At the beginning of every session, the facilitator sat participants at the computer terminals far from each other, so as to prevent them from communicating or peeping, and briefly illustrated the goal of the experiment and its rules. Then, he gave participants a folder containing their log-in credentials for the platform, the system guide, some general notes on auctions or negotiations, and the description of the case, including both public and private information (see Section 3.4 for details). Participants were asked to read the material. After 25 minutes, participants were administered a quiz to ascertain their comprehension of the case: if they gave a wrong answer, the system did not allow them to proceed. Then, their expectations on the task, behavior, and outcomes, and a subjective assessment on the case understanding were investigated through a pre-questionnaire.

The interaction in itself lasted 50 minutes at most: during this phase, participants submitted bids on behalf of their hypothetical companies, each having different features and priorities. If an agreement was reached, the corresponding transaction ended in advance. At the end, all the participants were asked to complete the final feedback to capture their reactions concerning some items, and leave comments. A short debriefing closed each session.

3.4. Business case

We used the same procurement case in both auctions and negotiations. Milika, a producer of perishable goods (the buyer) is seeking a logistics service provider who would provide transportation from a single depot to a large number of customers. The buyer wants to sign a contract with a single provider for one year with a possibility of renewal. Milika assures the minimum quantity of goods to be transported. The contract consists in defining some attributes. In two-attribute transactions they are: (i) the standard rate of transportation, i.e. the amount per unit that the buyer pays to the provider, and (ii) the penalty for delay in providing customers with the requested goods on time. In three-attribute transactions, there is also (iii) the rush rate for unexpected delivery, i.e. the amount per unit that the buyer pays to the provider for rush orders, requested by customers, to transport the good on an ad-hoc basis. The possible ranges for each attribute are known to every participant.

The producer assigns the service through a transaction (auction or negotiation), to which he invites four distinct providers with a proven record. Therefore, four sales team managers participate to the transaction on behalf of their own logistics service company. Participants are told that the company they represent estimated a revenue function based on the problem attributes. For each configuration of attribute values, revenue value can easily be calculated using a simple calculator which is embedded in the case description. In order to simplify comparison of different offers or bids, the revenue is represented as ratings between 0 and 100 interval. Ratings are secret and the higher the rating is, the better the contract will be for the participant.

Every participant knows that if he accepted a contract below a given a break-even rating, the firm he represents would incur losses. Every participant is also given reservation values for the attributes. The revenue formulae, as well as reservation and breakeven values, may be different among providers.

3.5. Measures

As discussed in Section 2.1, five constructs (objective outcome, substantive outcome, trust, satisfaction with dealing, and perception of opportunism) have been taken into account (Table 1). The first of them can be directly measured and has been operationalized in terms of providers' profit, defined as the difference between the rating that the provider reaching the agreement actually achieves by the contract and his break-even rating. Based on such a definition, we can compare results, which come from sellers having different break-even ratings.

The other four constructs, which cannot be directly measured, are assessed by items adapted from the existing literature. These items have been put into questions and included in the questionnaire, which has been administered to the participants at the end of the transaction. Answers were expressed in terms of scores along a seven-point Likert scale (from "strongly disagree" to "strongly agree").

Table 1. List of constructs and related items.

Substantive outcome	OUT1	I am satisfied with the results that I achieved.
	OUT2	I achieved more than what I had expected.
	OUT3	The outcome is better for the buyer than it is for the provider.
	OUT4	The results I obtained are not favorable for my company.
Trust	TRU1	I think that the buyer will keep the promises it makes to my company in the future.
	TRU2	When making important decisions, the buyer considers my company' welfare as well as its own.
	TRU3	My company trusts the buyer to keep our best interests in mind.
Satisfaction with dealing	DEA1	Dealing with this buyer benefits my company.
	DEA2	This buyer is a good company to do business with.
Perception of opportunism	OPP1	In future interactions, I believe that the buyer would be unwilling to accept responsibility for its mistakes.
	OPP2	In future interactions, I believe that the buyer would try to "nickel and dime" my company.

3.6. Validity and reliability

To examine the existence of underlying constructs correlated to the items, we recurred to exploratory factor analysis, extracting factors through unweighted least-squares method and Kaiser's rule, and using direct oblimin as rotation method. As the research hypotheses can be referred to the entire sample as well as to specific subsets of it (obtained selecting data according to the desired values of the independent variables), distinct analyses have been conducted, each taking into account different sets of data: the whole sample of respondents (ALL), only the ones participating to auctions (AUC) or negotiations (NEG), as well as to transactions with three (HIGH) or two (LOW) attributes.

This study is part of a wider research, which analyzed constructs (and related items) that have not been described above, as they are outside the scope of this paper. However all the factor analyses refer to the entire set of items (dependent variables).

Results show that in all factor analyses the items related to the four constructs of interest in this study load only three factors, each of which is uncorrelated with any of the items associated with the other constructs not here investigated. Furthermore, the constructs *substantive outcome* and *perception of opportunism* correspond to factors independent from each other, whereas the constructs *trust* and *satisfaction with dealing* collapse into one factor, which we then treat as a unique construct, named *positive attitude toward the buyer*.

Table 2. Results of explorative factor analyses and reliability analyses on the five sets of data.

ALL				
	Loading	Mean	St. dev.	α
Positive attitude toward the buyer		*2.58*	*0.89*	*0.832*
TRU2	0.711			
TRU3	0.693			
DEA1	0.838			
DEA2	0.725			
Perception of opportunism		*2.73*	*0.73*	*0.583*
OPP1	0.643			
OPP2	0.652			

AUC				
	Loading	Mean	St. dev.	α
Substantive outcome		*-2.38*	*1.42*	*0.827*
OUT1	- 1.028			
OUT2	- 0.721			
Positive attitude toward the buyer		*2.48*	*0.89*	*0.789*
TRU2	0.614			
TRU3	0.670			
DEA1	0.754			
DEA2	0.614			

NEG				
	Loading	Mean	St. dev.	α
Positive attitude toward the buyer		*2.65*	*1.01*	*0.878*
TRU1	0.614			
TRU2	0.797			
TRU3	0.699			
DEA1	0.850			
DEA2	0.739			
Perception of opportunism		*3.20*	*0.94*	*0.743*
OPP1	0.829			
OPP2	0.798			

LOW				
	Loading	Mean	St. dev.	α
Substantive outcome		*-2.11*	*1.27*	*0.831*
OUT1	-0.873			
OUT2	-0.733			
Positive attitude toward the buyer		*2.16*	*0.96*	*0.817*
TRU1	0.651			
DEA1	0.674			
DEA2	0.710			
Perception of opportunism		*3.30*	*0.93*	*0.702*
OPP1	1.008			
OPP2	0.550			

HIGH				
	Loading	Mean	St. dev.	α
Substantive outcome		*-2.64*	*1.41*	*0.842*
OUT1	-0.999			
OUT2	-0.693			
Positive attitude toward the buyer		*2.71*	*0.88*	*0.842*
TRU1	0.647			
TRU2	0.757			
TRU3	0.691			
DEA1	0.801			
DEA2	0.669			

For each set of data, Table 2 illustrates results for all the factor analyses. The table includes the list of items corresponding to every factor, their loadings, mean and standard deviation of the factor scores, and the Cronbach's alpha. The latter has been adopted to test the reliability of factors: since all the coefficients but one – i.e. the one associated with the perception of opportunism in the analysis related to the entire set of data – are larger than 0.70, which is assumed as cut-off value (Nunnaly, 1978), the existence of an adequate internal consistency is proven (Hair et al., 2010).

4. Results

As a consequence of the explorative factor analysis, hypotheses H3 and H4, as well as H8 and H9, collapsed into the following hypotheses, respectively:

H3*. Auctions will generate a lower positive attitude toward the buyer than negotiations.
H8*. Transactions with high complexity of representation will generate a lower positive attitude toward the buyer than transactions with low complexity of representation.

These hypotheses, together with the hypotheses H1-H2, H5-H7, and H10, were tested via ANOVA both considering the entire set of data and within each subset (i.e. AUC, NEG, LOW, HIGH). Since certain hypotheses do not make sense in given subsets (e.g. H3* does not make sense in both AUC and NEG), we have 26 hypotheses. However a few of them could not be tested as the factor or reliability analyses prevented us from using the related dependent variables. Table 3 summarizes the ANOVA results for the 17 remaining hypotheses. Hypotheses having $p < 0.10$ (in bold) are assumed statistically significant, i.e. the corresponding null hypothesis (H_0: $\mu_1 = \mu_2$) is rejected. For these, Table 4 reports mean and standard deviation of the two groups, defined by varying the value of the independent variable.

Table 3. Results of ANOVA. Significant results are in bold.

Set	Hypothesis	Total variance		Within-group variance			Between-group variance			F	p
		Sum of squares	d.f.	Sum of squares	d.f.	Mean squares	Sum of squares	d.f.	Mean squares		
ALL	**H1**	**13017.92**	**49**	**9831.92**	**48**	**204.83**	**3186.00**	**1**	**3186.00**	**15.55**	**0.00**
ALL	H3*	192.73	197	191.05	196	0.98	1.68	1	1.68	1.72	0.19
ALL	H6	13017.92	49	12614.64	48	262.81	403.28	1	403.28	1.54	0.22
ALL	**H8***	**192.73**	**197**	**185.86**	**196**	**0.95**	**6.86**	**1**	**6.86**	**7.24**	**0.01**
AUC	H6	3810.96	21	3710.55	20	185.53	100.41	1	100.41	0.54	0.47
AUC	H7	175.16	87	174.04	86	2.02	1.12	1	1.12	0.55	0.46
AUC	**H8***	**68.80**	**87**	**64.39**	**86**	**0.75**	**4.41**	**1**	**4.41**	**5.88**	**0.00**
NEG	H6	6020.96	27	5698.64	26	219.18	322.32	1	322.32	1.47	0.24
NEG	H8*	110.36	109	109.15	108	1.01	1.21	1	1.21	1.20	0.28
NEG	H10	96.57	109	96.13	108	0.89	0.44	1	0.44	0.50	0.48
LOW	**H1**	**8384.00**	**24**	**6532.34**	**23**	**284.02**	**1851.66**	**1**	**1851.66**	**6.52**	**0.02**
LOW	H2	159.39	99	159.32	98	1.63	0.08	1	0.08	0.05	0.83
LOW	H3*	91.54	99	91.49	98	0.93	0.05	1	0.05	0.05	0.82
LOW	H5	85.67	99	83.73	98	0.85	1.94	1	1.94	2.27	0.14
HIGH	**H1**	**4230.64**	**24**	**2876.85**	**23**	**125.08**	**1353.79**	**1**	**1353.79**	**10.82**	**0.00**
HIGH	H2	193.23	97	189.87	96	1.98	3.37	1	3.37	1.70	0.20
HIGH	**H3***	**74.47**	**97**	**72.39**	**96**	**0.75**	**2.08**	**1**	**2.08**	**2.76**	**0.10**

Table 4. Mean and standard deviation of dependent variables for statistically significant hypotheses.

Set	hypothesis	dependent variable	independent variable			
			name	value	mean	st. dev.
ALL	H1	objective outcome	exchange mechanism	auction	-7.05	13.47
				negotiation	9.04	14.93
ALL	H8*	positive attitude	complexity of representation	2 attributes	2.39	1.02
				3 attributes	0.14	0.65
AUC	H8*	positive attitude	complexity of representation	2 attributes	2.26	0.53
				3 attributes	0.13	0.67
LOW	H1	objective outcome	exchange mechanism	auction	-4.91	12.90
				negotiation	12.43	19.35
HIGH	H1	objective outcome	exchange mechanism	auction	-9.18	14.31
				negotiation	5.64	7.99
HIGH	H3*	positive attitude	exchange mechanism	auction	0.14	0.54
				negotiation	2.58	0.65

Results show that the exchange mechanism affects the providers' objective outcome: specifically, investigating the whole set of data (ALL) the objective outcome, which is measured in terms of profit, is lower for auctions than for negotiations. This result is obtained also limiting the analysis to the subsets of transactions with both three and two attributes (HIGH and LOW), i.e. representing the logistics service in a more and, respectively, less complex way. Furthermore, for transactions with high complexity in representing the service (HIGH), the exchange mechanism reveals significant as to the providers' positive attitude toward the buyer: the latter, indeed, is higher in negotiations than in auctions.

As to the complexity of representation for the service to be procured, results show that a higher number of attributes reduces the providers' positive attitude toward the buyer. This is statistically proven both for all the set of data (ALL) and for auctions only (AUC), whereas there is no statistical evidence of this upshot if we consider negotiations only (NEG).

5. Discussion and implications

The aim of this study was to examine how the design of the system that companies adopt in procurement of logistics services affects the process performance. The topic has been widely investigated by scholars, especially in the last decade, when the pervasiveness of information and communication technologies put emphasis on the nexus between the choice of a specific market mechanism and the effects on actors' behavior. This study, however, is innovative in that it considers multi-attribute mechanisms (both negotiation and auction), as well as it utilizes the same business case and technological platform to compare different mechanisms (which avoids biases due to features other than the mechanisms themselves).

Specifically, we focused on two key dimensions to describe the system, i.e. (i) the exchange mechanism that rules the transaction and (ii) the level of complexity by which the service itself is described. On the other hand, we measured as dependent variables the objective outcome (i.e. the profit that logistics providers gain) and other performances related to behavioral issues, i.e. substantive outcome, positive attitude toward the buyer, and perception of opportunism.

The analysis, conducted by means of laboratory experiments, gave us evidence that the logistics providers' objective outcome is affected by the exchange mechanism, and decreases if auctions are adopted, regardless the level of complexity. Also, the positive attitude of providers toward the buying company diminishes with the complexity of the service description, and this is especially true in auctions.

Both results have practical managerial implications. In particular, when companies need to buy logistics services requiring a complex description and, at the same time, are interested in enhancing the positive attitude of their counterpart, the latter result suggests them to adopt negotiations rather than auctions.

Possible limitations of our study concern the existence of several auction and negotiation types, each of them could be implemented through diverse transaction environments. We had to consider a specific auction and negotiation type as well as to make a choice on the transaction environment. Furthermore, we could analyze performance under the supplier's point of view. It would be useful to complement the analysis under the buyer's perspective as well.

Further research should address the above limitations as well as consider an additional relevant question. In fact, the number of potential suppliers (in our case assumed to be equal to four) could affect performance and such an impact is likely to be different in auction and negotiation.

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References

Andersson, D., Norrman, A. (2002). Procurement of logistics services – a minute's work or a multiyear project. *European Journal of Purchasing and Supply Management* 8, 3-14.

Beall, S., Carter, C., Carter, P.L., Germer, T., Hendrick, T., Kaufman, L., Maciejewski, D., Monczka, R., Petersen, K. (2003). The role of reverse auctions in strategic sourcing, *CAPS Research Report*, Tempe, Arizona.

Bellantuono N., Kersten, G.E., Pontrandolfo, P. (2008) Exchange Mechanisms in Logistics Services Markets, *Proceedings of the Group Decision and Negotiation Meeting*, Coimbra (Portugal), June 17-20.

Benton, W.C., Maloni, M. (2005). The influence of power driven buyer/seller relationships on supply chain satisfaction. *Journal of Operations Management* 23(1), 1-22.

Berglund, M., van Laarhoven, P., Sharman, G., Wandel, S. (1999). Third-party logistics: is there a future? *International Journal of Logistics Management* 10(1), 59-70.

Bichler, M., Kersten, G.E., Strecker, S. (2003). Towards the Structured Design of Electronic Negotiation Media. *Group Decision and Negotiation* 12(4), 311-335.

Brown, J.R., Dev, C.S., Lee, D.J. (2000). Managing Marketing Channel Opportunism: The Efficacy of Alternative Governance Mechanisms. *The Journal of Marketing* 64(2), 51-65.

Carter, C.R., Stevens, C.K. (2007). Electronic reverse auction configuration and its impact on buyer price and supplier perceptions of opportunism: a laboratory experiment. *Journal of Operations Management* 25, 1035-1054.

Chen-Ritzo, C.H., Harrison, T.P., Kwasnica, A.M., Thomas, D.J. (2005). Better, Faster, Cheaper: An Experimental Analysis of a Multiattribute Reverse Auction Mechanism with Restricted Information Feedback. *Management Science* 51(12), 1753-1762.

Colquitt J.A. (2008). Publishing laboratory research in AMJ: a question of when, not if. *Academy of Management Journal* 51(4), 616-620.

Cummings, L.L., Bromiley, P. (1996). The organizational trust inventory (OTI): development and validation. In: Kramer, R.M., Tyler, T. (eds.), *Trust in Organizations: Frontiers of Theory and Research*, pp.302-330. Sage, Thousand Oaks, CA.

Doney, P.M., Cannon, J.P. (1997). An examination of the nature of trust in buyer-supplier relationships. *Journal of Marketing* 61 (2), 35–51.

Ferrin, B.G., Plank, R.E. (2002). Total Cost of Ownership Models: An Exploratory Study. *Journal of Supply Chain Management* 38(3), 18-29.

Fitzsimmons, J.A., Noh, J., Thies, E. (1998). Purchasing Business services. *Journal of Industrial Marketing* 13 (4/5), 370-380.

Gadde, L.E., Snehoda, I. (2000). Making the most of supplier relationships. *Industrial Marketing Management* 29, 305-316.

Gattiker, T.F., Huang, X., Schwarz, J.L. (2007). Negotiation, email, and Internet reverse auctions: How sourcing mechanisms deployed by buyers affect suppliers' trust. *Journal of Operations Management* 25(1), 184-202.

Ghijsen, W.T.Y., Semeijn, J., Ernstson, S. (2010). Supplier satisfaction and commitment: the role of influence strategies and supplier development. *Journal of Purchasing and Supply Management* 16(1), 17-26.

Goffin, K., Lemke, F., Szewjczewski, M. (2006). An exploratory study of 'close' supplier-manufacturer relationships. *Journal of Operations Management* 24(2), 189-209.

Hair, J.F., Black, B., Babin, B., Anders, R.E., Tatham, R.L. (2010). *Multivariate Data Analysis*, Pearson Prentice-Hall, Upper Saddle River, NJ.

Humphreys, P.K., Li, W.L., Chan, L.Y. (2004). The impact of supplier development on buyer–supplier performance. *Omega The International Journal of Management Science* 32(2), 131-143.

Ivanova-Stenzel, R., Kroger, S. (2005). Behavior in Combined Mechanisms: Auctions with a Pre-Negotiation Stage - An Experimental Investigation. *Working paper,* http://econ.arizona.edu/downloads/Seminars/Kroger.pdf *(last accessed on 10 December, 2011)*.

Jap, S.D. (2003). An exploratory study of the introduction of online reverse auctions. *Journal of Marketing* 67(3), 96–107.

Johnston, D.A., McCutcheon, D.M., Stuart, F.I., Kerwood, H. (2004). Effects of supplier trust on performance of cooperative supplier relationships. *Journal of Operations Management* 22(1), 23-38.

Kagel, J.H., Levin, D. (2012). Auctions: A Survey of Experimental Research (1995-2010). In: Kagel, J., Roth, A. (eds.), *The Handbook of Experimental Economics*, vol. 2, Princeton University Press, Princeton.

Kersten G.E., Pontrandolfo, P., Vahidov, R., Gimon, D. (2012). Negotiation and Auction Mechanisms Two Systems and Two Experiments. In: *Web 2011 Proceedings*, Dongsong Zhang, Wei T. Yue (Eds.), Lecture Notes in Business Information Processing (LNBIP), Springer.

Kim, D.J., Ferrin, D.L., Rao, H.R. (2008). A trust-based consumer decision-making model in electronic commerce: The role of trust, perceived risk, and their antecedents. *Decision Support Systems* 44, 544-564.

Kim, J., Mahoney, J.T. (2010). A Strategic Theory of the Firm as a Nexus of Incomplete Contracts: A Property Rights Approach. *Journal of Management* 36 (4), 806-826.

Kumar N. (1996). The power of trust in manufacturer–retailer relationships. *Harvard Business Review* 74(6), 92-106.

Liu, Y., Li, Y., Zhang, L. (2010). Control mechanisms across a buyer–supplier relationship quality matrix. *Journal of Business Research* 63(1), 3-12.

Lovelock, C.K. (1983). Classifying services to gain strategic market insights. *Journal of Marketing* 47 (3), 9-20.

Macneil, I.R. (1981). Contracts: adjustment of long-term economic relations under classical, neoclassical, and relational contracts. *Northwestern Law Review* 72(6), 854-901.

Naquin, C.E., Paulson, G.D. (2003). Online bargaining and interpersonal trust. *Journal of Applied Psychology* 88(1), 113-120.

Nunnaly, J. (1978). *Psychometric theory*. McGraw-Hill, New York.

Oliver, R.L. (1993). Cognitive, affective, and attribute bases of the satisfaction response. *Journal of Consumer Research* 20, 418–430.

Oliver, R.L., Balakrishnan, P.V., Barry, B. (1994). Outcome satisfaction in negotiation: a test of expectancy disconfirmation. *Organizational Behavior and Human Decision Process* 60, 252–275.

Ping, R.A., 1997. Voice in business-to-business relationships: cost-of-exit and demographic antecedents. *Journal of Retailing* 73(2), 261-281.

Rousseau, D.M., Sitkin, S.B., Burt, R.S. Camerer C. (1998), Not So Different After All: A cross-Discipline View of Trust, *Academy of Management Review*, 23(7), 393-404.

Skjoett-Larsen, T. (2000). Third party logistics – from an interorganizational point of view. *International Journal of Physical Distribution & Logistics Management* 30(2), 112-127.

Smeltzer, L.R., Carr, A.S. (2002). Reverse auctions in industrial marketing and buying. *Business Horizons* 45(2), 47-52.

Smeltzer, L.R., Ogden, J.A. (2002). Purchasing professionals' perceived differences between purchasing materials and purchasing services. *The Journal of Supply Chain Management* 38(1), 54-70.

Strecker, S., Kersten, G.E., Kim, J.B., Law, K. P. (2006). Electronic Negotiation Systems: The Invite Prototype. In: *Proceedings of the Collaborative Business MKWI'06*, Potsdam, Germany.

Williamson, O.E. (1975). *Markets and Hierarchies: Analysis and Antitrust Implications*. The Free Press, New York.

Williamson, O.E. (1985). *The Economic Institutions of Capitalism,* The Free Press, New York.

Wong, A. (2000). Integrating supplier satisfaction with customer satisfaction. *Total Quality Management* 11(4/5/6), 427–432.

Zaheer, A., McEvily, B., Perrone, V. (1998), Does trust matter? Exploring the effects of interorganizational and interpersonal trust on performance. *Organization Science* 9(2), 141-159.

Testing Software Agents' Strategies in Negotiation with Humans: An experiment

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Abstract: The purpose of this work is to investigate the prospects of human – software agent negotiations in experimental settings. To this end an electronic negotiation system incorporating software agents has been built. The system was used in experiments with human subjects to measure such outcomes as utility of agreements and number of agreements.

Keywords: e-negotiation, negotiation software agents, automated negotiation, online negotiation experiments, human-agent negotiation

1 Introduction

Negotiation is an important mechanism for facilitating economic transactions. In the course of negotiations parties exchange offers in order to jointly explore the possibilities of finding acceptable solutions. Negotiations involving more than issue allow for more degrees of freedom in search for agreements that would be beneficial to the negotiators due to the asymmetry of their preference structures.

Online negotiations supported by electronic negotiation systems allow the parties exchange offers over the internet. In addition to enabling anytime/anywhere mode of interactions, they may also incorporate analytical facilities for supporting negotiators in their preparation and conduct of negotiations. This support can range from such tools as those for capturing and modeling negotiator's preferences, to providing active advice and critique, and all the way to complete automation of the negotiation conduct (Kersten & Lai, 2007).

Despite early optimistic expectations of the growth of negotiations as one of the primary mechanisms of conducting online transactions, in the reality only few commercial sites offer such capabilities to their customers. One such website that allows customers to make (a limited number of) offers is Priceline.com. One possible explanation to the scarcity of negotiating websites is that negotiations imply a relatively high cognitive load, especially if multiple issues are involved (e.g. price, warranty, product attributes, shipment, etc.). This load may translate into a prohibitive cost when day-to-day transactions involving people who are not negotiation experts are concerned.

Software agents may circumvent this problem by automating negotiation process while working with customers towards an acceptable deal. Moreover, they can also ensure consistency in reaching negotiation outcomes according to the set policies.

Software agents can be configured to behave in a competitive or collaborative fashion, depending on the context and the needs of a business. However, up to date little experimental work has been done in assessing the potential of human customer vs. software agent negotiations in terms of objective and subjective variables.

The purpose of this work is to investigate the prospects of human – software agent negotiations in experimental settings. To this end an electronic negotiation system incorporating software agents has been built. The system was used in experiments with human subjects to measure such outcomes as utility of agreements and number of agreements. Additionally, such subjective variables as satisfaction and perceived usefulness were also measured.

2 Negotiation software agents

Research on automated negotiations involving software agents has been extensive (Beam, Segev & Shanthikumar, 1996; Benyoucef, Alj & Keller, 2001; Braun et al., 2005; Jennings et al., 2001). While thorough coverage of the past work in the area is well beyond the scope of this paper, we will review the representative publications in the context of business exchanges. One could categorize these in accordance with the context of interactions (i.e. C2C, B2B, B2C), and the extent of automation.

One well-known early work in this direction was the construction of the Kasbah electronic marketplace (Chavez et al., 1997; Maes, Guttman & Moukas, 1999). Targeting primarily the C2C domain the marketplace allowed human users to configure agents, which would then be sent to the marketplace to negotiate with each other. Three types of agents ranging from competitive to the conceding ones were provided. Negotiations included a single issue, i.e. price.

In B2B applications software agents have been proposed for automating various aspects of supply chain management. For example, Wang et al. (2009) and Kim et al. (2006) propose agent-based architecture for dynamic supply chain formation. The agents acting as brokers representing various entities within supply chain negotiated agreements with each other in building up the chain.

There has also been work targeting the B2C transactions (Ahmadi, Charkari & Enami, 2011). Huang, et al. (2007; 2010) propose an agent-based architecture for automated negotiations between businesses and consumers. The buyer agents incorporated such components as searcher and negotiator, while seller agents featured negotiator module whose strategy was set by the sales department. The sales agent has the capabilities for negotiation and persuasion. The agent employed reinforcement learning in the process. In their experiments with human subjects they found that the agent using persuasion capability has increased buyer’s product valuation and willingness to pay.

It has been argued by many that complete automation of real-life negotiations, in particular in business contexts does not seem to be a viable solution (e.g. Lin & Kraus, 2010). Automation in general is applicable only when tasks concerned are well-structured, which is rarely the case in many business situations. However, since efficient policies can be set for multiple daily interactions with the customers regarding the sales of products and services, it seems that a relatively high level of automation may be feasible.

While the work reviewed above concerns fully automated negotiations, there has been some research into sharing responsibilities between human negotiators and negotiation agents. Chen et al. (Chen, Vahidov & Kersten, 2005) designed and implemented a software environment in which agents actively supported human decision making in the negotiation process. An agent advised the human user on the acceptability of the received offer, helped with the preparation of the counter-offer, and critiqued offers composed by the users when it deemed necessary to intervene.

Vahidov (2005) proposes an agent-based architecture for managing multiple negotiations. In this architecture a fleet of agents negotiated deals with customers. These negotiations were monitored by a coordinating agent, which, based on the analysis of situation instructed the negotiating agents to adjust their strategies and reservation levels within the limits of its authority. The overall process was monitored by a human user who could intervene to make changes if necessary.

The current work is aimed at investigating how software agents perform in agent-to-human dyads as compared to human-human dyads. Various types of agents following different strategies have been configured for the comparison of their performance. Subjective measures have also been employed to measure the perceptions on the human side.

3 Agents and their strategies

The negotiation case developed for the experimental study concerned the sale of a desktop computer. There were five issues including the price, type of monitor, hard drive, service plan, and software loaded. Each option for each issue had a corresponding level of utility (attractiveness), these levels being different for the buyers vs. sellers. In order to calculate the total utility of the offer the issues were assigned different weights. These were then used in an additive utility function to estimate the level of attractiveness of an offer. Agents used this information in order to decide on the acceptability of the received offers and generate offers.

All agents acted on the seller side, and they were not aware of the buyers' preference structures. The weights were slightly different for sellers than buyers to facilitate tradeoffs, which have been considered one of the key integrative negotiation characteristics (Raiffa, Richardson & Metcalfe, 2003). Thus, agents would decide on the utility of the next offer first, according to their concession schedules, and then generate the corresponding offer.

We have chosen to use five different concession schedules, three of which were similar to those used in Kasbah experiments. These included: competitive, neutral, collaborative, competitive-then-collaborative, and tit-for-tat strategies.

1. The competitive agents (CM) tend to make smaller concessions in terms of utility of generated offers in the beginning of the negotiation period. However, as they approach the end of the period, they would start making larger concessions in search of an agreement.
2. Neutral strategy (NT) dictates that an agent concedes the constant amount of utility regardless of the time period, i.e. the concession schedule is linear.
3. Collaborative schedule (CL) implies making large concessions in the very beginning of the negotiation period in search of a quick agreement. This represents the case where an agent is anxious to sell the product. However, as the agent quickly drops the utility close to the reservation levels, it cannot make large concessions later in the process.
4. Competitive-then-collaborative schedule (CC) models more complex behavior of the agents. In the beginning of the process an agent behaves competitively, however, in the middle of the negotiation period it changes its profile to a collaborative one.
5. Tit-for-tat strategy is used by agents that do not rely on utility calculations. Rather, they watch the opponent moves and simply mirror them in composing counter-offers. In other words, when an opponent makes a new offer an agent determines the difference between this offer and the previous one made by the opponent, and applies the same difference to its own offer. If, say an opponent made a large change to a price, the agent would do the same.

Every agent followed the same algorithm. In the beginning of the process the agent makes an offer that has highest utility to an agent. It then waits for the opponent to respond. If an opponent agrees, the process terminates. If an opponent makes a counter-offer the agent calculates its acceptable utility level according to the concession schedule employed. If the opponent's offer is equal or higher than the acceptable utility, the agent accepts the offer. Otherwise, the agent generates a new offer according to the acceptable utility level. It takes the opponent's offer as a starting point, and employing hill-climbing algorithm changes it to get close to the set utility level. This heuristic method is used instead of analytical one, since most of the issues are not continuous variables. It then sends this offer to the opponent

4 Human-agent negotiations

In the current work we were interested in the objective outcomes of agent – human negotiations, as well as subjective variables capturing human perceptions of the process, outcomes and system. The objective variables included the utility of the agreements, and the proportion of agreements achieved. These relate to the economic benefits of agent-human negotiations. The subjective variables included satisfaction with the outcomes, satisfaction with the process, ease of use, and perceived usefulness of the system. These are important indicators from the information systems literature, especially relating to the acceptance and use of the system by human users.

The subjects in the study were university students enrolled in the introductory course on information technology. Thus, the negotiation case was well in line with the learning objectives of the course. The treatments included pairing up the subjects with various types of agents described in an earlier section. We also paired up humans with humans in a control group.

The experiment was conducted via the web, whereby subjects could perform their tasks from any location in an asynchronous mode during a two-day period. The subjects were invited to join the negotiations via email containing the link to the system. Negotiations began by sellers making the first offer. The agent sellers then checked for the status of negotiations at fixed intervals of time (every 3 hours). At those points of time, if they have not received new offers, they would wait until the next period of time elapsed. If an offer was received they would evaluate it and would either accept it, or would make a counter-offer.

Human subjects were free to terminate the negotiation at any time without reaching an agreement with their counter-parts. After either reaching an agreement, or terminating the negotiations the human subjects were asked to complete a questionnaire measuring their perceptions of the outcome, process, and the system.

We considered 436 usable negotiation instances. Of these, 66% ended up in an agreement, while in 35% of cases the agreement was not reached. The proportion of agreements depends on the agents' strategy. The largest proportion of agreements (82%) was reached in the collaborative agent category. This an intuitive result, since collaborative agents make large concessions early in the negotiations process, and thus they have a higher chance of making a deal with the human counterparts. It is interesting to see that human-to-human dyads have a second-lowest record in terms of proportion of agreements made. Thus, the majority of agent-involved dyads have reached more agreements than purely human dyads.

Competitive agents were able to reach an agreement in 53% of cases. Competitive-then-collaborative agents have made agreements in 75% of cases, falling between the CL and CM categories, but higher than neutral category. The lowest number of agreements was achieved in tit-for-tat category. This is the only agent strategy that does not employ utility function, and, thus it does not necessarily drop its utility level to the minimum towards the end of the period.

The base case involved human-human negotiations; 50% such dyads achieved an agreement as compared to 66% human-agent dyads.

Overall findings suggest that agents have performed better than human negotiators, in particular in terms of number of agreements and the average utility of the agreements. In human-human dyads the sellers achieved much lower utility levels than buyers (39% vs. 73%). This could be explained by the reference frames which the participants adopted. Since both sellers and buyers in this category were undergraduate student subjects, they tended to shift the price levels downwards to what they consider to be acceptable regions. Nonetheless, as it can be seen from the table, the human sellers had reached the lowest levels of utility.

The highest average utility achieved agents that used tit-for-tat strategy (72.4%). However, as already mentioned, they performed worst in terms of proportion of agreements reached. In terms of proportion of agreements competitive selling agents have performed slightly better than human sellers. However, utility-wise these agents have considerably outperformed their human "colleagues" (63.2% vs. 35.9%). Collaborative agents did only slightly better than humans, reaching 36.5% utility. However, they had much higher proportion of agreements. Competitive-then-collaborative agents have reached the average utility level of 40.4%, and the neutral ones had a slightly higher value of 43.8%. Overall, agents did better than human negotiators (46.8% vs. 35.9 %).

More detailed results obtained both in terms of objective, as well as subjective measures are also discussed.

References

Ahmadi, K. D., Charkari, N. M. & Enami, N. (2011). E-Negotiation System Based on Intelligent Agents in B2C E-Commerce. *Advances on Information Sciences and Service Sciences*, 3(2), 60-70.

Beam, C., Segev, A. & Shanthikumar, J. G. (1996) In *CMIT Working Paper 96-WP-1019*Haas School of Business, University of California, Berkeley.

Benyoucef, M., Alj, H. & Keller, E. K. (2001) In *Proceedings of the Twelfth International Workshop on Database and Expert Systems Applications (DEXA 2001)*IEEE, Munich, pp. 737-741.

Braun, P., J. Brzostowski, Kersten, G. E., Kim, J. B., Kowalczyk, R., Strecker, S. & Vahidov, R. (2005). e-Negotiation Systems and Software Agents: Methods, Models, and Applications. In J. Gupta, G. Forgionne & M. Mora (Eds.), *Intelligent-Decision Making Support System.* New York: Springer.

Chavez, A., Dreilinger, D., Guttman, R. & Maes, P. (1997). A real-life experiment in creating an agent marketplace. *Software Agents and Soft Computing Towards Enhancing Machine Intelligence*, 160-179.

Chen, E., Vahidov, R. & Kersten, G. E. (2005). Agent-supported Negotiations on E-marketplace. *International Journal of Electronic Business,* 3(1), 28-49.

Huang, S. & Lin, F. (2007). The design and evaluation of an intelligent sales agent for online persuasion and negotiation. *Electronic Commerce Research and Applications*, 6(3), 285-296.

Huang, S. L. & Lin, C. Y. (2010). The search for potentially interesting products in an e-marketplace: An agent-to-agent argumentation approach. *Expert Systems with Applications*, 37(6), 4468-4478.

Jennings, N. R., Faratin, P., Lomuscio, A. R., Parsons, S., Wooldridge, M. J. & Sierra, C. (2001). Automated Negotiations: Prospects, Methods and Challenges. *Group Decision and Negotiation,* 10(2), 199-215.

Kersten, G. E. & Lai, H. (2007). Negotiation Support and E-negotiation Systems: An Overview. *Group Decision and Negotiation*, 16(6), 553-586.

Kim, H. S., Cho, J. H., Choi, H. R., Hong, S. & Kang, M. H. (2006) ACM, pp. 579-583.

Lin, R. & Kraus, S. (2010). Can Automated Agents Proficiently Negotiate with Humans? *Communications of the ACM,* 53(1), 78-88.

Maes, P., Guttman, R. H. & Moukas, A. G. (1999). Agents that Buy and Sell. *Communication of the ACM*, 42(3), 81-91.

Raiffa, H., Richardson, J. & Metcalfe, D. (2003). *Negotiation Analysis. The Science and Art of Collaborative Decision Making.* Cambridge: Harvard University Press.

Vahidov, R. (2005). Intermediating user-DSS interaction with autonomous agents. *IEEE Transactions on Systems, Man and Cybernetics, Part A: Systems and Humans,* 35(6), 964-970.

Wang, M., Wang, H., Vogel, D., Kumar, K. & Chiu, D. K. W. (2009). Agent-based Negotiation and Decision Making for Dynamic Supply Chain Formation. *Engineering Applications of Artificial Intelligence*, 22(7), 1046-1055.

There is more to Negotiation than Reaching an Agreement: Substantive, Relational, and other Objectives of the Negotiators

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Abstract: Many experiments show that a significant proportion of participants reaches inefficient agreements but are unwilling to improve these agreements when given an opportunity to do so. One possible explanation is that the negotiators have other objectives, in addition to those which are used in efficiency assessment. We conducted experiments in which participants were asked explicitly about their objectives and the objectives' significance. This paper presents a preliminary study and outlines an exploratory follow-up experiment. The preliminary results show that experiment participants use objectives both related and unrelated to the negotiations. Different objectives are found to influence the negotiators' expectations and the negotiation process and outcomes. The participants' consideration of the importance of their objectives is used to propose five distinct profiles. A research model to study negotiators' objectives and profiles, and their consequences is proposed.

Keywords: e-negotiations, online negotiation experiments, negotiators' objectives, efficient agreements, relationship management.

1 Introduction

Seeking an agreement is considered the purpose of negotiations. According to social exchange theory, the explicit search for an agreement distinguishes the two key exchange mechanisms: negotiation and reciprocity (Blau 1994; Cook and Rice 2006; Molm 2010). In reciprocated exchanges the focus is to maintain and enhance relationship between the parties. Any problem they face is only one step in the process of building trust, reputation, and affect. While the negotiators part their way after they reach an agreement or breakdown, for the reciprocators there is no such conclusion. "Once the process is in motion, each consequence can create a self-reinforcing cycle" (Cropanzano and Mitchell 2005, p. 876). The termination is when one side defects violating the reciprocity rule.

If the sole purpose of negotiations is to achieve an agreement, then we expect the negotiators to try to reach the best possible agreement. However, on one hand, in real-life negotiations the achievement of an efficient agreement may be difficult because of not clearly formulated preferences, lack of information, or strategic misrepresentation. On the other hand negotiators' unwillingness to reach an efficient agreement or to improve it may be due to a number of reasons, including psychological traits, biases, and cognitive limitations (Neale and Bazerman 1991; Thompson, Nadler et al. 2006; Stanovich 2010), as well as sociological and cultural aspects (Hofstede 1989; Gelfand, Higgins et al. 2002; Welsh 2003).

These influences should not, however, have significant impact in low-stakes negotiation experiments conducted in labs or online. However, many experiments show that a significant percentage of participants reach inefficient agreements and, more importantly, are unwilling to improve these agreements when given an opportunity to do so (e.g., Alemi, Fos et al. 1990; Weingart, Hyder et al. 1996; Korhonen, Phillips et al. 1998; Kersten and Mallory 1999).

We may categorize these factors into two groups: (1) fears and limitations which make people "blind" to the opportunities they have and are afraid to move ahead, and (2) situational and social constraints which make people forgo gains or accept losses by following certain principles and customs.

The above limitations and constraints may cause that an agreement is inefficient. There may, however, be other reasons why people accept an agreement which, from the negotiation-analytic perspective, is inefficient, even though it need not be, if we expand the perspective.
Decision attributes are characteristic of the entity which is the subject of negotiations; these are discussed and agreed by the parties. These agreed values are also known as the substantive outcomes of a successful negotiation (Thompson 1990).

Negotiation literature recognizes also relational outcomes which are the attribute values describing relationship between the negotiators. Relational outcomes include commonality, trust, attraction, empathy, and dependency (Greenhalagh and Chapman 1995; Curhan, Elfenbein et al. 2006). They are the subjective results of the parties' communication process which may change the pre-existing relationship or create a relationship when the parties are not interdependent prior to the negotiation (Gelfand, Major et al. 2006).

Negotiation context is another factor that may influence negotiators' behavior. The same person may bargain differently over an old lamp when she wants to buy it from a hawker or from a small shopkeeper.

Negotiation literature recognizes that the subject of the negotiation (described by decision attributes), the relationship between the parties, and the context in which the process is immersed (including stakeholders) affect the process and its outcomes. These influences may take the form of constraints and limitations and/or they may be directly incorporated into the negotiators objectives. In the former case the negotiators seek the best solution within the limits imposed on the process and the set of alternatives. In the latter case they augment their objectives prior to entering the process and seek solutions that satisfy these objectives to the highest possible extent. In the latter case, negotiators may differ in terms of the objectives selected and their perceived significance. These differences could explain the situation when some negotiators are satisfied with an inferior agreement while others try to improve it. If such differences exist, then their configurations may depend on socio-psychological traits which would help us establish a stronger link between the negotiator, negotiation process and its various outcomes.

In the next section we briefly discuss an experiment in which we attempted to determine if negotiators use one or more objectives. The results of this experiment were used to revise the questionnaire and conduct the second experiment discussed in Section 3. The results and a tentative model that these results suggest are given in Section 4.

2 Preliminary study

Results of experiments which we have conducted in the past, discussions with their participants, and reviews of other studies (Teich, Korhonen et al. 1997; Kersten, Köszegi et al. 2003; Vetschera, Kersten et al. 2006; Weber, Kersten et al. 2006) led us to reconsider the assumption that participants accept and play the role described in the case and use only the objective(s) specified in it. Some participants were more interested in interacting with their counterparts than in achieving substantive outcomes. Other participants wanted to do as little as possible but enough to obtain course credits allocated to the experiment. We found that in most cases the participants were sufficiently motivated to take the negotiation seriously but their objectives seemed to differ. This was despite the negotiation experiments being—Teich, Korhonen et al. (2000) suggest—contextually relevant to the participants and the context being rich and heterogeneous (it included the negotiation case and the course assignment in which this case was used). Motivation literature, also suggests that the individual predispositions influence individuals' motivation which may cause that some aspects of the context are seen more important than others.

Following methodological suggestions made in literature (e.g., Gneezy and Rustichini 2000; Teich, Korhonen et al. 2000) we considered increasing or changing incentives, e.g., by associating the negotiation substantive results with monetary incentives combined with giving a fee for participation. Imposing monetary incentives is, however, problematic. Some behavioral economists assume that such incentives improve performance (Cameron and Pierce 1994; Gneezy and Rustichini 2000) others concur with psychologists who claim that monetary incentives hinder it (Frey and Jegen 2001). Recently, several experimental studies showed that monetary incentive has at best negligible impact on students' performance (Angrist, Lang et al. 2009; Leuven, Oosterbeek et al. 2010; Fryer Jr 2011).

Introduction of monetary rewards in negotiations is problematic because any measure of performance is either inadequate or may be attained with negative implications to the process and/or outcomes. For example, rewarding for joint gain may lead to participants' full disclosure and joint search for the best solution. Because the stakes in experiments are low (a disclosure would not undermine participants' future) the participants may do it solely because they are driven by the reward with no regard to the cooperative activities. For the above reasons we decided against using monetary incentives.

Therefore, we do not consider objectives to be associated with monetary gain.

In the preliminary study, we decided to add to the post-negotiation questionnaire several questions about the importance of the experiment participants' objectives. Literature review and internal discussions led us to the formulation of seven questions shown in Table 1.

Table 1. Seven objectives and their single-word descriptions (items)

Please tell us how each of the following objectives was important for you in this negotiation:	Item name
Achieving as high a rating for the agreement as possible.	Rating
Applying and testing my negotiation skills.	Skills
Establishing a friendly atmosphere with my counterpart.	Atmosphere
Learning about myself as a negotiator.	Learning
Learning a new system and using its functions.	System
Acquiring knowledge which is required for the assignment.	Assignment
Learning how to negotiate online.	Online

Rating corresponds to the value (utility) of the alternative; it is the only substantive objective in the list. Skills, learning, system, assignment and online are objectives associated with learning, albeit they serve different purposes. The single relational objective is "atmosphere".

2.1 Experiment and data collection

To study the negotiation process and outcomes we used an online e-negotiations system, Inspire (http://interneg.concordia.ca/inspire). The system allows the negotiator for the specification of their own preferences, assessment of offers, communication through free-text messages, and graphical display of the negotiation's progress.

The negotiators can set up their preferences by specifying a numerical value for each issue and its options. The system uses these values to calculate rating of each contract package. The package rating represents a substantive value of the contract to the negotiators. During the negotiations, the system automatically calculates the rating of each offer from both sides based on the negotiator's own preferences, which can be used to assess the offers and construct counter offers.

A business case was used to provide the negotiation context and task. The case (called Yowl-Pop) involves contract negotiations between an agent representing an artist and the manager of an entertainment company. The contract comprises four fixed issues: (1) number of new songs, (2) royalties for CDs, (3) number of promotional concerts, and (4) contract signing bonus. Each issue has three to five options to choose from. Every contract package to be negotiated is a particular combination of one option from each issue. As the parties are not allowed to propose new issues or options, the agreement can only be one out of 240 possible contract packages (alternatives).

All participants were provided with general information about the contract and the confidential information about the interests of the artist or the entertainment company respectively. The negotiators then set up their preferences according to the given information.

During the negotiation, the participants could exchange offers with their counterparts by constructing or selecting contract packages. They could also attach messages with offers or send messages only for argumentation or communication. The parties needed to agree on a complete package (i.e. values of four issues) in order to reach an agreement.

The negotiators were given three weeks; however, they could finish earlier or, if needed, request a deadline extension. They were also informed about the availability of competitors on both sides so that they could terminate the negotiation and open a new one.

2.2 Participants and their objectives

The preliminary study involved students from six universities: two in Austria, and one each in Canada, Poland, the U.S.A. and Taiwan. Data analysis is based on 330 complete responses obtained from 358 participants who negotiated during the same period. Small proportion (i.e., 5%) of participants were younger than 20, most of them were between 20 and 25 years old (i.e., 66.4%), 20.5% were between 26 and 30 years old, while 8.1% were 30 years and older. The number of female and male participants was almost equal (i.e., respectively 49.8% vs. 50.2%). Over 95% participants had not used any decision/negotiation support systems before and more than 91% never participated in negotiation experiments. Majority were students of business and management (52.9%), 29.8% were students of information technologies and the remaining 17.3% were students from other programs.

Table 2. Objectives and their importance (per cent)

Objectives	Not important	Neutral	Slightly important	Important	Very important
Rating	4.2	3.6	21.2	46.7	24.2
Skills	3.6	9.7	22.7	39.1	24.8
Atmosphere	8.5	12.1	27.3	37.6	14.5
Learning	4.5	10.3	22.4	38.5	24.2
System	10.3	14.2	27	37	11.5
Assignment	8.2	13.9	23	42.1	12.7
Online	6.4	12.7	21.8	39.4	19.7

From Table 2 it follows that 70.9% of the participants considered *rating* as important or very important, *skills* – 63.9%, *learning* – 62.7%, *online* – 59.9%, *assignment* – 54.8%, *atmosphere* – 52.1%, and *system* – 48.5.

We also found that the participants considered different objectives as important. For example, 11.2% of participants stated that all seven and 17.3% stated that six objectives were important or very important.

If participants were to focus solely on the case and negotiate to achieve the best agreement for the party they represent, then the sole important objective should be *rating*. Clearly this was not the case because only 3% of the participants considered *rating* as the most important or very important objective.

Considering the participants' demographics, we found that: (1) more female students than male students considered *atmosphere*, *learning*, *system* and *assignment* to be important; (2) novice negotiators considered *learning*, *system* and *assignment* to be more important than the experienced negotiators; and (3) graduate students considered practicing *skills* to be more important than undergraduate students.

2.3 Implications of participants' objectives

Results shown in Table 2 are insufficient to claim that the seven items are indeed objectives used by the participants. The participants could make decisions (propose offers and counteroffers, and decide on concessions) following one rather than many objectives but their answers could suggest that they used many objectives. In the preliminary study this cannot be rejected, however we found strong association between different objectives and several variables which describe negotiation preparation, process and results. We estimated these associations using regression. The results are shown in Table 3.

The analysis involves three types of variables that can be influenced by objectives: (1) expectations defined here by an alternative a negotiator aspires to agree upon (converted to aspiration rating value), the worst possible but still acceptable alternative (converted to reservation rating value), and the expected friendliness of the negotiation; (2) process defined by the rating of the first offer made by a negotiator, number of offers made, number of offers with and without accompanying messages, number of negotiation days, and the total length of messages (measured in words); and (3) outcome measured by the agreement rating.

For each regression, the F-test was significant at the 0.01 level. The adjusted R^2 values show that the seven objectives accounted for:

- Over 70% of variability in the negotiators' expectation;

- Over 60% of variability in the negotiation process (except 50% in the message length); and
- 84% in the agreement rating.

The results shown in Table 3 indicate that *rating* strongly affected the participants' expectation of the negotiation minimum acceptable and expected as well as the process friendliness. Negotiation *skills* are strongly associated with aspiration levels and the expectation regarding negotiation friendliness, while *learning* – with reservation levels and friendliness. *Atmosphere* is associated with expectations but less strongly than *rating*. In addition, the results indicate that *system* is associated with friendliness. Interestingly, participants who focused on acquiring knowledge for the assignment were not concerned with any of the expectations.

Table 3. Regression of seven objectives on negotiation expectation, process and outcomes

	Rating	Skills	Atmosphere	Learning	System	Assignment	Online	R^2
Expectations								
Aspiration rating	0.44**	0.17**	0.11**	0.09	0.07	0.04	0.08	0.82
Reservation rating	0.51**	0.04	0.09*	0.16**	0.06	0.00	0.07	0.73
Friendliness	0.40**	0.17**	0.15**	0.17**	0.08*	0.00	0.04	0.83
Process								
First offer rating	0.40**	0.17**	0.12**	0.13**	0.07	0.07	0.05	0.84
No. of offers	0.40**	0.08	0.04	0.14	-0.01	0.06	0.16*	0.64
No. of messages w/o ofrs.	0.35**	0.15*	0.03	0.15*	-0.04	0.04	0.17*	0.62
Negotiation days	0.41**	0.24**	0.01	0.09	0.08	0.08	0.00	0.68
Message length	0.28**	0.24**	0.13*	0.27**	-0.13	0.07	-0.11	0.51
Outcomes								
Agreement rating	0.45**	0.17**	0.12**	0.12*	0.07	0.03	0.05	0.84

* T-test is significant at the 0.05 level;
** T-test is significant at the 0.01 level; values are standardized coefficients; R^2 values are adjusted

Furthermore, the results given in Table 3 also show that individual objectives have different impact on the process. Focus on *rating* influenced the participants' first/last offer, the number of offers/messages and the length of negotiations, showing that negotiators who were motivated by an expectation to reach a high rating agreement negotiated more seriously and put more effort. The objective *skills* is related to the opening offers and negotiation length; however, it did not affect the number of offers but messages and particularly the message length. This indicates that those negotiators were applying or trying to apply their skills in making offer and in communicating with the counterparts with more arguments.

The relational objective *atmosphere* was found to affect the first offer and message length, indicating that the opening offers may have been an instrument to define the negotiation atmosphere and that the atmosphere was strengthened via more communication. *Learning* was only related to the opening offer, the number of messages and their length, whereas *online* only was related only to the number of offers/messages. This indicates that the negotiators with *learning* or *online* objectives put less effort on reaching an agreement. Again, *assignment* did not appear to affect the negotiators' activities.

Regarding the outcome, the agreement rating was associated with *rating*, *skills*, *atmosphere* and *learning* but not with other objectives. *rating* was shown to have a strong influence as it may lead the negotiators to achieve a higher rating of agreement. For some participants, the outcome may have been influenced by the assessment of their negotiation skills; for others, it may have been influenced by the counterparts' feeling.

3 Exploratory study

The results of this preliminary study suggest that negotiators have objectives either directly related to the role they are asked to play or not relevant to the role but rather to their profession (students, learners), interests and broader contexts. The results also showed that relationship (atmosphere) may be relevant to negotiators even if it is not discussed in the case.

The list of items in which we enquired about the participants' objectives is insufficient to categorize them into three types (substantive, relational and learning). The factor analysis indicates that substantial changes in the research instrument are needed. Therefore, the second experiment discussed in this section is also of exploratory nature. We modified the questionnaire and introduced it before the negotiations. The purpose was to study the effect of the objectives on the negotiation process and its outcomes.

3.1 Negotiator's objectives - revisited

In the preliminary study, we found that the proposed objectives were significantly correlated with each other. We were thus looking for common factors that could be explained by those items. An exploratory factor analysis showed a pattern of four-factor model: Factor 1 loaded on *rating*, Factor 2 on *learning*, *system*, *assignment* and *online*, Factor 3 on *atmosphere*, and Factor 4 on *skills* and *learning*. The model was not fitting very well to the data as *learning* was cross loading on both learning and practice and the loading of *skills* was not high. Nonetheless, it indicates that negotiators may have four types of objectives:

1. Substantive outcome which focuses on the achievement of outcomes included in the terms of contract and aggregated into the agreement rating (utility);
2. Relational outcome which aims at establishing a good atmosphere and thus focuses on the development of good relationship with the counterpart;
3. Learning-oriented outcomes which are related to the process and its implications for acquiring knowledge and new skills but much less for the specifics of the negotiations; and
4. Practice which focusses on training and skills improvement.

Taking into account these findings, we revised the items and added a few more. Table 4 shows the final list of items and their classification.

Table 4. Revised objectives and their classifications

Classification	Objective	Item name
Substantive	Achieving as high a <u>rating</u> for the agreement as possible.	Rating
	Trying to achieve the best possible <u>agreement</u>.	Agreement
	Obtaining the best results for the <u>company</u> that I represent.	Company
Relational	Establishing a friendly <u>atmosphere</u> with my negotiation partner.	Atmosphere
	Building a good <u>relationship</u> with my negotiation partner.	Relationship
	Achieving results that are <u>good for both</u> my negotiation partner and me.	Joint value
	Making the process as <u>pleasant</u> as possible.	Pleasant
Learning	Learning a new <u>system</u> and using its functions.	System
	Acquiring <u>knowledge</u> which is necessary for course work.	Knowledge
	Learning how to negotiate <u>on-line</u>.	Online
	Obtaining <u>information</u> which is useful for my assignment.	Information
Practice	Applying my <u>ability</u> as a negotiator.	Ability
	Preparing for <u>real-life</u> negotiations.	Real-life

3.2 Participants and their objectives

There were 224 students participating in the second experiment from Austria, Poland, Switzerland, the U.S.A. and Ukraine. Data analysis was based on 174 complete responses to the pre-negotiation questionnaire. The participants' demographics were similar to the first experiment.

We tested the correlations among these objectives and the results showed that several objectives were highly correlated. We then performed an un-weighted least squares factor analysis with oblimin rotation. Table 5 shows the sorted item loadings and the explained variance.

The two items, *ability* and *real-life*, which are associated with Practice (Table 4) loaded poorly and they were excluded. Therefore, items related to practices for real-life negotiations and applying negotiation skills were excluded.

In effect, three factors were identified corresponding to three types of objectives: relational outcomes, substantive outcomes and learning experience. The total variance explained is 61.2%

indicating an adequate factor structure for self-reported scales, and all, except one, factor loadings are above 0.50 which is acceptable in exploratory studies. Moreover, most cross-loadings are below 0.10 and the highest cross-loading is 0.22.

Table 5. Exploratory factor analysis (pre- negotiation)

Type	Item	Factor 1	Factor 2	Factor 3
Substantive	Agreement	**0.87**	0.05	-0.06
	Company	**0.70**	-0.04	0.22
	Rating	**0.51**	0.05	-0.05
Relational	Atmosphere	0.05	**0.81**	-0.07
	Relationship	0.00	**0.78**	0.04
	Pleasant	-0.06	**0.66**	0.02
	Good-for-both	0.10	**0.49**	0.07
Learning	Course-work	-0.07	-0.04	**0.80**
	System	0.03	0.08	**0.59**
	Online	0.16	-0.06	**0.53**
	Assignment	-0.08	0.13	**0.53**
Eigenvalues		1.56	3.71	1.46
Explained variance		14.21	33.75	13.31

Note: Items are sorted by factor loadings.

3.3 Objectives' impact

The identified three types of objectives of negotiators may affect their perceptions and behavior in a negotiation and thus the outcomes. As mentioned above, we analyzed the effects of the three classifications of objectives from the participants' responses before the experiment, which allows us to consider the objectives as predicators of the negotiation process and outcomes. The results are shown in Table 6.

Table 6. Regression of objective classifications on negotiation process and outcomes (pre-negotiation)

	Substantive	Relational	Learning	R^2
	Expectations			
Aspiration rating	0.53**	0.09	0.34*	0.92
Reservation rating	0.40*	0.08	0.43*	0.81
Friendliness	0.35*	0.29*	0.35*	0.95
	Process			
First offer rating	0.56**	0.17	0.25*	0.95
No. of messages	0.92*	0.16	-0.55	0.28
No. of messages w/o ofrs.	0.65**	0.08	0.15	0.76
Negotiation days	0.67*	0.38	-0.24	0.64
Message length	0.80*	0.32	-0.39	0.53
	Outcomes			
Agreement rating	0.55**	0.06	0.35*	0.90

Similar to the findings from the preliminary study, we found that the substantive objectives strongly affected the negotiators' expectations, behavior and substantive outcomes. The relational objectives partially determined the participants' expectations of friendliness of the negotiation but not of substantive issues (e.g. aspirations and reservations). These objectives did not significantly influence the process and its substantive outcome (agreement rating). The learning objectives affected the negotiators' expectations but not as strongly as the substantive objectives. They also affected the rating of the first offer and the agreement, but not the number of offers/messages, message length and negotiation length. This shows that the negotiators who focused on learning were caring about the outcome but not as seriously as the ones who wanted to achieve substantive outcomes.

3.4 Objective-based profiles

Using the items listed in Table 5, we recoded the factor values to four values for each factor: unimportant (value 0), neutral (value 1), somewhat important (value 2), and important (value 3). Using these scales we used K-means cluster analysis and obtained four clusters. Because we identified 2 outliers, we used 172 data points. Each of the three factors was found significant at the level lower than 0.001. The four clusters, given in Table 7 can be used to classify the participants into groups. Each group differs regarding the members' consideration of the three types of objectives and their importance ([0; 0.750 is unimportant; [0.75; 1.5) – neutral; [1.5; 2.25) – somewhat important and [2.25; 3] – important).

Table 7. Participants‘ profiles based on objectives' importance.

Type	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Substantive	0.56	2.35	2.2	2.48	0.5
Relational	0.53	2	0.26	2.23	1.88
Learning	0.56	0.61	1.51	2.59	1.79
Focused on:	*Nothing*	*Negotiation*	*Agreement*	*Everything*	*Overall process*
# (%) of participants	36 (21%)	23 (13%)	35 (20%)	44 (26%)	34 (20%)

The five profiles have different importance levels, shown in Table 7, of each of the three types of objectives. Based on these importance levels we distinguish the following five profiles:

1. Focused on nothing: the participants considered none of the three types of objectives important;
2. Focused on negotiation: the participants considered both substantive and relational outcomes important, and they did not consider study-related objectives important;
3. Focused on agreement: this group was highly motivated to achieve substantive outcomes, while relationship with their counterpart was not important;
4. Focused on everything: this group represents participants who were interested in all types of objectives;
5. Focused on the overall process: this focus comprises both the negotiation process (excluding the agreement) that leads in relational outcomes and the learning process which results in enhancing knowledge and improving skills

The number of participants in each cluster indicates that: (1) 21% of participants were not interested in any of the objectives types and the remaining 79% were interested in at least two types; (2) 25% of participants were interested in each type; (3) 59% of participants were interested in substantive objectives; and (4) 59% were interested moderately to strongly in relational objectives. These results show that the experiment's participants differ in terms of their view of the importance of objectives. Note that over 66% participants in the "nothing" group, were interested in practice; they considered objective *ability* and *real-life* (Table 4) as important or very important.

These results suggest that it is a norm rather than an exception that the negotiators use other objectives in addition to substantive. What is more, for 26% of them (i.e., 57 out of 172) substantive outcomes are unimportant.

4 Discussion

The exploratory study allows us to suggest relationships among factors discussed above; they are shown in Figure 1.

The results given in Table 7 indicate that participants may be grouped according to the importance they attach to the objectives. The results given in Table 6 indicate that there may be direct relationship between the objectives used in negotiations (and their importance) and the participants' expectations, their activities during the process and the outcomes. Further experiments will be conducted to determine these relationships at both factor and item levels.

Based on the preliminary study we conducted an exploratory analysis which gives us strong indication regarding reasons for accepting inefficient agreements and unwillingness to improve if given an opportunity. Agreement efficiency is computed based on the utility (rating) that it yields for both sides.

In addition to the utility objective, the negotiators also use other objectives. These additional objectives describe the relationship between the negotiators and the context in which the negotiation take place. Negotiators, who are striving to achieve these other objectives, may have to accept achieving a lower utility value than otherwise would be possible.

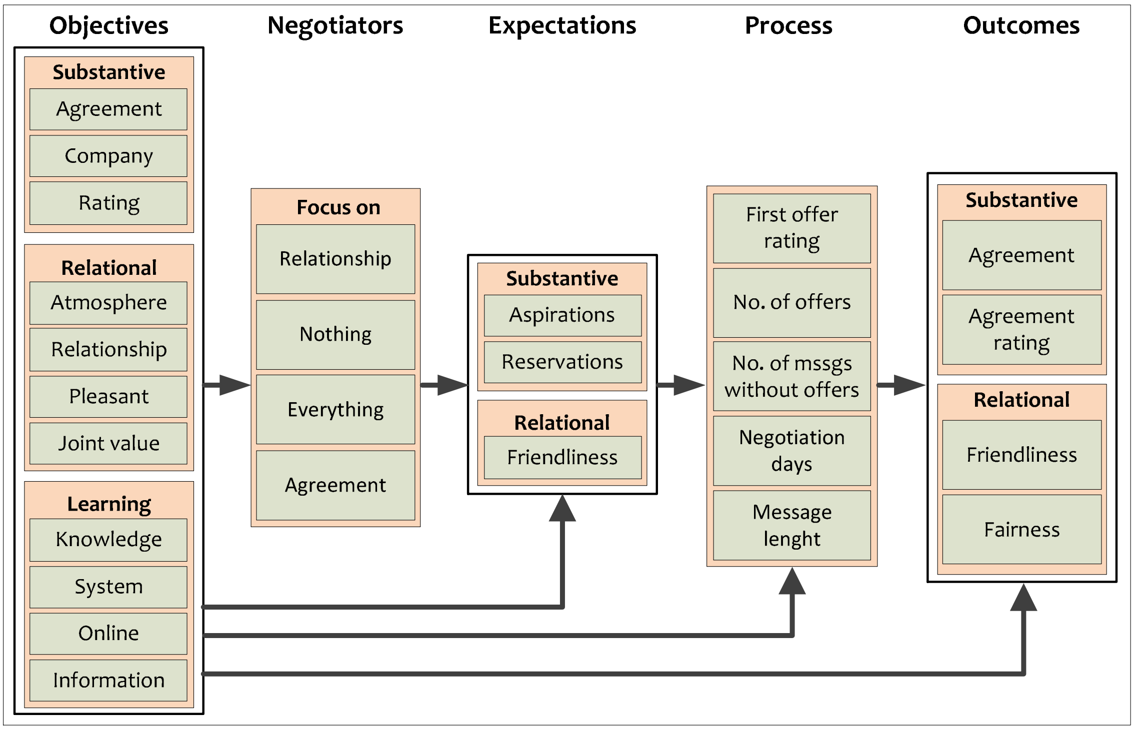

Fig. 1. Negotiators' objectives, profiles and their consequences.

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References

Alemi, F., P. Fos, et al. (1990). "A Demonstration of Methods for Studying Negotiations Between Physicians and Health Care Managers." Decision Sciences **21**(3): 633-641.

Angrist, J., D. Lang, et al. (2009). "Incentives and Services for College Achievement: Evidence from a Randomized Trial." American Economic Journal: Applied Economics **1**(1): 136-163.

Blau, P. (1994). Structural Contexts Of Opportunities Chicago, The University of Chicago Press.

Cameron, J. and W. D. Pierce (1994). "Reinforcement, Reward, and Intrinsic Motivation: A Meta-analysis." Review of Educational Research **64**(3): 363-423.

Cook, K. and E. Rice (2006). "Social Exchange Theory." Handbook of social psychology: 53-76.

Cropanzano, R. and M. S. Mitchell (2005). "Social Exchange Theory: An Interdisciplinary Review." Journal of Management **31**(6): 874-900.

Curhan, J. R., H. A. Elfenbein, et al. (2006). "What Do People Value When They Negotiate? Mapping the Domain of Subjective Value in Negotiation." Journal of Personality and Social Psychology **91**(3): 493-512.

Frey, B. S. and R. Jegen (2001). "Motivation Crowding Theory." Journal of Economic Surveys **15**(5): 589-611.

Fryer Jr, R. G. (2011). "Financial Incentives and Student Achievement: Evidence from Randomized Trials." TheQuarterlyJournalofEconomics: 1-44.

Gelfand, M. J., M. Higgins, et al. (2002). "Culture and Egocentric Perceptions of Fairness in Conflict and Negotiation." Journal of Applied Psychology **87**(5): 833.

Gelfand, M. J., V. S. Major, et al. (2006). "Negotiating Relationally: The Dynamics of the Relational Self in Negotiations." Academy of Management Review **31**(2): 427-451.

Gneezy, U. and A. Rustichini (2000). "Pay Enough or Don't Pay at All." Quarterly Journal of Economics **115**(3): 791-810.

Greenhalagh, L. and D. I. Chapman (1995). Joint Decision Making: The Inseparability of Relationship and Negotiation. Negotiation as a Social Process. R. M. Kramer and D. M. Messick. Thousands Oaks, CA, Sage**:** 166-185.

Hofstede, G. (1989). Cultural Predictors of Negotiation Styles. Process of International Negotiations. F. Mautner-Markhof. Boulder, CO, Westview Press**:** 193-201.

Kersten, G. E., S. Köszegi, et al. (2003). "The Effects of Culture in Computer-Mediated Negotiations: Experiments in 10 Countries." Journal of Information Technology Theory and Application **5**(2): 1-28.

Kersten, G. E. and G. R. Mallory (1999). "Rational Inefficient Compromises in Negotiation." Journal of Multi-Criteria Decision Analysis **8**(2): 106-111.

Korhonen, P., J. Phillips, et al. (1998). "Are Pareto Improvements Always Preferred by Negotiators?" Journal of Mulit-Criteria Decision Analysis **7**(1-2): 1-2.

Leuven, E., H. Oosterbeek, et al. (2010). "The Effect of Financial Rewards on Students' Achievement: Evidence from a Randomized Experiment." Journal of the European Economic Association **8**(6): 1243-1265.

Molm, L. D. (2010). "The Structure of Reciprocity." Social Psychology Quarterly **73**(2): 119-131.

Neale, M. A. and M. H. Bazerman (1991). Cognition and Rationality in Negotiation. New York, Free Press.

Stanovich, K. E. (2010). Decision Making and Rationality in the Modern World. Oxford University Press.

Teich, J., P. Korhonen, et al. (1997). Role of BATNA and Pareto Optimality in Dyadic Multiple Issue Negotiations. Essays in Decision Making. A Volume in Honour of Stanley Zionts M. H. Karwan, J. Spronk and J. Wallenius. Berlin, Springer**:** 313-330.

Teich, J., P. Korhonen, et al. (2000). "Conducting Dyadic Multiple Issue Negotiation Experiments: Methodological Recommendations." Group Decision and Negotiation **9**(4): 347-354.

Thompson, L. (1990). "Negotiation Behavior and Outcomes: Empirical Evidence and Theoretical Issues." Psychological Bulletin **108**(3): 515-532.

Thompson, L., J. Nadler, et al. (2006). "Judgmental Biases in Conflict Resolution and How to Overcome Them." The handbook of conflict resolution: Theory and practice: 243-264.

Vetschera, R., G. E. Kersten, et al. (2006). "The Determinants of NSS Success: An Integrated Model and Its Evaluation." Journal of Organizational Computing and Electronic Commerce **16**(2): 123-148.

Weber, M., G. E. Kersten, et al. (2006). "An Inspire ENS Graph is Worth 334 Words, on Average." Electronic Markets **16**(3): 186-200.

Weingart, L. R., E. B. Hyder, et al. (1996). "Knowledge Matters - the Effect of Tactical Descriptions on Negotiation Behavior and Outcome." Journal of Personality and Social Psychology **70**(6): 1205 - 1217.

Welsh, N. A. (2003). "Perceptions of Fairness in Negotiation." Marq. L. Rev. **87**: 753.

Concessions in Multiattribute Reverse Auctions and Multi-bilateral Negotiations

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Abstract: Concessions are a key element of a negotiation. They are made with the aim of moving towards an agreement and convincing the other party to improve their offer. This study analyzes concession making in both auctions and negotiation settings. The findings are based on data obtained from two experiments. The average concession made in the reverse auctions is significantly higher than the average concession made in negotiation. The comparison of the initial and final concessions in negotiations shows that while the number of positive concessions the value of concession, from the perspective of the concession-taker, decreases. The results also show that there is a significant proportion of negative and null concessions both in auctions and negotiations, the percentage of these concessions, however, decreases as the parties move closer to an agreement.

Keywords: e-negotiations, multiattribute auctions, multi-bilateral negotiations, concessions, concession comparison, online negotiation experiments

1 Introduction

Concession in negotiation means accepting a worse value of an issue with the purpose of convincing the other party to improve their offer. It is “a change of offer in the supposed direction of the other party’s interests that reduces the level of benefit sought” (Pruitt 1981, p. 19). Negotiators make concessions in order to move towards an agreement, prevent the counterpart from leaving the negotiation, and encourage the counterpart to reciprocate (Komorita and Esser 1975).

A concession is made by one party but assessed by both. It is therefore possible that what one side may consider a concession may not be seen as such by the other side. In other words, we may have two perspectives on concessions: (1) the concession-maker’s perspective; and (2) the concession-taker’s perspective.

The recognition that concessions are a key element of negotiation is behind behavioral researchers’ interest in concession behaviors (Benton, Kelley et al. 1972; De Dreu and Carnevale 1995; Kwon and Weingart 2004). Most studies, however, focus on single-issue bilateral negotiations in which concession-making is simple and easy to observe. The situation gets complicated in multi-issue negotiations because of the differences in importance each party attaches to individual issues. In experimental studies we may overcome this difficulty by either imposing or asking the participants to use preferences and utility functions.

Walton and McKersie (1965) note that concession making is not a mechanical process. Concessions convey information about negotiators’ utilities and about one party’s perception of another (Rubin and Brown 1975). The interdependence of concession means that negotiators reciprocate in their concessions (Smith, Pruitt et al. 1982), although power has been found to mitigate this effect (Michener, Vaske et al. 1975).

Concession-making depends on the negotiator’s approach. Competitive negotiators try making no concessions at all or as little as possible, unless they are forced to make more significant concessions in order to secure an agreement. Cooperative negotiators make greater concessions at the beginning of the process in order to show their willingness to reach an agreement. With the negotiation progress, they lower their concessions as they are getting closer to their reservation levels.

Time pressure and reservation levels also contribute to concession-making: concession rate was found to be greater when time pressure was high and reservation levels low (Smith, Pruitt et al. 1982).

However, in the case of low time pressure, frequent concessions made by one party were not reciprocated (Pruitt 1981). Additionally, negotiation approach affects the timing (when a concession is made) and content (how much is conceded) of concessions (Allen, Donohue et al. 1990; Kwon and Weingart 2004).

2 Overview

The data used in this study was obtained from two experiments conducted in 2011; one at a Canadian university and one at an Italian university. In both experiments the participants used one of two systems: Imbins for multi-bilateral negotiations and Imaras for reverse multiattribute auction.

The case involved a buyer representing a milk producing company who wanted to award a one-year contract to one of the four nominated transportation companies to deliver a certain amount of milk every month. In granting the contract, the milk producer (buyer) considered three main issues (attributes): The rate for standard delivery, the rate for rush delivery, and the amount of penalties for late or non-delivery. Sellers were representatives of the transportation companies; each company had different preferences over the three issues. For example, for one company the standard and rush rate had high priority and the penalty for delay was less important. For another company the penalty for delay was the most important issue.

In addition, the transportation companies had different utility functions and different reservation values which were based on their breakeven points. The reservation values for the four transportation companies labeled here as A, B, C, and D were 22, 15, 10 and 25 respectively. The goal of the buyer was to select the best company for the milk delivery through negotiation or auction. Both the system and the case are discussed in more detail in (Kersten, Pontrandolfo et al. 2012).

3 Concession analysis

A total of sixty-three negotiation experiments were carried out in the Canadian University. In each negotiation one buyer negotiated with four sellers. In about half of these experiments the buyers were trained to enter into the negotiation with a cooperative approach which is associated with a certain degree of openness, reciprocity, and concession-making that initially does not depend on the counterpart and in the later rounds need not be forced by threats and other pressures. For the other half of the experiments the buyers were instructed to follow a competitive approach that generally is associated with secrecy, making no concession as long as possible and exerting pressures on the counterpart to accept the competitor's offer. The sellers were neither trained nor informed about the approach of their counterparts (i.e., buyers).

In addition to the negotiation experiments, twenty-one multiattribute reverse auction experiments were also carried out. The concession behavior of the bidders has been compared and contrasted with that of the negotiators.

The following summarizes our findings about the concession behavior of users for the experiments conducted in Canada. It is important to note that the systems for both negotiation and auction experiments were equipped with a calculator which could rate the value (utility) of all offers by assigning a score between zero and one hundred, where zero was assigned to the worst possible offer from the point of view of the user and 100 to the best one.

Concession is defined here as the difference between the values of two offers made by the same person. Concession made by one side is evaluated by the opposing side. Therefore, we can distinguish the perspective of concession-maker and concession-taker. (For simplicity, we use the concept "concession" when we talk about the concession-maker perspective.) This duality of perspective means that concessions can positive, null, and negative. Positive concession requires that the concession-maker decrease his utility and yields an increase of the concession-taker's utility. Negative concession allows the concession-maker to increase utility value while the utility of concession-taker also increases. Null concession yields concession-taker's utility increase but results in no change in the concession-maker's utility.

Table 1 provides a summary of the average concession made in all offers within the experiments by the seller as well as the sellers' concession from the buyer's perspective.

Table 1. Average concession made by sellers.

	Auction	Negotiation	
		Coop.	Comp.
Number of instances	21	31	32
Number of offers/bids	435	697	746
Null concession or negative concession	2.2%	8.5%	9%
Avg. number of offers/bids per seller	5.6	6.4	6.5
Avg. seller's concession	13.1	6.3*	6.6*
Avg. seller's concession from buyer's perspective	14.1	6.97*	6.7*

We note that the average concession made in the reverse auctions is significantly higher than the average concession made in negotiation under both conditions (cooperative and competitive buyers' approaches). This is also true for the mean concession from the buyer's perspective.

Table 1 indicates that in auction settings null and negative concessions were made less frequently than in negotiation experiments. Null concessions in auction are possible when the minimum bid increment calculated in one round and used in the next round allow the seller to make bids which do not require decrease of his utility. In such a situation, the winning bid in the previous round does not force bidders to submit bids with a positive concession.

Figure 1 provides a histogram of the concession values. We note that in all three settings, the most popular concession value is around five.

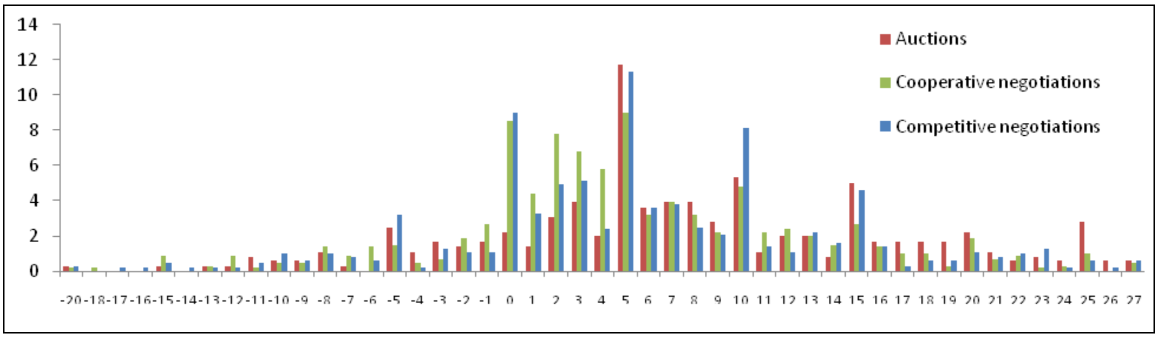

Fig. 1. Histogram of the concession values for auctions and negotiations.

An interesting observation in this graph is that in auctions and also in negotiations, high peaks of concession frequencies correspond to values that are multiples of five. It seems that in both negotiations and auctions where there are potentially 100 units of values to use, five is used as the bargaining unit. Thus, to win the auction or negotiation, it might be wise to have offers that are multiple of five plus one unit more.

4 Concession-making in multi-bilateral negotiation

To further analyze the concession behavior of both buyers and sellers, we extracted the characteristics of all the offers made in the cooperative and competitive auction experiments from the database of the two systems into three separate files. After deleting the records of all subjects who exchanged less than three offers, we constructed two measures of concession: one from the difference in the values of the second offer and first offer, and the other one from the difference in the values of the last offer and the one before the last. These are labeled as the first and last concession, respectively. The following results have been obtained from analyses of the first and last concessions.

4.1 Buyers' concession behavior

In the competitive setting there were 28 buyers with more than three offers of whom only one made a positive first concession (3.6%). The last concession in the negotiation, however, was made by six buyers (21.4%) buyers. This indicates that the buyers followed the experimenters' instructions.
In the cooperative negotiation setting the buyers also followed our instructions. Five buyers made the initial concessions which decreased their utility by 11.6 units on average. The number of buyers who made concessions increased to 11 in the last round, but the average increase dropped to 4.8 units. The difference between the first and last concessions was found to be statistically significant (p-value < .05).

4.2 Sellers' concession behavior

In the competitive setting, a total of 104 negotiations had more than three offers exchanged and for 82 (0.79%) of them the first concession was positive. The overall average value of concession for this group was 16.03 units. No significant difference was detected between the mean concession values of the four sellers companies made in their second offer. Seventy seven percent of this group made a positive concession in their last offer and the overall average value of their concession was 11.15 units.
The average value of the last concession was found to be significantly different for each of the four sellers (p-value < 0.001). The average concession made by each seller was: Seller A = 7.37, Seller B = 17.16, Seller C = 5.28 and Seller D = 17.36 units. Apparently, the concession behavior of negotiators representing companies A and C with regard to the last concession were similar. The same phenomenon was holding for representatives of the two companies B and D.

In the cooperative setting, 98 negotiators had more than three offers exchanged and for 74 of them (0.76%) the first concession was positive. The overall average concession was 11.56 units and similar to the competitive group no difference was detected between the mean values of the seller's concessions. In their last concessions 82 negotiators in this group (84%) had a positive concession with an overall average value of 10.7. Unlike the competitive group, the average values of the last concession for the sellers were not statistically different at the 0.05 level of significance.

Analysis of the auction data revealed that of the 66 auctions, 89.4% of the first concession and 90.9% of the last concession in this group were positive. The overall average value of concessions in this group was 26.74 and 10.63 units for the first and last concession, respectively. No significant differences were found between the average values of the first concession for the four seller groups, but the average values of the last concession for the four groups were found to be significantly different (p-value < 0.05). The average concession for the four groups was: A = 14.88; B = 8.35; C = 8.53; and D = 10.45 units. As previously noted, we observed that in auctions, the decrease of the utility value which is caused by the sellers' first concession is significantly higher than that of negotiations.

To explore the possible relationships between the number of messages sent or received and the amount of the first or last concessions, a correlation analysis was conducted for both competitive and cooperative negotiations experiments. No significant correlations were found between the number of messages (sent, received or total) and amount of concessions (first or last).

It is interesting to note that in various settings we found that between 6 to 14 % of sellers made negative concessions either in their second or their last offer which may be in line with Walton and McKersie's (1965) observations indicating reciprocation.

5 Summary and conclusions

Concession analysis can help us to better understand buyers' and sellers' behavior in auction and negotiation settings and to adjust our approach accordingly. A number of observations were made in this study. We found out that the average amount of concession made in auction settings is significantly greater than in negotiation settings. We also noted that at the start of cooperative negotiations, few people make concessions but the amount of the concessions they make is relatively large. However, toward the end of negotiations a larger number of negotiators make concessions but their concessions are significantly lower. These finding together with those indicated in Section 3 can be used in negotiation settings and auctions to modify our behavior during various stages of the process in a fashion that increases our chances of ending with a favorable outcome.

We noticed that the value of the last concession made in competitive negotiations and that of auctions differed for various sellers. We expected this difference to be associated with the reservation value of the company, however, no such relation was found. Additional studies are required to shed further light on these issues.

References

Allen, M., W. Donohue, et al. (1990). Comparing Hardline and Softline Bargaining Strategies in Zero-sum Situations Using Meta-analysis. Theory and Research in Conflict Management. M. A. Rahim, Greenwood**:** 86-103.

Benton, A. A., H. H. Kelley, et al. (1972). "Effects of Extremity of Offers and Concession Rate on the Outcomes of Bargaining." Journal of Personality and Social Psychology **24**(1): 73-83.

De Dreu, C. and P. Carnevale (1995). "Outcome Frames in Bilateral Negotiation: Resistance to Concession Making and Frame Adoption." European Review of Social Psychology **6**(1): 97-125.

Kersten, G. E., P. Pontrandolfo, et al. (2012). Negotiation and Auction Mechanisms: Two Systems and Two Experiments. Web 2011 Proceedings D. Zhang, C. Wagner and W. T. Yue. New York, Springer.

Komorita, S. and J. Esser (1975). "Frequency of reciprocated concessions in bargaining." Journal ol Personality and Social Psychology **32**(4): 699-705.

Kwon, S. and L. R. Weingart (2004). "Unilateral Concessions from the Other Party: Concession Behavior, Attributions, and Negotiation judgments." Journal of Applied Psychology **89**(2): 263-278.

Michener, H. A., J. J. Vaske, et al. (1975). "Factors Affecting Concession Rate and Threat Usage in Bilateral Conflict." Sociometry **38**(1): 62-80.

Pruitt, D. G. (1981). Negotiation Behavior. New York, Academic Press.

Rubin, J. Z. and B. R. Brown (1975). The Social Psychology of Bargaining and Negotiation. New York, Academic Press.

Smith, D. L., D. G. Pruitt, et al. (1982). "Matching and Mismatching: The Effect of Own Limit, Other's Toughness, and Time Pressure on Concession Rate in Negotiation." Journal of Personality and Social Psychology **42**(5): 876-883.

Walton, R. E. and R. B. McKersie (1965). A Behavioral Theory of Labor Negotiations. New York, McGraw-Hill.

Negotiation Support with Fuzzy TOPSIS

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Abstract: In this paper we present how to adopt and modify the fuzzy TOPSIS method to be applicable for the support of the ill-structured negotiation. When considering the ill-structured negotiation we focus mainly on the imprecise negotiation space definition and the problem of vague preferences. First we introduce the traditional fuzzy TOPSIS model and then we formalize an ill-structured negotiation problem pointing out some issues that require consideration and modification before applying this model.

Keywords: negotiation analysis, preference analysis, TOPSIS, fuzzy negotiation problem, fuzzy data, linguistic variables.

1 Introduction

TOPSIS (Technique for Order Performance by Similarity to Ideal Solution) is one of the methods used for solving multiple criteria decision problems. This method was firstly proposed by Hwang and Yoon (1981), however there are some earlier works of Czechoslovakian and Polish researchers that formulated very similar approach more than decade before (see Hellwig, 1968). The main idea of TOPSIS it to evaluate the alternatives by measuring simultaneously their distances from the Positive Ideal Solution (PIS) and the Negative Ideal Solution (NIS). The positive ideal solution is an alternative that is most preferred by the decision maker (DM), i.e. maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution is the least preferred one, i.e. maximizes the cost criteria and minimizes the benefit criteria. The preference order is built then according to alternatives relative closeness to PIS, which is a scalar criterion that combines these two distance measures. The classical TOPSIS method assumes that the evaluation criteria, criteria weights, alternatives and their resolution levels are precisely defined, i.e. that the problem is defined in a form of decision matrix filled with the crisp data (the problem is well structured). However, in the real-world decision making problems DMs are usually not able to express their evaluations by crisp data. They define them imprecisely in a vague way, operating with ranges rather than with the exact numbers or using the verbal descriptions or linguistic variables (see Chen and Hwang, 1992). The reasons for such a definition may be various: the time pressure, the lack of knowledge or data or the expert's limited expertise about the problem domain. Therefore, the extensions of TOPSIS were proposed, aiming at the adaptation of the traditional algorithm to the interval data or fuzzy environment (Jahanshahloo at el., 2006a,2006b, Chen 2000). All TOPSIS techniques such as the classical, interval or fuzzy ones help DMs to structure the problems, conduct computational analysis and rank the alternatives.

In this paper we analyze the applicability of the Fuzzy TOPSIS procedure to supporting negotiation process that takes into consideration the subjective and imprecise judgments of negotiators. The Fuzzy TOPSIS procedure would make possible the evaluation of negotiation offers, building the ranking of the compromise solutions, constructing the counteroffers, evaluating and comparing the size of potential concessions and also could help in improving the compromise achieved by negotiators themselves by searching for the Pareto optimal and dominant solutions. Usually for such an analysis the traditional simple additive weighting model (Keeney and Raiffa, 1976) is applied, like in the major negotiation support systems (NSS) or electronic negotiation systems: Inspire (Kersten and Noronha, 1999), Negoisst (Schop et al., 2003) and SmartSettle (Thiessen and Soberg, 2003). But the recent research on how electronic negotiator use and interpret SAW scores show (Wachowicz and Kersten, 2009; Paradis et al. 2010), that the NSS users very often misinterpret the ratings and prefer to operate with the linguistic equivalents of the ratings than the numbers as such. Therefore we decided to focus on the Fuzzy TOPSIS approach, which does not require of negotiators operating with crisp numbers and numerical definition of preferences and simultaneously has a very clear interpretation of the measures it uses (i.e. distances). Furthermore, some modifications we propose allow using Fuzzy TOPSIS for ill-structured negotiation problems, namely when the negotiation space is not or cannot be precisely defined.

This paper has 3 more sections. In Section 2 we present the classic algorithm of Fuzzy TOPSIS, applying simultaneously the notion of linguistic scales to handle the imprecise definition of negotiators' preferences. In Section 3 we discuss the possible extensions and modification required to handle the problems that may occur when Fuzzy TOPSIS is applied to ill-structured negotiation problem. We focus mainly on the problem of the definition of negotiation space by means of aspiration and reservation levels and the possible consequences, e.g. the necessity of evaluation of the counterpart's proposals that are out of such a predefined negotiation space. We also construct a formal model of negotiation for Fuzzy TOPSIS support. Finally, in Section 4 we give an illustrative example of scoring offers by means of the modified Fuzzy TOPSIS method and analyze the consequences of its application.

2 The TOPSIS Methodology

2.1 The statement of the decision problem

The multiple criteria decision making (MCDM) problem is a problem of selecting the best alternative, described by many different and usually conflicting criteria, out of the set of predefined feasible alternatives. The MCDM is a process that requires (Jahanshahloo at el. 2006a):

- establishing system evaluation criteria that relate system capabilities to goals;
- developing alternative systems for attaining the goals;
- evaluating alternatives in terms of criteria;
- applying a normative multiple criteria analysis method;
- accepting one alternative as "optimal" (preferred);

If the final solution is not accepted, gather new information and go into the next iteration of multiple criteria optimization.

Suppose the DM has to choose one of (or rank) m alternatives: $A_1, A_2, ..., A_m$ described by n criteria: $C_1, C_2, ..., C_n$. This problem may be concisely expressed in a matrix form as $X = [x_{ij}]$, $w = [w_1, w_2, ..., w_n]$, where x_{ij} is the resolution level of the alternative A_i $(i = 1,2,...,m)$ with respect to the criterion C_j $(j = 1,2,...,n)$, and w_j is the weight of criterion C_j (Chen 2000). The MCDM problems may be divided into two categories. One is the classical MCDM problems, where the ratings and criteria weights are measured by means of crisp numbers. Another one, is the fuzzy multiple criteria decision-making (FMCDM), where the ratings and criteria weights are usually expressed imprecisely, subjectively and vaguely by means of linguistic terms, fuzzy numbers or intuition fuzzy numbers (Jahanshahloo at el. 2006b; Chen 2000).

2.2 Fuzzy sets, fuzzy numbers and linguistic variables

The crisp data is very often inadequate to model real-life problems. Uncertain human judgments, luck of information, vague preferences cannot be estimated by exact numerical equivalents. Zadeh (1965) introduced the fuzzy set theory to modeled imprecision or vagueness. The fuzzy numbers are the special classes of fuzzy quantities – more precisely, a fuzzy number $\widehat{A}$ is a convex normalized fuzzy set. There are different types of fuzzy numbers, but in practice the triangular and trapezoidal fuzzy numbers are the most frequently used in problem modeling (Chen, 2000; Kahraman at el., 2007). In our paper we use the triangular fuzzy numbers (TFNs) because of their computational simplicity and easiness in representing information.

Technically, the fuzzy numbers are characterized by an interval of real numbers, each with a grade of membership between 0 and 1. The membership function of a TFN is express in the following way:

$$\mu_{\widehat{A}}(x) = \begin{cases} 0 \quad dla \quad x < a \\ \dfrac{x-a}{b-a} \quad dla \quad a \le x \le b \\ \dfrac{c-x}{c-b} \quad dla \quad b \le x \le c \\ 0 \quad dla \quad x > c \end{cases} \tag{1}$$

A TFN, denoted by $\widehat{A} = (a,b,c)$, is defined by three real numbers, that indicate the smallest possible value (a), the most promising value (b), and the largest possible value (c) of this TFN. Note, that the both the crisp data x and the interval data (a,c) can be regarded as the fuzzy triangular number – see formulas (2) and (3) respectively:

$$\widehat{x} = (x,x,x) \tag{2}$$

$$\widehat{x} = (a, \tfrac{a+c}{2}, c) \tag{3}$$

A TNF $\widehat{A} = (a,b,c)$, is the non-negative fuzzy number, if (and only if) $a \ge 0$. For non-negative TFNs various arithmetic operations may be used. We list below the major operations used later in TOPSIS procedure Let $\widehat{A}_1 = (a_1,b_1,c_1)$ and $\widehat{A}_2 = (a_2,b_2,c_2)$ be two positive triangular fuzzy numbers, then:

- multiplication of TFN by a real number k requires:

$$k \otimes \widehat{A}_1 = (ka_1, kb_1, kc_1), \tag{4}$$

- identification of max and min TFN requires:

$$\max(\widehat{A}_1, \widehat{A}_2) = (\max(a_1,a_2), \max(b_1,b_2), \max(c_1,c_2)), \tag{5}$$

$$\min(\widehat{A}_1, \widehat{A}_2) = (\min(a_1,a_2), \min(b_1,b_2), \min(c_1,c_2)), \tag{6}$$

- calculation of vertex distance requires:

$$d(\widehat{A}_1, \widehat{A}_2) = \sqrt{\tfrac{1}{3}\left((a_1-a_2)^2 + (b_1-b_2)^2 + (c_1-c_2)^2\right)}. \tag{7}$$

The linguistic variable is a variable the values of which are words or sentences in a natural or artificial language (Zadeh 1975). The notion of linguistic variable provides means to approximate characterization of phenomena, which are too complex or too ill-defined to be described in conventional, crisp quantitative terms. These linguistic variables should have quantitative equivalents. The one possibility is define these equivalents in a form of positive triangular fuzzy numbers. The example of such a linguistic variable is given Table 1.

Table 1. Linguistic variables for the ratings.

Linguistic variables	Fuzzy triangular numbers
Very Poor (VP)	(0,0,1)
Poor (P)	(0,1,3)
Medium Poor (MP)	(1,3,5)
Fair (F)	(3,5,7)
Medium Good (MG)	(5,7,9)
Good (G)	(7,9,10)

Very good (VG)	(9,10,10)

Source: Chen 2000.

Similarly, the criteria weights may be expresses by means of the linguistic variables and TFNs equivalents (Table 2).

Table 2. Linguistic variables for criteria weights.

Linguistics variables	Fuzzy triangular numbers
Very Poor (VP)	(0, 0, 0.1)
Poor (P)	(0, 0.1, 0.3)
Medium Poor (MP)	(0.1, 0.3, 0.5)
Fair (F)	(0.3, 0.5, 0.7)
Medium Good (MG)	(0.5, 0.7, 0.9)
Good (G)	(0.7, 0.9, 1)
Very good (VG)	(0.9, 1, 1)

Source: Chen 2000.

2.3 The Fuzzy TOPSIS procedure

The classic TOPSIS method proposed by Hwang and Yoon (1981) has already been extended to deal with fuzzy multi-criteria decision-making problems. The process of weight estimation in TOPSIS can be resolved by using analytically hierarchy process (AHP) (Tsaur et al., 2002), analytic network process (ANP) (Shyur and Shin, 2006), linguistic values (Jadidi et al., 2008) or other techniques. The attributes' weights can be crisp (Tsaur et al.,2002), fuzzy (Chen and Hwang, 1992; Chen 2000; Jahanshahloo et al., 2006b) or linguistic (Jadidi et al., 2008). The values of attributes can be triangular numbers (Jahanshahloo et al., 2006b), trapezoidal (Kahraman et al., 2007) or linguistic (Jadidi et al., 2008). In TOPSIS procedure some types of measures have been used, such as Euclidean distance (Chen, 2000), the least absolute value terms (Olson, 2004), Minkowskis metrics (Lin et al., 2008) and weighted Euclidean distance (Shyur and Shin, 2006). Chen (2000) extended the TOPSIS method to fuzzy group decision-making by triangular fuzzy numbers and defines crisp Euclidean distance between two fuzzy numbers. Tsaur et al. (2002) transformed a fuzzy MCDM problem into a crisp one through centroid defuzzification. Chu (2002) changed a fuzzy MCDM problem into a crisp one and solved the crisp MCDM problem using the TOPSIS method. Chen and Tzeng (2004) used fuzzy integral to transform a fuzzy MCDM problem into a non-fuzzy MCDM and they employed grey relation grade to define the relative closeness of each alternative. Jahanshahloo et al. (2006b) transformed TFNs into intervals using alpha-level sets and then normalized them by means of interval arithmetic. Wang and Elhag (2006) proposed a fuzzy TOPSIS method based on alpha-level sets, which is formulated as a nonlinear programming (NLP) problem and can determine the exact fuzzy relative closeness. Kahraman et al. (2007) presented a hierarchical fuzzy TOPSIS method, in which the hierarchical structure was unfolded and represented by an extended decision matrix, the PIS and NIS were determined by using the generalized mean for fuzzy numbers.

Here we presented one of Fuzzy TOPSIS procedure based on positive TFNs (Chen 2000). The idea can be expressed in a series of following steps:

Step 1. *Defining the fuzzy decision matrix and vector of weight*.

The fuzzy decision matrix is constructed as $X = [\hat{x}_{ij}]$, where $\hat{x}_{ij}$ is a positive TFN. The vector of weights has the form of $w = [w_1, w_2, ..., w_n]$, $w_i \in \Re$ and $\sum_j w_j = 1$.

Step 2. *Building the normalized fuzzy decision matrix.*

In this procedure linear scale transformation is used for normalization. The normalization procedure depends on the type of criterion. Let I be a set of benefit criteria (the greater value the better) and J be a set of cost criteria (the lower value the better).

The normalized fuzzy decision matrix $Z = [\hat{z}_{ij}]$ can be indicated by the following formula:

$$\widehat{z}_{ij} = \left(\frac{a_{ij}}{\max\limits_i c_{ij}}, \frac{b_{ij}}{\max\limits_i c_{ij}}, \frac{c_{ij}}{\max\limits_i c_{ij}} \right) \text{ where } \quad j \in I,\ j = 1,2...,n \tag{8}$$

$$\widehat{z}_{ij} = \left(\frac{\min\limits_i a_{ij}}{c_{ij}}, \frac{\min\limits_i a_{ij}}{b_{ij}}, \frac{\min\limits_i a_{ij}}{a_{ij}} \right) \text{where } \quad j \in J,\ j = 1,2...,n \tag{9}$$

Step 3. *Building the weighted normalized fuzzy decision matrix*.

In the weighted normalized fuzzy decision matrix $V = \left[\widehat{r}_{ij}\right]$ the criteria importance is taken into consideration:

$$\widehat{r}_{ij} = w_j \otimes \widehat{z}_{ij} \text{ for } i = 1, \ldots, m;\ j = 1, \ldots, n. \tag{10}$$

Step 4. *Determining the fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS).*

The FPIS $\left(A^+\right)$ and FNIS $\left(A^-\right)$, are determined as:

$$A^+ = \left(\widehat{v}_1^+, \widehat{v}_2^+, ..., \widehat{v}_n^+\right) = \left(\max_i \widehat{r}_{i1}, \max_i \widehat{r}_{i2}, ..., \max_i \widehat{r}_{in} \right) \tag{11}$$

$$A^- = \left(\widehat{v}_1^-, \widehat{v}_2^-, ..., \widehat{v}_n^-\right) = \left(\min_i \widehat{r}_{i1}, \min_i \widehat{r}_{i2}, ..., \min_i \widehat{r}_{in} \right) \tag{12}$$

Step 5. *Calculate the distance of each alternative to FPIS and FNIS, respectively*.

The distance of each alternative from FPIS and FNIS are calculated using vertex distance between two fuzzy triangular numbers as:

$$d_i^+ = \sum_{j=1}^{n} d(\widehat{r}_{ij}, \widehat{v}_j^+),\ \ i = 1,2,...,m \tag{13}$$

$$d_i^- = \sum_{j=1}^{n} d(\widehat{r}_{ij} \widehat{v}_j^-),\ \ i = 1,2,...,m. \tag{14}$$

Step 6. *Calculating the relative closeness to the FPIS*.

A closeness coefficient of *i*th alternative (CC_i) is defined to rank all possible alternatives. CC_i represents the distances to FPIS $\left(A^+\right)$ and FNIS $\left(A^-\right)$, simultaneously and is calculated as:

$$CC_i = \frac{d_i^-}{d_i^- + d_i^+} \tag{15}$$

where $0 \le CC_i \le 1,\ \ i = 1,2,...,m.$

Step 7. *Ranking all alternatives according to descending* CC_i .

3 The negotiation model based on Fuzzy TOPSIS procedure

3.1 Formalization the negotiation problem

Negotiation is a complex process of interaction between sides including the exchange of offers, concessions and argumentation. MCDM methods and models may be useful for supporting negotiation process (see Raiffa et al., 2002). Usually the crisp MCDM models are proposed, that are mathematically elegant, but (since the negotiation processes are usually very complex) they oversimplify the real negotiation situation and make the practical results unsatisfactory. It is because the negotiation are usually described by the parties in the natural language, which operates with words. It is also difficult to precisely assign the numerical data, such as scores or ratings, to the negotiation issues and options. Therefore the fuzzy MCDM seems to be more appropriate for supporting negotiation processes. The fuzzy approach can effectively handle both qualitative and quantitative context of negotiation, expressed offers not only by crisp data, but also by interval data, fuzzy numbers or linguistic variables.

We will try to formalize the negotiation process using the TFNs and fuzzy TOPSIS method. We start with the following notations:

- *a negotiation package* is an offer, which negotiator may send to or receive from their opponent,
- *an issue* is a criterion negotiator use to evaluate the offers,
- an *option* is an criterion potential resolution level.

We assume that negotiator has to choose one of (or to rank) m feasible packages $P_1, P_2, ..., P_m$ taking into consideration the issue set $Z = \{Z_1, Z_2, ..., Z_n\}$. Z can be divided into two sets I and J, where I is a subset of benefit issues and J is a subset of cost issues. Let $w = [w_1, w_2, ..., w_n]$ be a vector of issue weights, which is obtained by subjective opinion, AHP method (Saaty, 1980), linguistic variables.

On the preliminary step the negotiator chooses crisp, interval, fuzzy numbers or linguistic variables for describing the issues' resolution levels and represents all of them by TFNs $\hat{x} = (a, b, c)$. The crisp data is transformed to TFNs using formulas (2), (3) and Table 1. In this way every package P_i is represented by a vector $P_i = [\hat{x}_{i1}, \hat{x}_{i2}, ..., \hat{x}_{in}]$, where $\hat{x}_{ij}$ is a TFN representation of the *j*the issue's resolution level in the *i*th package. We also define the lowest acceptable target value as well as an ideal value for each criterion. Those values give the maximum limit of demands as well as the minimum limit of concessions and define the negotiation space for each issue.

We can use now the ideas of the fuzzy TOPSIS, however some modifications of the algorithm are required. We need to define the ideal and anti-ideal solution first. Normally, the coordinates of ideal and anti-ideal solution are represented by maximum and minimum values of options for all the criteria. Nevertheless, the set of packages which the negotiator defines to evaluate may not cover all possible packages that could be proposed within the forthcoming negotiations. So, we suggest to introduce two new packages, that will play role of the ideal and anti-ideal offers. Negotiator defines the ideal and anti-ideal values for each issue by comparing them with the extremes defined in the negotiation space (FPIS and FNIS) or propose two independent packages, the ideal one (P_I) and anti-ideal one (P_{AI}) [1]. If the criteria are defined numerically we can set extreme values x_j^+, x_j^- such as

$$x_j^- \le \min_i x_{ij} \quad \text{for} \quad i = 1,2,...,m;\ j = 1,2,...,n; \tag{16}$$

$$x_j^+ \ge \max_i x_{ij} \quad \text{for} \quad i = 1,2,...,m;\ j = 1,2,...,n. \tag{17}$$

Then,

[1] Naturally, it will change the results of the fuzzy matrix normalization.

$$\hat{x}_{P_I j} = \begin{cases} (x_j^+, x_j^+, x_j^+) \text{ if } j \text{ is a benefit criterion} \\ (x_j^-, x_j^-, x_j^-) \text{ if } j \text{ is a cost criterion} \end{cases} \tag{18}$$

and

$$\hat{x}_{P_{AI} j} = \begin{cases} (x_j^-, x_j^-, x_j^-) \text{ if } j \text{ is a benefit criterion} \\ (x_j^+, x_j^+, x_j^+) \text{ if } j \text{ is a cost criterion} \end{cases} \tag{19}$$

are the TFNs that represent the resolution levels for *j*th issue in the packages P_I, P_{AI} respectively. For the criteria represented by linguistic value we can use extreme linguistic values such as: Very good (VG) or Very poor (VP) (see Table 1).

We will apply then the fuzzy TOPSIS procedure to rank packages from the set $P \cup \{P_I, P_{AI}\} = \{P_1, P_2, ..., P_m, P_I, P_{AI}\}$. Let us denote set $C = \{CC(P_i), i \in P\}$ of closeness coefficients, the differences of which ($\Delta CC_{i/k} = CC(P_i) - CC(P_k)$ can be interpreted as a cardinal measure of concessions made by a negotiator $(i, k = 1,2,...,m)$.

The negotiator decision problem can be formally described thus as the eight-tier

$$(Z, P, I, J, w, P_I, P_{AI}, C). \tag{20}$$

It should be emphasize that it is very important to define the negotiation problem (20) well at the beginning of negotiation, in particular the negotiation space described by P, P_I, P_{AI}, since the evaluation of the negotiation offers outside of this space during the negotiation may cause the confusion and change the initial scoring system C (see section 3.2).

3.2 Negotiation process

Let t_r be the time variable denoting the negotiation round $(r = 0,1,...,T)$. In the round t_0 one party makes a proposal, i.e. submits an offer, which their counterpart may accept or reject. Acceptance means an *agreement* and the negotiation concludes successfully. Rejection means *disagreement* and the negotiation proceeds to the round t_1, in which the counterpart makes their proposal (that focal negotiator may accept or reject). The process continues as long as one of the offers will be accepted or rejected without any following counteroffer. The negotiations are thus the paths of offers and counteroffers that are concluded with agreement or disagreement:

We will denote by $(Z, P, I, J, w, P_I, P_{AI}, C)(t_r)$ the negotiator's decision problem in the round t_r. Let us assume, that during the negotiation process (in a round t_r) the negotiator has to take into consideration a new package P_N. We will call the negotiation problem stable with respect to new package P_N, if this package, added to the negotiation problem definition (20), does not change the normalization results (formulas 8 and 9) and/or the definition of FPIS and FNIS packages (formulas 11 and 12). If the new package P_N does not change the stability of the negotiation problem, the only thing we need to do is simply to incorporate this package into the decision matrix $(P_N \cup P)$ and to calculate P_N's closeness coefficient, which needs also to be included in the new definition of the negotiation problem, i.e. $CC(P_N) \cup C$.

The problem that needs to be solved is what to do if the new package P_N makes the problem unstable. Unfortunately, it is impossible to give an obvious recommendation in such a situation, since it depends on the negotiation problem itself and the negotiators' philosophy of evaluating such a new offer. The simplest way to solve this problem is to add this new package to the decision matrix, i.e. $P_N \cup P$, and to apply then the fuzzy TOPSIS algorithm to rescore all the feasible negotiation offers. Unfortunately, all the scores obtained within the set C before adding P_N will change, which may lead to ranking reversal (see an example in Section 4). From the negotiators' perspective such a modification may be confusing. Basing on the previous ratings, they may have rejected some counterparts' proposals that in the current ranking (determined after adding P_N) could have quite a high position.

To avoid such an ambiguity in the offers' scoring, we may try to evaluate the new package P_N within the scoring system defined by the initial negotiation problem. However, two more questions arise while trying to make such an evaluation. The first one concerns the way that we decide whether P_N is better than P_I (or worse than P_{AI}) with respect to some issue (or all package). While such a comparison is quite obvious while comparing the crisp data, here we cannot clearly confirm the relation $P_{Nj} > P_{Ij}$ (or $P_{Nj} < P_{AIj}$) for *j*th issue. The second one concerns the way we interpret (and take into consideration) the potential excess of the package P_N over P_I (or its shortage to P_{AI}). Negotiators may wish to evaluate them from the non-compensatory basis. If so, they would not take into consideration the excess of value between P_N and P_I , assuming that P_N simply gives them the maximum possible satisfaction as P_I does (consequently, they would not take into consideration the shortage of value between P_N and P_{AI} , assuming that this offer gives them the lowest possible satisfaction, as P_{AI} does). If the compensation needs to be taken into consideration a new problem arises, how to score the new package (its excesses or shortages on some issues) since the notion of distance is no longer legitimate (P_N may be much better and therefore distant to P_I , which should be considered as a good point of P_N and increase its score). Below we give some recommendation for both the situations.

The non-compensatory approach

The consequence of the non-compensatory assumption on our problem is that no package can be scored higher than the P_I and lower than P_{AI} . Therefore, even if on some issues P_N results in better consequences than P_I , it is assumed that its true performance is equal to P_I 's one. Since the performance of each offer for each issue is described by means of TFNs we need to checked then, whether neither of the three parameters describing the performance of the incoming offer P_N is better (worse) than the corresponding parameter describing the P_I 's (P_{AI} 's) performance for this issue. If so, we have to limit (upgrade) these resolution levels to the corresponding maximum values of P_I (minimum values of P_{AI}).

Let us denote by $\hat{x}_{P_N j} = (a^j_{P_N}, b^j_{P_N}, c^j_{P_N})$, $\hat{x}_{P_I j} = (a^j_{P_I}, b^j_{P_I}, c^j_{P_I})$ and $\hat{x}_{P_{AI} j} = (a^j_{P_{AI}}, b^j_{P_{AI}}, c^j_{P_{AI}})$ the fuzzy triangular numbers that represent the resolution levels for *j*th issue in the packages P_N, P_I, P_{AI} respectively. Let us assume furthermore, without loosing generality of the reasoning, that the *j*th issue is of the benefit type (i.e. $Z_j \in I$). Before evaluating the incoming package P_N by means of the Fuzzy TOPSIS scoring algorithm, all the $\hat{x}_{P_N j}$ values (for j = 1, …, n) need to be rewritten to the following form

$$\hat{x}_{P_N j} = (\bar{a}^j_{P_N}, \bar{b}^j_{P_N}, \bar{c}^j_{P_N}) , \tag{21}$$

where

$$\bar{y}^j_{P_N} = \begin{cases} y^j_{P_I}, & \text{if } y^j_{P_N} > y^j_{P_I} \\ y^j_{P_{AI}}, & \text{if } y^j_{P_N} < y^j_{P_{AI}} \\ y^j_{P_N}, & \text{otherwise} \end{cases} .^2 \tag{22}$$

for $y = a,b,c -$ denoting the triangular number parameters respectively.

[2] The inequality relations will be inverse if $Z_j \in J$.

Such an approach to redefinition of the new incoming offers will assure that the non-compensatory assumption would be taken into consideration while measuring the distances both to FPIS and FNIS. Limiting the values of P_N to the resolution levels of P_I will make P_N offer as good as P_I and as distant to P_{AI} as P_I is, for each negotiation issue respectively, which must be guaranteed to keep the CC calculations coherent (the same stays true for upgrading the values to the resolution levels of P_{AI}).

The quasi-compensatory approach

The compensatory assumption requires taking into consideration the fact that P_N 's may be somehow better than P_I (or worse than P_{AI}). It is not easy to conduct all the necessary TOPSIS calculation according to this assumption, since the method itself bases on the measuring distances to the reference points that are assumed to be the extreme points, and therefore it is implicitly assumed that this distances have the clear meanings. The distance to FPIS says of how much the offer under consideration is worse than FPIS, while the distance to FNIS says of how much it is better than FPIS. If we assume now, that the offers under consideration may be better than the P_I (or worse than P_{AI}) with respect to some issue then the notion of the distance as such is not sufficient to describe the P_N 's attractiveness, since it increases the denominator of the formula (15), and consequently decreases the value of the closeness coefficient. The most intuitive idea how to handle this problem is to change the notion of distance in TOPSIS scoring algorithm and replace it with the notion of deviation, identifying simultaneously the positive and negative deviations. The negative deviation would be the equivalent of the distance function used in standard TOPSIS algorithm, while the positive deviation would describe the excess (shortage) over P_I (to P_{AI}), and consequently should not be added within the scoring formula, but subtracted rather to compensate the fact the offer under consideration is over-good (or under-bad).

Such an approach changes the fundamental notions of TOPSIS method and requires the detailed theoretical investigation and consideration that we will not conduct in this paper. We suggest instead a simpler solution that keeps the general notion of measuring distances unchanged. We will not change for the calculations the form of P_N as we did before (formulas 21 and 22), however we will still assume that if P_N is better that P_I the distance (measured for each issue separately) between these packages should be 0. Simultaneously we will take into consideration the P_N 's potential excess over P_I while measuring its single criteria distances to P_{AI} . It will make this offer to be more distant from P_{AI} on some issues, which can compensate the shorter distances (i.e. the worse performances) on other issues. It will make the d_i^- elements of the formula (15) increase, while d_i^+ will remain stable. The value of the overall closeness coefficient will increase then. Similarly, if P_N is worse than P_{AI} on some issues the single criteria distances between these packages will be 0, but the corresponding distances to P_I will increase and compensate (reduce) the shorter distances (i.e. the better performances) on other issues. It will make the d_i^- elements of the formula (15) stable, while d_i^+ will increase. The value of the overall closeness coefficient will decrease then.

What should be emphasize here, is that the approach we propose is not fully compensatory. It still does not take into consideration the potential excesses (shortages) in the resolution levels while measuring the distances to P_I (P_{AI}). These over-good (under-bad) performances are taken into consideration in measuring the distances to P_I (P_{AI}) solely. The consequence of such an approach is that if P_N is globally over-good (i.e. better than P_I on all the issues) its closeness coefficient will be still 1. We may call this approach to be a quasi-compensatory then. Formally, the process of measuring the distances for quasi-compensatory approach will require the single distance formula (7) to be modified. For the *j*th issue the distance between P_N and P_I should be measured now as:

$$d(P_{Nj}, P_{Ij}) = \sqrt{\tfrac{1}{3}\left(\tilde{a}_j^2 + \tilde{b}_j^2 + \tilde{c}_j^2\right)}, \qquad \textbf{(23)}$$

where

$$\tilde{x}_j = \begin{cases} x^j_{P_N} - x^j_{P_I}, & \text{if } x^j_{P_N} - x^j_{P_I} < 0 \\ 0, & \text{otherwise} \end{cases}, \qquad \textbf{(24)}$$

for $x = a, b, c -$ denoting the triangular number parameters.

Similarly we define the distance between P_N and P_{AI}:

$$d(P_{Nj}, P_{AIj}) = \sqrt{\tfrac{1}{3}\left(\tilde{a}_j^2 + \tilde{b}_j^2 + \tilde{c}_j^2\right)}, \qquad \textbf{(25)}$$

where

$$\tilde{x}_j = \begin{cases} x^j_{P_N} - x^j_{P_{AI}}, & \text{if } x^j_{P_N} - x^j_{P_{AI}} > 0 \\ 0, & \text{otherwise} \end{cases}, \qquad \textbf{(26)}$$

for $x = a, b, c$ - denoting the triangular number parameters.

Note that while normalizing the P_N 's resolution levels we may still use the formulas (8) and (9) with the $\max_i c_{ij}$ and $\min_i a_{ij}$ determined within the predefined set of the feasible alternatives P. The only effect of such position normalization would be that the single criteria performances of P_N that exceeds the initial P_I would obtain the normalized value greater than 1.

Differences between non-compensatory and quasi-compensatory approach – an example

Let us consider a simple numerical example, in which the incoming offer needs to be evaluated by comparing it to the reference alternatives P_I and P_{AI} with respect to a single criterion described by means of fuzzy numbers. Let us assume that the negotiator personally defined the reference points, which are: $P_I = (3,5,8)$ and $P_{AI} = (1,4,6)$. The incoming offer $P_N = (2,4,9)$. According to the non-compensatory approach we will determine the distance between P_N and the reference points using the P_N 's modifications (formulas 23 and 24). Since $c_{P_N} > c_{P_I}$, we will need to rewrite P_N to the form $P_N = (2,4,8)$. The distances may be calculated now[3]:

$$d(P_N, P_I) = \sqrt{\frac{1}{3}\left((3-2)^2 + (5-4)^2 + (8-8)^2\right)} \approx 0.82, \qquad \textbf{(27)}$$

$$d(P_N, P_{AI}) = \sqrt{\frac{1}{3}\left((1-2)^2 + (4-4)^2 + (6-8)^2\right)} \approx 1.29. \qquad \textbf{(28)}$$

Consequently $CC(P_N) = \dfrac{1.29}{1.29 + 0.82} \approx 0.61.$

The quasi-compensatory approach will not modify the P_N 's form as such. According to the formula (26) it will only neutralize the difference between c_{P_N} and c_{P_I}, while in measuring the distance between P_N and P_{AI} the original value of c_{P_N} will be taken into consideration. The distance is calculated in the following way:

$$d(P_N, P_I) = \sqrt{\frac{1}{3}\left((3-2)^2 + (5-4)^2 + 0\right)} \approx 0.82, \qquad \textbf{(29)}$$

$$d(P_N, P_{AI}) = \sqrt{\frac{1}{3}\left((1-2)^2 + (4-4)^2 + (6-9)^2\right)} \approx 1.82. \qquad \textbf{(30)}$$

[3] We do not need to normalize the performance values since we consider single criterion only.

Thus we obtain $CC(P_N) = \frac{1.82}{1.82 + 0.82} \approx 0.69.$

4 An example

In this section we demonstrate the calculation process of the proposed approach. Let us consider a Buyer and a Seller, bargaining about the conditions of the potential contract. The following issues are discussed: Z_1 – unitary price (EUR), Z_2 – payment conditions (days), Z_3 – returns policy. Suppose that the vectors of the issues' weights are: $w_B = [0.7, 0.2, 0.1]$ for Buyer and $w_S = [0.6, 0.2, 0.2]$ for Seller. The issues Z_1, Z_2 are represented by TFNs, and Z_3 is scaled using linguistic variables which are decoded to TFNs (see Table 1). The negotiation spaces defined by the crisp values for Z_1, Z_2 and linguistically for Z_3 are the following:

- Price: $\langle 3.5, 4.5 \rangle$ for Buyer, $\langle 4, 5 \rangle$ for Seller;
- Payment: $\langle 1, 30 \rangle$ for both parties,
- Returns: ⟨Very Poor (VP), Very Good (VG)⟩ for both parties.

Z_1 is the benefit (cost) issue for Seller (Buyer), Z_2 is cost (benefit) for Seller (Buyer). Z_3 is estimated by both of them as benefit. The negotiators consider 18 possible packages and the initial decision making problem represented by TFNs is presented in the Table 3.. We will analyze two cases:

Case 1: The FPIS and the FNIS solution in TOPSIS procedure are represented by the best and the worst possible offers.

Case 2: The FPIS and the FNIS solution in TOPSIS procedure are based on the limit variables negotiation spaces for issues (Table 4).

Table 3. Negotiation packages.

Package	Z_1 Price	Z_2 Payment	Z_3 Returns	
	Buyer/Seller	Buyer/Seller	Buyer	Seller
P_1	(4,4,4)	(2,4,6)	(5,7,9)	(1,3,5)
P_2	(4,4,4)	(7,11,13)	(3,5,7)	(3,5,7)
P_3	(4,4,4)	(14,17,20)	(5,7,9)	(1,3,5)
P_4	(4,4,4)	(2,4,6)	(3,5,7)	(3,5,7)
P_5	(4,4,4)	(7,11,13)	(5,7,9)	(1,3,5)
P_6	(4,4,4)	(14,17,20)	(3,5,7)	(3,5,7)
P_7	(4.2,4.2,4.2)	(2,4,6)	(5,7,9)	(1,3,5)
P_8	(4.2,4.2,4.2)	(7,11,13)	(3,5,7)	(3,5,7)
P_9	(4.2,4.2,4.2)	(14,17,20)	(5,7,9)	(1,3,5)
P_{10}	(4.2,4.2,4.2)	(2,4,6)	(3,5,7)	(3,5,7)
P_{11}	(4.2,4.2,4.2)	(7,11,13)	(5,7,9)	(1,3,5)
P_{12}	(4.2,4.2,4.2)	(14,17,20)	(3,5,7)	(3,5,7)
P_{13}	(4.5,4.5,4.5)	(2,4,6)	(5,7,9)	(1,3,5)
P_{14}	(4.5,4.5,4.5)	(7,11,13)	(3,5,7)	(3,5,7)
P_{15}	(4.5,4.5,4.5)	(14,17,20)	(5,7,9)	(1,3,5)
P_{16}	(4.5,4.5,4.5)	(2,4,6)	(3,5,7)	(3,5,7)
P_{17}	(4.5,4.5,4.5)	(7,11,13)	(5,7,9)	(1,3,5)
P_{18}	(4.5,4.5,4.5)	(14,17,20)	(3,5,7)	(3,5,7)

Table 4. The Ideal and Anty-ideal package based on the negotiation spaces

Package	Z_1 Price		Z_2 Payment		Z_3 Returns	
	Buyer	Seller	Buyer	Seller	Buyer	Seller
Ideal	(3.5,3.5,3.5)	(5,5,5)	(30,30,30)	(1,1,1)	(9.9.10)	(9.9.10)
Anty-ideal	(4.5,4.5,4.5)	(4,4,4)	(1,1,1)	(30,30,30)	(0,0,1)	(0,0,1)

The results of calculation of the CC_i coefficients and the final ranking are presented in Table 5. In Case II the ranking does not include the ideal and anty-ideal solutions.

Table 2. Closeness coefficients (CC_i) and the ranking.

Package	Buyer				Seller			
	Case I $CC_i(B)$	Case I Rank	Case II $CC_i(B)$	Case II Rank	Case I $CC_i(S)$	Case I Rank	Case II $CC_i(S)$	Case II Rank
P_1	0.434299	11	0.355492	9	0.474233	8	0.23528	12
P_2	0.614253	7	0.405742	6	0.323746	12	0.222927	13
P_3	1	1	0.546687	1	0	18	0.128609	18
P_4	0.337788	13	0.312375	12	0.716895	4	0.309821	6
P_5	0.710509	5	0.448663	4	0.081175	17	0.147316	17
P_6	0.903489	2	0.503916	2	0.242662	14	0.204311	14
P_7	0.289533	14	0.290137	14	0.587475	6	0.282238	7
P_8	0.469868	10	0.340275	11	0.436946	9	0.270800	8
P_9	0.855234	3	0.481282	3	0.113242	16	0.176455	16
P_{10}	0.193022	15	0.246890	16	0.830137	2	0.356887	2
P_{11}	0.566124	8	0.383326	8	0.194375	15	0.195077	15
P_{12}	0.758723	4	0.438381	5	0.355904	11	0.252271	10
P_{13}	0.096511	17	0.202998	17	0.757338	3	0.352674	3
P_{14}	0.277354	15	0.252987	15	0.606745	5	0.342611	4
P_{15}	0.662212	6	0.394075	7	0.283105	13	0.248226	11
P_{16}	0	18	0.159578	18	1	1	0.427487	1
P_{17}	0.373611	12	0.296210	13	0.364174	10	0.266718	9
P_{18}	0.565701	9	0.351000	10	0.525767	7	0.324211	5

According to the decreasing closeness coefficient we may build the ranking of 18 packages under consideration:

- Buyer's ranking:

Case 1:

$P3 \succ P6 \succ P9 \succ P12 \succ P5 \succ P15 \succ P2 \succ P11 \succ P18 \succ P8 \succ P1 \succ P17 \succ P4 \succ P7 \succ P14 \succ P10 \succ P13 \succ P16$

Case 2:

$P3 \succ P6 \succ P9 \succ P5 \succ P12 \succ P2 \succ P15 \succ P11 \succ P1 \succ P18 \succ P8 \succ P4 \succ P17 \succ P7 \succ P14 \succ P10 \succ P13 \succ P16$

- Seller's ranking:

Case 1:

$P16 \succ P10 \succ P13 \succ P4 \succ P14 \succ P7 \succ P18 \succ P1 \succ P8 \succ P17 \succ P12 \succ P2 \succ P15 \succ P6 \succ P11 \succ P9 \succ P5 \succ P3$

Case 2:

$P16 \succ P10 \succ P13 \succ P14 \succ P18 \succ P4 \succ P7 \succ P8 \succ P17 \succ P12 \succ P15 \succ P1 \succ P2 \succ P6 \succ P11 \succ P9 \succ P5 \succ P3$

The introduction of two additional alternatives results in the change of values within the data matrix normalization, so the results of the final ranking change. However this change is not radical. The nine packages for Buyer and eight for Seller do not change their positions. The others change their positions only of one or two levels.

Symmetrical analysis allows for identification of the Pareto-optimal packages. For Case 1 the efficient offers are: P3, P4, P6 ,P10, P12, P16 and P18 (see Figure 2).

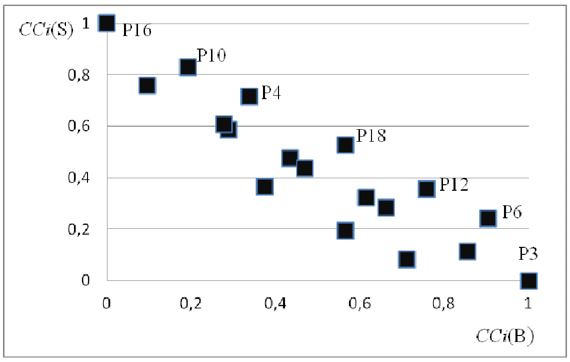

Fig. 2. Negotiation packages in the criteria space of the negotiators - Case 1.

For Case 2 the Pareto-optimal packeges are: P3, P6, P10, P12, P14, P16 and P18 (see Figure 3).

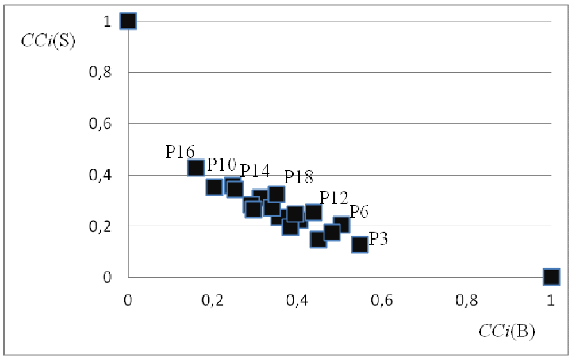

Fig. 3. Negotiation packages in the criteria space of the negotiators - Case 2.

4 Conclusion

One of the key advantage of fuzzy TOPSIS is it can deal with the different types of values: crisp, interval, fuzzy or linguistic. Fuzzy TOPSIS algorithm allows all the data to be transformed into a common domain of TFNs, and conduct all calculation required using fuzzy arithmetic. Its application to negotiation support allows analyzing the ill-structured negotiation process, in which the problem itself as well as the negotiators preferences cannot be precisely defined. However, the specificity of the negotiation process requires some modification to be applied to the classic fuzzy TOPSIS approach.

In this paper we addressed the main problems that may occur when applying fuzzy TOPSIS for negotiation support. First we formalized the negotiation problem and built the model of ill-structured negotiation problem, in which the negotiators preferences cannot be defined by means of crisp values. Next we suggested to define the negotiation space by means of the subjectively defined ideal and anti-ideal solutions, which may allow avoiding the problem of scoring the counterparts offers out of the negotiation space, propose later on during the negotiation phase. We discussed the issue of scoring such offers on the basis of two distinct approaches: non-compensatory and quasi-compensatory. What is important, the ranking will vary depending on the approach applied. What we finally tried to show is the application of the modified fuzzy TOPSIS algorithm to the symmetric analysis of the ill-structured negotiation process, which will allow for conducting post-optimization analysis and potential determining of the arbitration solutions. The future work will focus on the applying the fully compensatory approach and replacing the notions of distances in traditional TOPSIS algorithm by the idea of positive and negative deviations.

References

Chen, C.T. (2000), Extension of the TOPSIS for group decision-making under fuzzy environment, *Fuzzy Sets and Systems*, 114, 1–9.

Chen, C.T, Hwang, C.L. (1992), *Fuzzy Multiple Attribute Decision Making Methods and Applications*, Springer-Verlag, Berlin.

Chen, M.F., Tzeng, G.H. (2004), Combining grey relation and TOPSIS concepts for selecting an expatriate host country, *Mathematical and Computer Modelling*, 40, 1473–1490.

Chu, T.C. (2002), Facility location selection using fuzzy TOPSIS under group decisions, *International Journal of Uncertainty, Fuzziness & Knowledge-Based Systems*, 10, 687–701.

Hwang, C. L., Yoon, K. (1981), *Multiple Attribute Decision Making: Methods and Applications*, Springer-Verlag, Berlin.

Hellwig, Z. (1968), Procedure of evaluating high level manpower data and typology of countries by means of the taxonomic method, *Statistical Review* (pol. Przegląd Statystyczny), 15(4), 308-327 (full text in Polish).

Jadidi, O., Hong, T.S., Firouzi, F., Yusuff, R.M., Zulkifli, N. (2008), TOPSIS and Fuzzy Multi-Objective Model Integration for Supplier Selection Problem, *Journal of Achievements in Materials and Manufacturing Engineering*, vol. 31(2), 762-769.

Jahanshahloo, G.R., Hosseinzadeh Lofti F., Izadikhah, M. (2006a), An Algorithmic Method to Extend TOPSIS for Decision Making Problems with Interval Data, *Applied Mathematics and Computation*, 175, 1375-1384.

Jahanshahloo, G.R., Hosseinzadeh Lofti F., Izadikhah, M. (2006b), Extension of the TOPSIS Method for Decision-Making Problems with Fuzzy Data, *Applied Mathematics and Computation*, 181, 1544-1551.

Kahraman, C., Buyukozkan, G., Ates, N.Y. (2007), A two phase multi-attribute decision-making approach for new product introduction, *Information Sciences*, 177, 1567–1582.

Keeney, R., Raiffa, H. (1976), *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*, New York: Cambridge University Press.

Kersten, G.E., Noronha, S.J. (1999), WWW-Based Negotiation Support: Design, Implementation And Use. *Decision Support Systems*, 25, 135-154.

Lin M-C, Wang C-C, Chen, M-S, Chang, CA. (2008), Using AHP and TOPSIS approaches in customer driven product design process, *Comput Indus* 59(1), 17–31.

Olson, D.L. (2004), Comparison of weights in TOPSIS models, *Math Comput Modell* 40(7-8),721–727.

Paradis, N., Gettinger, J., Lai, H., Surboeck, M., Wachowicz, T. (2010), E-Negotiations via Inspire 2.0: The System, Users, Management and Projects. In: de Vreede, G.J. (ed.). *Group Decision and Negotiations 2010. Proceedings*. The Center for Collaboration Science, University of Nebraska at Omaha, 155-159.

Raiffa, H., Richardson, J., Metcalfe, D. (2002), *Negotiation Analysis*. The Belknap Press of Harvard University Press, Cambridge.

Saaty, T.L. (1980). *The Analytic Hierarchy Process*, New York, N.Y., McGraw Hill.

Schoop, M., Jertila, A., List, T. (2003), Negoisst: a negotiation support system for electronic business-to business negotiations in ecommerce. *Data Knowledge Engineering*, 47, 371-401.

Shyur, H.J, Shih, H.S. (2006), A hybrid MCDM model for strategic vendor selection, *Math Comput Modell* 44(7–8), 749–761.

Thiessen, E.M., Soberg, A. (2003), Smartsettle described with the montreal taxonomy. *Group Decision and Negotiation*, 12, 165-170.

Tsaur, S.H, Chang, T.Y, Yen, C.H. (2002), The evaluation of airline service quality by fuzzy MCDM, *Tourism Management* 23(2), 107–115.

Wachowicz, T., Kersten, G.E. (2009), Decisions And Manners Of Electronic Negotiation System Users. In: Kłosiński, K.A., Biela, A. (eds.). *Proceedings of An International Scientific Conference "A Man And His Decisions"*, The Publisher of The John Paul II Catholic University Of Lublin, 63-74.

Wang, Y.M., Elhag, T.M.S. (2006), Fuzzy TOPSIS method based on alpha level sets with an application to bridge risk assessment, *Expert Systems with Applicatio*ns 31 309–319.

Zadeh, L.A. (1965), Fuzzy sets, *Information and Control*, 8, 338-353.

Zadeh, L.A. (1975), The concept of a linguistic variable and its application to approximate reasoning: Part 1., *Information Sciences*, 8, 199-249.

TOPSIS Based Negotiation Support System and Its Modification

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Abstract: TOBANS 2.0 is a Web-based negotiation support system, which supports the offers evaluation and exchange in bilateral negotiation. The TOPSIS method is used to support the preference elicitation phase, however, the traditional algorithm was modified to adjust the TOPSIS distance functions to the negotiators preference functions. We discussed the modified model as well as propose another modification that allows negotiators to define preferences by specifying the packages examples with scores assigned.

Keywords: negotiation support systems, preference analysis, TOPSIS, distance function sensitivity analysis, gradient descent.

1 Introduction

Very many software solutions that are used for negotiation support provide their users with the tools for decision analysis and negotiation offers evaluation. Deriving from negotiators preferences they build the negotiation offers' scoring systems that are used in actual negotiation phase for evaluating the offers under consideration, suggesting the counteroffers, measuring the scale of concessions made by the parties, tracking the negotiation progress and – in post-negotiation phase – conducting the symmetric analysis of the negotiation space in order to find the fair and mutually accepted solution. Such a decision support is proposed in the most known negotiation support systems (NSSs) like: Inspire (Kersten and Noronha, 1999), Negoisst (Schoop et al., 2003) or SmartSettle (Thiessen and Soberg, 2003). Naturally, this support is given on the basis of the formal operations research models applied in these systems, that are mainly derived from multiple attribute utility theory (MAUT). Usually the simplest solution is applied, i.e. an additive weighting method (SAW), originally proposed by Keeney and Raiffa (1976) – or its modifications. It requires of negotiators assigning the abstract scores (e.g. utilities or desireabilities) to all pre-defined negotiation issues and options (i.e. resolution levels of these issues). Conceptually, the scoring algorithm is very clear and simple. However, it assumes the negotiation problem itself to be adequately structured, well formalized and defined in a form of discrete decision problem. Such a structuring may be effective if the negotiation problem is small or the negotiation issues' resolution levels can be clustered into few distinctive sets of salient options only, then the scores' assignment process would be neither time consuming nor tiring. Unfortunately, the real negotiation problems are usually too complicated to be presented in a discrete form. What is more, some research show that despite its simplicity, SAW results are quite often misinterpreted by the negotiators (see Wachowicz and Kersten, 2009; Paradis et al., 2010).

In this work we present a new negotiation support system, called TOBANS (ver. 2.0), the evaluation capabilities of which are implemented by means of the main ideas of TOPSIS method (Hwang and Yoon, 1981). To apply TOPSIS for scoring continuous negotiation problems some modifications need to be implemented in the original algorithm. We discuss all these technical modification as well as present some additional solutions that should be taken into consideration to make the TOPSIS scoring describe the negotiators' preferences more precisely. In the next section of the paper we give a brief reminder of classic TOPSIS method and then we discuss all the modifications required to apply it to the preferences elicitation process in the negotiation context. In particular, we discussed the possibilities of modification of the traditional forms of distance measures used in TOPSIS, to make these measures describe the negotiators' preferences in more accurate way. We used the statistical notion of manipulating the sensitivity of the distance measures for both small and large changes of values. Next, in section 3, we describe TOBANS 2.0 system specifying its technical configuration and major functionalities. We show in details how the preference elicitation process is supported currently by TOBANS system. In section 4 we present the possible modification of the currently applied preference elicitation mechanism. We change the philosophy of preference definition, rejecting the original idea that aggregates the single criteria analysis to obtain the global score. Instead, we try to find all the TOPSIS scoring formula parameters by analyzing the packages examples built by negotiators and decomposing the global scores assigned to this packages.

2 TOPSIS for decision support in negotiations

2.1 TOPSIS fundamentals

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) was developed as the method for ranking the alternatives described by multiple criteria. However there are some earlier works formulating the very similar problem and suggesting its similar solution (see Hellwig, 1968), there were Hwang and Yoon (1981) that proposed the method in this present form. The method uses a bipolar reference system comprised with the positive ideal solution (PIS) and the negative ideal solution (NIS), to which the distances are determined for each alternative that needs to be ranked. A single scalar criterion is built then as an aggregate of these distances, that is used to find the final global ranking.
TOPSIS requires decision problem to be well structured, namely all m alternatives and n evaluation criteria need to be predefined as well as the numerical consequences of each alternative with respect to each criterion (the strong-scale variables must be used). The decision maker (DM) defines also the vector of weights $w = (w_1, w_2, \ldots, w_n)$ (where $\sum_{j=1}^{n} w_j = 1$ and j denotes the number of evaluation criteria), reflecting the relative importance of the criteria. Having the problem structured this way, the TOPSIS formal ordering procedure may be applied, that consists of the seven following steps:

1. *Building the decision matrix of the problem:*

$$X = [x_{ij}], \qquad (1)$$

where x_{ij} is a resolution level of ith alternative with respect of jth criterion ($i = 1,2,....,m;\ j = 1,2,...,n$ and $x_{ij} \in \Re$).

2. *Building the normalized decision matrix:*

$$N = [\widehat{x}_{ij}], \qquad (2)$$

where $\widehat{x}_{ij}$ is determined using the following normalization formula

$$\widehat{x}_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} {x_{ij}}^2}}, \qquad (3)$$

for $i = 1,2,....,m$ and $j = 1,2,...,n$.

3. *Computing the weighted normalized decision matrix:*

$$V = [w_j \widehat{x}_{ij}] = [v_{ij}], \qquad (4)$$

for $i = 1,2,....,m$ and $j = 1,2,...,n$.

4. *Determining the positive ideal* (A+) *and negative ideal* (A–) *solutions:*

$$A^{+} = (v_1^{+}, v_2^{+}, \ldots, v_n^{+}), \quad (5)$$

where $v_j^{+} = \begin{cases} \max\limits_i v_{ij}, & \text{if } j \text{ is a benefit criterion} \\ \min\limits_i v_{ij}, & \text{if } j \text{ is a cost criterion} \end{cases}$,

$$A^{-} = (v_1^{-}, v_2^{-}, \ldots, v_n^{-}), \quad (6)$$

where $v_j^{-} = \begin{cases} \min\limits_i v_{ij}, & \text{if } j \text{ is a benefit criterion} \\ \max\limits_i v_{ij}, & \text{if } j \text{ is a cost criterion} \end{cases}$.

5. *Calculating the distances from* PIS (d_j^{+}) *and* NIS (d_j^{-}):

$$d_i^{+} = \sqrt[p]{\sum_{j=1}^{n} \left| v_{ij} - v_j^{+} \right|^{p}}, \text{ for } i = 1,\ldots,m, \quad (7)$$

$$d_i^{-} = \sqrt[p]{\sum_{j=1}^{n} \left| v_{ij} - v_j^{-} \right|^{p}}, \text{ for } i = 1,\ldots,m, \quad (8)$$

where p is the distance coefficient (usually p = 2 for the Euclidean distance).

6. *Determining the relative closeness of each alternative to the ideal solution*:

$$S_i = \frac{d_i^{-}}{d_i^{+} + d_i^{-}}, \text{ for } i = 1,\ldots,m, \quad (9)$$

where $0 \le S_j \le 1$.

7. *Ranking the alternatives in descending order using* S_j.

Having completed the above scoring procedure the decision maker obtains a full order of the alternatives. The higher score of the alternative, the better (more preferred) it is.

2.2 Using TOPSIS for scoring negotiation offers

TOPSIS scoring algorithm may be applied directly to scoring negotiation offers only if the negotiation problem id defined as a discrete decision problem and all the issues have a quantitative character. If not, the series of modification need to be implemented in the algorithm depending on the negotiation context, problem's structure, types of issues and the philosophy of trade-offs making. There are some theoretical works on the TOPSIS modifications and its legitimacy when applied to negotiation support (see Wachowicz, 2011; Roszkowska and Wachowicz, 2012). Here we only describe the modifications of the traditional TOPSIS algorithm (see Section 2.1) when the continuous negotiation problem is considered, that base on the Wachowicz previous ideas (Wachowicz, 2011b).
TOPSIS operates on a decision matrix X, the values of which are used for normalization (step 2, formula 3) and identification of both PIS and NIS (step 4, formulas 5 and 6). We cannot perform these steps of algorithm when the continuous problem is considered. Therefore we will follow an alternative approach, which does not refer to the whole set of the issues' options. When defining PIS and NIS alternatives we will use the aspiration and reservation levels of each negotiation issue that negotiators usually define within a pre-negotiation preparation phase. The issues' aspiration values x_j^{asp} will define the hypothetical ideal solution, while the reservation ones x_j^{res} – the hypothetical anti-ideal solution. We will assume then, that the negotiation space is limited to the ranges defined by aspiration and reservation levels, which may

cause problems in actual negotiation phase with scoring the counterpart's offers that are outside of this space. We will not discuss such problems in this paper, however there are some theoretical solutions that allow to cope with scoring such alternatives applying both non-compensatory and quasi-compensatory approach (see Roszkowska and Wachowicz, 2012).
Having defined ideal and anti-ideal solutions by means of the aspiration and reservation options we may handle the problem of normalization by replacing the classic normalization formula (3) by the one that refers to the interval between the extreme values (e.g. the linear normalization formula)

$$\hat{x}_{ij} = \frac{x_{ij} - x_j^{\text{res}}}{x_j^{\text{asp}} - x_j^{\text{res}}}, \text{ for } j = 1,\ldots,n. \qquad \textbf{(10)}$$

To have a clear definition of PIS and NIS alternatives (normalized and weighted) we will change the negotiation problem to the vector maximization problem. Therefore any cost-type negotiation issue should be changed into the benefit-type, using the classic statistical procedures of transformation between stimulant and destimulant variables. According to the formulas (5) and (6) we would be able then to define PIS and NIS alternatives in the following forms

$$A^+ = \left[v_j^+ : \underset{j=1,\ldots,n}{\forall} v_j^+ = w_j \right], \qquad \textbf{(11)}$$

$$A^- = \left[v_j^- : \underset{j=1,\ldots,n}{\forall} v_j^- = 0 \right]. \qquad \textbf{(12)}$$

In our continuous negotiation problem we do not have the matrix V explicitly defined, which would combine the weights with the alternatives' normalized resolution levels. Thus the weights will be taken into consideration while the distances are calculated. Instead of using the original the formulas (7) and (8) the classic Gower's measure (Gower, 1971) may be applied, which is an aggregate of the weighted single-criterion distances

$$d_{ab}^G = \sum_{j=1}^{n} w_j d_{ab,j}, \qquad \textbf{(13)}$$

where $d_{ab,j}$ denotes the distance between two alternatives a and b for jth criterion.
The formula (13) will be used for calculating the separation measures for any feasible negotiation offer proposed by the parties within the actual negotiation phase. The relative closeness (S_j) of jth alternative can be determined then using the original formula (9).

2.3 TOPSIS modification for more accurate preference mapping

One of the major problems in applying TOPSIS for solving DM's multi-criteria problem is the selection of the proper form of the distance measure. Usually the Euclidean distance is applied or the Minkowski general distance formula with various p coefficients. No attention is paid to the appropriateness of such a distance measure, i.e. to the selection of the distance measure that reflects the DM's preferences in most accurate way. However, it is possible to take into consideration the shapes of preference function in the TOPSIS scoring. Here we refer to the some earlier studies (Wachowicz, 2011b; Roszkowska and Wachowicz, 2011) the results of which were adopted and implemented in TOBANS 2.0 system. Later, in Section 4, we will propose another approach that may be applied for identifying the most adequate distance function for TOPSIS based negotiation scoring system.
The shape of distance function that map the true shape of negotiator's preference function may be determined using the statistical approach of analyzing the sensitivity of various distance metrics to small changes of variables' values. By using this approach we may build a single-criteria distance function being a p root of the classic Minkowski single-criteria distance measure, i.e.

$$d_{ab,j} = \sqrt[p]{\left| v_{aj} - v_{bj} \right|}, \qquad \textbf{(14)}$$

that may be used as the components of the global distance function (13). The only problem is to determine the true *p* coefficients that describe the negotiator's single-criteria preferences the best. We may apply the following interactive procedure to find these coefficients (Roszkowska and Wachowicz, 2011):

1. Select the evaluation criteria, for which the distance function needs to be determined.
2. Present to DM the resolution level of a selected criterion, being an average value of ideal and anti-ideal solutions.
3. Get form DM their evaluation of the presented resolution level (the evaluation may be defined by means of a linguistic scale, verbally, numerically etc.).
4. Decode this evaluation to the normalized metric value and use it as $d_{ab,j}$ in the formula (14),
5. Find *p* coefficient by solving formula (14), where v_{aj} is a normalized value of the average resolution level, and $v_{bj} = v_j^+$ (note that $v_{aj} - v_{bj} = 0.5$).
6. Repeat steps 1 – 5 and aggregate the results in the multi-criteria Gower's distance formula.

The main idea of this interactive procedure is presented in Figure 1. Let us assume that the DM has evaluated the average resolution level of the considered criterion using a linguistic scale as a quite good, which was mapped to the numerical equivalent of 0.65. This numerical equivalent is a similarity coefficient *s*, but to keep our analysis in terms of distances we need to transform it to the dissimilarity coefficient. We use the traditional transformation formula $s = 1 - d$, and obtain $d = 1 - 0.65 = 0.35$. We introduce this coefficient as $d_{ab,j}$ to the formula (14)

$$0.35 = \sqrt[p]{0.5}\,, \qquad \textbf{(15)}$$

and find $p \approx 0.67$.

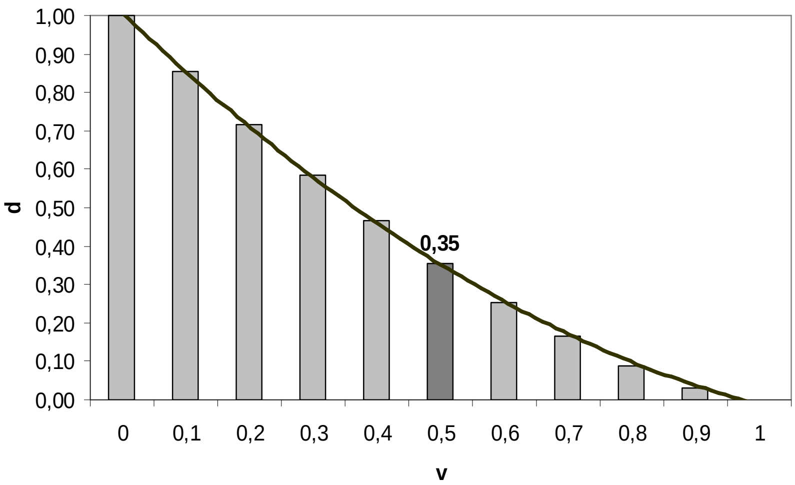

Fig. 1. Estimation of distance function sensitivity coefficient *p* for TOPSIS

3 TOBANS 2.0 – the system configuration and functionalities

TOPSIS method and its modifications described in section 2 were applied in TOBANS 2.0 – TOPSIS Based Negotiation Support System. TOBANS was developed to support negotiators' activities pre-negotiation and actual negotiation phases. It is developed as a distributed system and is deployed on Web. Technically, TOBANS 2.0 is coded according to the MVC architectural pattern in PHP 5.3.0 script language with all the data stored in MySQL database. The general configuration of the system is similar to the one used in Inspire (Kersten and Noronha, 1999) and Negoisst (Schoop et al., 2003) systems and is presented in Figure 2.

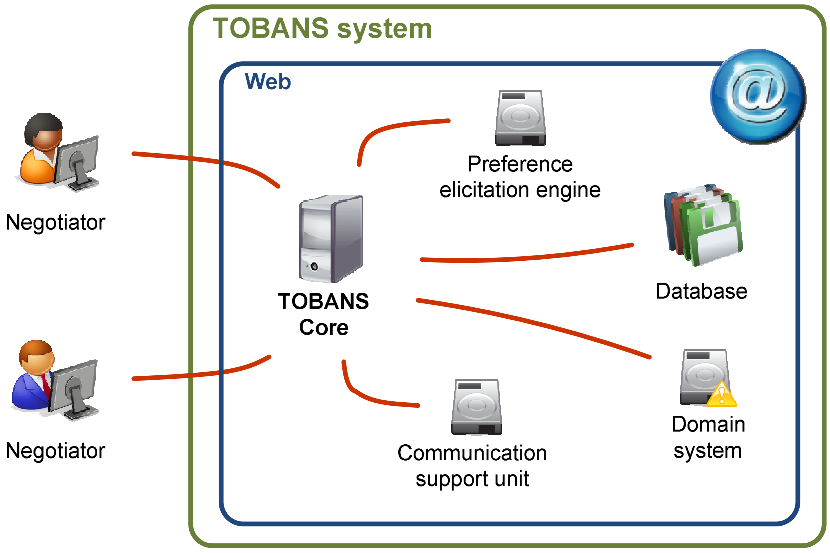

Fig. 2. TOBANS 2.0 configuration

In this configuration there is one core system through which users negotiate and interact with other satellite supportive sub-systems, here the preference elicitation engine (PEE) and communication support unit (CSU). It is also connected to the database where all the information about the historical and ongoing negotiation processes is stored; and to the domain system, in which the system parameters and global variables and constants are defined. The whole system works as a "third party" and remains independent of the negotiators. They may use it as a supportive tool for their own negotiation activities, since the system provides them with the models and algorithms allowing for the asymmetric analysis. However, all the data gathered and processed by the system (including the sensitive and strategic information about negotiators' interests, preferences etc.) is confidential and negotiators are not allowed to use it for their own private purposes. Such information may be used only by the system itself in conducting the symmetrical analysis of the negotiation problem, which aims at finding the fair and mutually accepted agreement (by implementing some game-theoretic concepts of arbitration and fair division).

TOBANS major functionalities are provided by the system's core (supported by the domain system), communication support unit, and the preference elicitation engine. The core coordinates the negotiators activities as well as all the supportive functionalities provided by the satellite sub-systems. It allows negotiators to register (i.e. create their individual negotiation accounts) and watches the negotiation process to be realized according to the protocol specified by the domain system. Furthermore, it presents to the users all the additional supportive tools that do not require an advance coding, such as the psychometric personalities tests (TOBANS 2.0 implements Thomas-Kilmann Conflict Mode Instrument the negotiators may use for identifying their negotiation styles (Kilmann and Thomas, 1983)). The core is also responsible for implementing all the preference elicitation procedures and communication facilities provided by PEE and CSU.

The preference elicitation unit provides the system's core with all procedures and algorithms necessary for preparing the negotiation offers' scoring system within the pre-negotiation phase. Namely, it provides the protocol for negotiation problem definition and the formalized algorithm for preference elicitation and modifications (here, the one based on the modified TOPSIS procedure presented in Section 2). Within this algorithm the system's user needs to specify the importance of the issues and evaluate an average resolution level for each issue. This evaluation is done by means of the verbal descriptors that are encoded to the numerical equivalents according to the predefined linguistic scales usually used in TOPSIS (see Chen, 2000). Technically, the sliders are used in the preference analysis template and the negotiator defines their preferences using these graphical elements of the website (Figure 3).

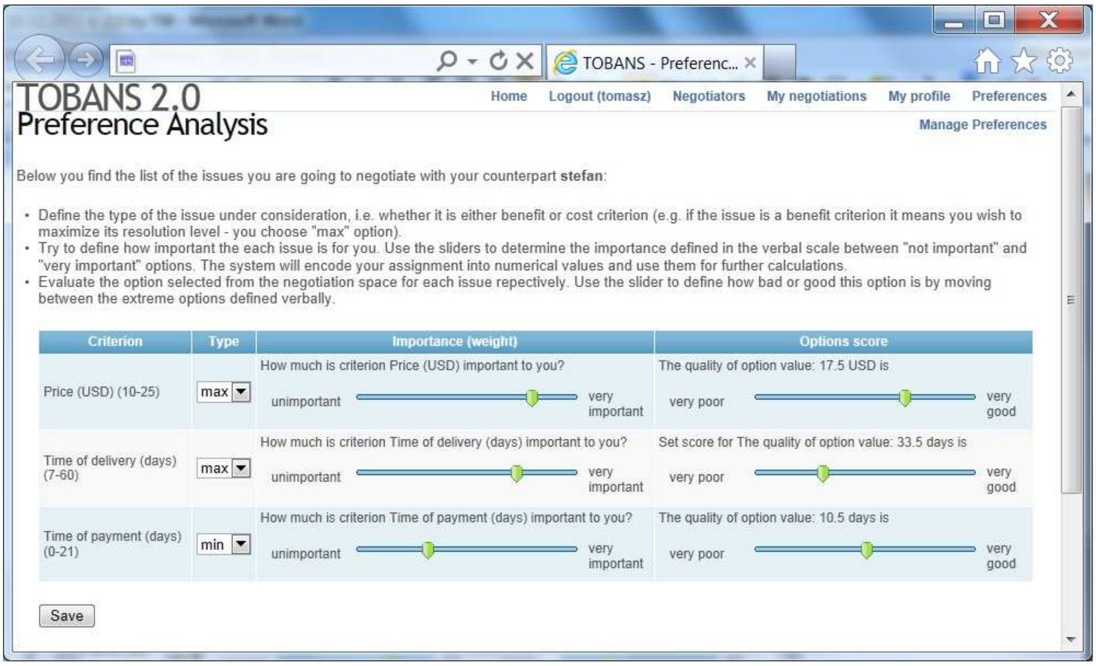

Fig. 3. Defining preferences in TOBANS 2.0

Using this basic information PEE visualizes the preferences in the forms of the graphs of the single criteria distance functions with some salient options marked on them. The user may change the estimated shapes of the distance functions manipulating with the sliders (Figure 4).

The communication support unit is responsible for facilitating the actual negotiation phase. It provides the system's core with the set of templates for offers and messages exchange and tracking the negotiation history. The offers exchange template offers to the user the message box for presenting the argumentation line and separate table, in which the negotiation offer may be defined in a form of the full package. Using the JQuery solutions CSU is able to calculate the virtual score of the currently built offer and present it to the user before accepting and sending this offer to the counterpart. The negotiation history template provides the users with the interactive history graph and the list of offers, comprising a useful interface to track the negotiation progress, examine the scale of concession made by the parties and giving a quick access to the sequence of offers sent in the successive negotiation rounds (Figure 5).

TOBANS does not offers currently the tools for supporting the post-negotiation phase. However, the system is still being developed and a new unit is being built now that will be responsible for post-negotiation analysis for the negotiators who achieved a compromise in actual negotiation phase. This unit will apply the Kalai-Smorodinsky's notion of bargaining solution (Kalai and Smorodinsky, 1975) to find an improvements of the negotiation agreement, similarly to the solutions used in other negotiation support systems, like NegoManage (Brzostowski, 2011b).

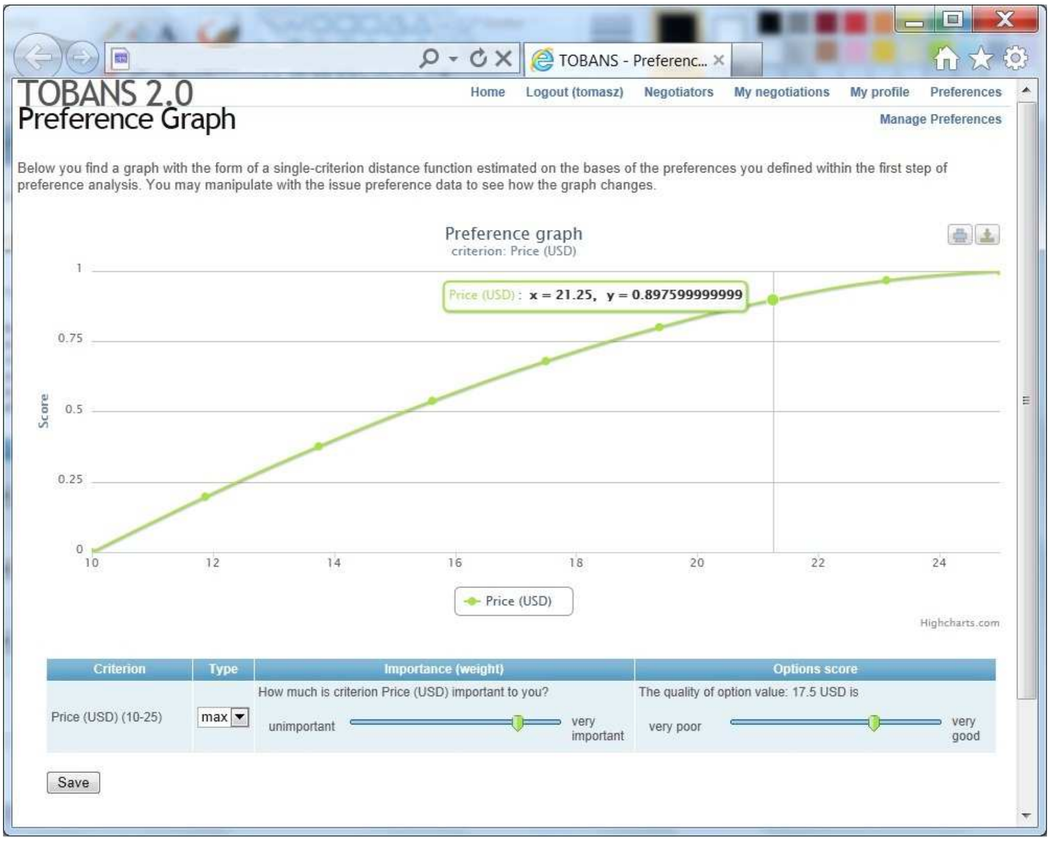

Fig. 4. TOBANS's single-criteria distance functions for describing negotiators' preferences

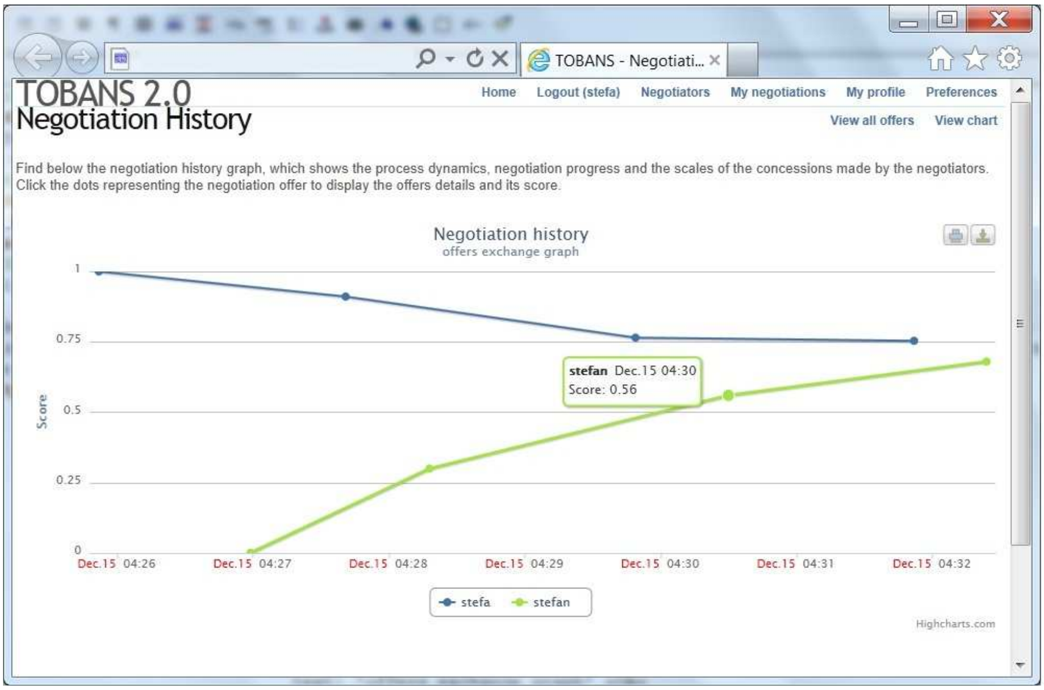

Fig. 5. Negotiation history graph and transcript in TOBANS 2.0

4 Alternative method for building the offer' scoring system

The preference elicitation interactive procedure currently applied in TOBANS 2.0 NSS is quite simple and straightforward but it generates the global form of single-criteria preference function based on a negotiator's single assessment of the predefined option. The question arises here, whether the estimated form of distance function would change if another option is selected for the evaluation or if more than one options are evaluated simultaneously. The main advantage of the proposed approach is that it does not require of negotiator to take part in time consuming and tiresome process of scoring the dozens of options and issues, but it may be considered as the over-generalizing the individuals' preferences. However, another approach may be proposed, that would allow to find the sensitivity coefficients of TOPSIS distance functions and simultaneously would not derive only from the single examples of the option scores for each issue separately. This approach is based on the series of the examples of the full packages the negotiator is able to construct indentifying simultaneously their quality levels.

We propose to use a notion of a gradient descent optimization (see Avriel, 2003; Snyman, 2005) that would allow us to find the sensitivity coefficient of single-criteria distance function. The evaluation of an alternative $\overline{x}_i = (x_{i1}, x_{i2}, \ldots, x_{ij})$ with varying value of sensitivity (tuning) coefficients $\overline{p} = (p_1, p_2, \ldots p_n)$ is defined, according to the TOPSIS scoring algorithm, as follows:

$$S_i(\overline{p}) = \frac{d_i^-}{d_i^- + d_i^+}, \tag{16}$$

where $d_i^- = \sum_{j=1}^{n} w_j \hat{x}_{ij}^{p_j}$ and $d_i^+ = \sum_{j=1}^{n} w_j (1 - \hat{x}_{ij})^{p_j}$ and NIS and PIS resolution levels for each criterion are normalized to achieve the values of 0 and 1 respectively .

We aim at determining the values of tuning parameters for a given set of examples. The scoring for each alternative from a set $X = \{\overline{x}_1, \overline{x}_2, \ldots, \overline{x}_k\}$ is given as follows $S = \{s_1, s_2, \ldots, s_k\}$. These scores, to be coherent with the TOPSIS scoring results, should be the real values form the range $\langle 0;1 \rangle$. However, they do not need to be defined by the negotiators directly in a form of the numerical values, since they may use one of the linguistic scales proposed for TOPSIS procedure (Chen, 2000). The determination of tuning parameter will require to solve an optimization problem of the following form:

$$\overline{p}_0 = \arg\min \sum_{i=1}^{k} | S_i(\overline{p}) - s_i | . \tag{17}$$

To have the objective function in a differentiable form we solve the problem of least squares minimization:

$$\overline{p}_0 = \arg\min \sum_{i=1}^{n} (S_i(\overline{p}) - s_i)^2 . \tag{18}$$

Therefore the objective function is of the following form:

$$s(\overline{p}) = \sum_{i=1}^{k} (S_i(\overline{p}) - s_i)^2 = \sum_{i=1}^{k} \left(\frac{\sum_{j=1}^{n} w_j x_{ij}^{p_j}}{\sum_{j=1}^{n} w_j x_{ij}^{p_j} + \sum_{j=1}^{n} w_j (1 - x_{ij})^{p_j}} - s_i \right)^2 . \tag{19}$$

To derive the gradient of the objective function we compute the partial derivatives and form the gradient as follows:

$$\nabla s(\overline{p}) = \left[\frac{\partial s}{\partial p_1}(\overline{p}), \frac{\partial s}{\partial p_2}(\overline{p}), \ldots, \frac{\partial s}{\partial p_n}(\overline{p}) \right]. \tag{20}$$

To apply the steepest descent algorithm we choose a starting point first. Let us assume that we have chosen starting point $\overline{p}_0 = (p_{01}, p_{02}, \ldots, p_{0n}) \in D$. For this point we compute the negative gradient $-\nabla s(\overline{p}_0)$ value, which requires computing all the partial derivatives in the point $\overline{p}_0$. In every iteration the value of $\overline{p}_{m+1}$ is computed based on the value computed in previous iteration and the gradient value in the previous point. Since the algorithm converges only to local minimum of the objective function we can run the algorithm parallel for different starting points distributed in the parameters space, so the chance of finding the global minimum increases.
Having determined the vector $\overline{p}$ we may use these sensitivity coefficients for building the offers' scoring system as it was defined in Sections 2.1 and 2.2. Such a scoring system will have the same functionalities as the one proposed in Section 2.3 and may be alternatively applied (after solving a few implementation and technical problems) in TOBANS system.

5 Summary

In this work we discussed a general idea of using TOPSIS method in negotiation support. We presented the TOBANS system, that operates with a formal supportive framework based on the modified TOPSIS algorithm, and – as we tried to show – has (or may have, if developed further) the similar functionalities to the other NSSs that employ different formal models, in particular the most popular simple additive model – implemented in Inspire, SmartSettle or Negoisst systems. We decided to use an alternative approach for preference modeling since, as some research show, the simple additive weighting model may be sometimes misused (Paradis et al., 2010) and is traditionally limited to support the discrete negotiation (decision) problems. Using TOPSIS for negotiation support reduces the workload of negotiators in the pre-negotiation preference elicitation stage, since the only input data it requires is the vector of issues' weights. However, application of the traditional TOPSIS algorithm requires using the arbitrarily defined distance measure, which may not be strictly coherent with the preferences of the focal negotiator. Therefore we used a statistical approach for changing the sensitivity of the distance measures for small/large changes of values close to the reference value 0 (see Roszkowska and Wachowicz, 2011) to model the shape of distance function similar to the shape of negotiator's single-criteria preference function. Such a solution is applied in TOBANS 2.0 system, which general functionalities we discussed in Section 3. However, such an approach may be criticized for being too general, in particular, for over-generalizing the whole form of the distance function on the basis of the evaluation of the single resolution level chosen form the whole range of potential options. Thus, we developed a theoretical framework for an alternative approach that is based on the complete packages' evaluation made by the negotiator and employs the idea of a gradient descent optimization. It is however more complicated form the computational point of view and it may be difficult to implement it in the client-server configuration of the TOBANS interface. The calculations requires the series of iterations that are time consuming and, run by a few users simultaneously may overload the TOBANS server with the work. To solve this technical problem the future implementation of this approach may require moving the computational part of the TOPSIS algorithm to the client's side.

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References

Avriel, M. (2003), *Nonlinear Programming: Analysis and Methods.* Dover Publishing.

Brzostowski, J. (2011). Preference Analysis Approach based on formation of indifference sets for different values of extended linguistic scale, *The 21st International Conference on Multiple Criteria Decision Making 2011*, June 13-17, Jyvaskyla, Finalnd.

Brzostowski, J. (2011b). Improving negotiation outcome in the NegoManage system by the use of bargaining solution. *Conference on Methods and Applications of Operations Research 2011*, 16-18 October 2011, Trzebieszowice, Poland.

Chen C.T. (2000), Extension of the TOPSIS for group decision-making under fuzzy environment, *Fuzzy Sets and Systems*, 114, 1–9.

Gower, J.C. (1971), A general coefficient of similarity and some of its properties. *Biometrics*, 27, 857-874.

Hellwig, Z. (1968), Procedure of evaluating high level manpower data and typology of countries by means of the taxonomic method, *Statistical Review* (pol. Przegląd Statystyczny), 15(4), 308-327 (full text in Polish).

Hwang, C. L., Yoon K. (1981), *Multiple Attribute Decision Making: Methods and Applications*, Springer-Verlag, Berlin.

Kalai E., Smorodinsky M. (1975). Other solutions to Nash's bargaining problem. *Econometrica*, 43(3): 513–518.

Keeney, R., Raiffa, H. (1976), *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*, New York: Cambridge University Press.

Kersten, G.E., Lai, H. (2007). Negotiation Support and E-negotiation Systems: An Overview. *Group Decision and Negotiation*, 16, 553-586.

Kersten, G.E., Noronha, S.J. (1999), WWW-Based Negotiation Support: Design, Implementation And Use. *Decision Support Systems*, 25,135–154.

Moshkovich, H., Mechitov, A., Olson, D. (2005), *Verbal Decision Analysis*. Springer, New York.

Neumann, J. von, Morgenstern, O. (1944), *Theory of Games and Economic Behavior*, Princeton University Press.

Paradis, N., Gettinger, J., Lai, H., Surboeck, M., Wachowicz, T. (2010), E-Negotiations via Inspire 2.0: The System, Users, Management and Projects. In: de Vreede, G.J. (ed.). *Group Decision and Negotiations 2010. Proceedings*. The Center for Collaboration Science, University of Nebraska at Omaha, 155-159.

Roszkowska, E., Wachowicz, T. (2011), Methodological and Applicational Study of TOPSIS Method. *Conference on Methods and Applications of Operations Research 2011*, 16-18 October 2011, Trzebieszowice, Poland.

Roszkowska, E., Wachowicz, T. (2012), Negotiation Support with Fuzzy TOPSIS. *International Conference on Group Decision and Negoitation – GDN 2012*, 20-24 May 2012, Recife, Brasil.

Schoop, M., Jertila, A., List, T. (2003), Negoisst: a negotiation support system for electronic business-to business negotiations in e-commerce. *Data and Knowledge Engineering*, 47, 371–401.

Snyman, J.A. (2005), *Practical Mathematical Optimization: An Introduction to Basic Optimization Theory and Classical and New Gradient-Based Algorithms*. Springer Publishing.

Thiessen, E.M., Soberg, A. (2003), Smartsettle described with the montreal taxonomy. *Group Decision and Negotiation*, 12, 165-170.

Wachowicz, T. (2011). Application of TOPSIS Methodology to the Scoring of Negotiation Issues Measured on the Ordinal Scale. In: T. Trzaskalik, T. Wachowicz (eds.) *Multiple Criteria Decision Maiking'10-11*. Publisher of the University of Economics in Katowice, pp. 238-258.

Wachowicz, T. (2011b), TOPSIS Based Negotiation Offers' Scoring Approach For Negotiation Support Systems. In: Dargam, F., Delibasic, B., Hernández, J.E., Liu, S., Ribeiro, R., Zaraté, P. (eds.). *Proceedings Of The EWG-DSS London-2011 Workshop On Decision Support Systems.* London, UK, 2011, June 23-24, 24.

Wachowicz, T., Kersten, G.E. (2009), Decisions And Manners Of Electronic Negotiation System Users. In: Kłosiński, K.A., Biela, A. (eds.). *Proceedings of An International Scientific Conference "A Man And His Decisions"*, The Publisher of The John Paul II Catholic University Of Lublin, 63-74.

Keeping the Peace? Towards Evaluation of the Role of Online Support and Counseling in Avoiding Family Dispute Resolution

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Abstract: Participation in online support and counseling constitutes an essential but often overlooked second step in the Lodder-Zeleznikow (2010) model of online dispute resolution; dialogue techniques. This paper highlights the potential role that online support and counseling can play in avoiding extreme family conflict and potential litigation. It identifies key considerations and approaches for those developing, enhancing and evaluating online support and counseling sites in the future. The goal of this research is to assist Relationships Australia Victoria to construct online support and counseling services for men who have lost day-to day contact with their children and have diminished social networks.

Keywords: Family Dispute Resolution, online support and counseling, evaluation.

1 Introduction

In Australia, parents who are separating are required to participate in at least one mediation session prior to seeking a Parenting Order through the Family Court. This approach aims to place the interests of the child before all other concerns (through reductions in parental conflict) and reduce financial and administrative burdens on the court system through reductions in litigation (Bellucci et al., 2010).

Adjusting to single parenthood can be difficult for men and women. Although a parenting order is in place and mandatory mediation has been completed, major conflicts can and do arise. As a result, the majority of separating men lose day-to-day contact with their children, plus many of their social networks. As Smyth (2004) reports, in1997 around one million children in Australia under 18 were living with one natural parent and had a parent living elsewhere. This represents about 21 per cent of all children under 18 in Australia. For 88 per cent of these children, the parent with whom they lived was their mother. Only a tiny proportion (3 per cent) were in 'shared care' arrangements, although another 4 per cent of children had daily face-to-face contact with a non-resident parent (Smyth and Ferro, 2002). A later recent estimate based on both mothers' and fathers' reports, derived from the HILDA Survey, suggest that around 6 per cent of separated households share the care of dependent children. Of those who do see their non-resident parent, a significant minority (34 per cent) never stay overnight. Again, these estimates are mirrored with more recent data based on both mothers' and fathers' reports.

The research presented in this paper results from a request to the authors to help develop and evaluate a new Australian support and counseling web site that is being established in-part to assist fathers who have lost daily contact with their children[1]. Whilst the site will grow beyond this initial target demographic, an initial pilot is planned that will focus on men who no longer have daily access to their children.

1.1 Online Support and Counseling

Online support web sites consist of discussion boards or real time chat facilities which are sometimes complemented by information and support resources. Participation in online support web sites allows people to communicate and share information with others with similar interests and experience (Erera and Baum, 2009, Welbourne et al., 2009, Barak et al., 2008). Participants may not have friends in their face to

[1] In many countries such fathers are known as non-custodial parents.

face networks who share such interests and experience or they may not feel comfortable seeking support offline (Welbourne et al., 2009). Such sites allow people from distant locations, cultures and backgrounds who would otherwise not meet, to connect and form relationships (Rosen et al., 2010, Welbourne et al., 2009).

Time shifting is another facet of support web sites. They are open for review and input 24 hours a day (Welbourne et al., 2009, White and Dorman, 2001). This aspect makes them useful for people who like to reflect and post careful responses and people who are unable to participate in traditional support groups due to personal obligations or disability (White and Dorman, 2001).

Social support is a term used to describe the giving and receiving of information, messages of understanding or sympathy through a social exchange (Tixier et al., 2009, Thoits, 1986, Mickelson, 1997). Online (social) support sites also have the potential to reduce a sense of isolation and loneliness in active participants (Barak et al., 2008). Research indicates that actively engaging in an online support site can aid coping with stress and reduce negative impact on health providing an enhanced sense of well-being (Welbourne et al., 2009, Barak et al., 2008).

Online counseling web sites mostly use real-time text based, audio or audio visual chat based technologies (some may use asynchronous tools like discussion boards) to allow individuals to interact with trained counselors (Gedge, 2002, Barak, 2004). Such interaction may also be called telehealth (Wood and Griffiths, 2007) and e (Gedge, 2002, Barak, 2004), cyber or virtual therapy (Barak, 2004) (although these alternative terms can refer to structured medical interventions for diagnosed conditions that are beyond the scope of this paper). Online counseling can be complementary to face to face counseling and offer users flexibility in time and place of access and in some cases, reduced costs when compared with fees for face to face therapy (Barak, 2004, Urbis Keys Young, 2002).

Support web sites created by lay people who do not seek to profit from them and professional therapy and counseling web sites are quite different in outcomes for participation (Barak et al., 2008). Support sites focus on providing an enhanced general sense of well-being, whereas therapeutic benefit may be obtained from interacting with trained professionals in a therapy or counseling environment (Barak et al., 2008).

Online support and counseling sites combine the aforementioned approaches to provide individuals with information and resources, the opportunity to engage in peer support communities via discussion boards or to consult a trained counselor via synchronous communication tools. Health and well-being organizations and medical practitioners have the opportunity to complement their face to face services with online support and counseling sites, providing their clients with access to reputable information and services (Tixier et al., 2009, Barak et al., 2008). The following section highlights one such opportunity.

1.2 Online Support and Counseling for Separated Australian Fathers

Bickerdike et al. (2009) claim that men’s social contacts and family networks may be less available once they have separated. If they are still intact, men may be reluctant to use them for support. Isolating themselves may seem like a good idea or the easiest option, but it may not help men to overcome their losses and will leave them alone. Withdrawing socially will limit the number of people they can talk to about the distressing events that have taken place. The loss, or lack of use, of social networks can increase the risk of prolonged depression, reliance on drugs and alcohol, and even suicide.

Such individuals can have a very negative experience in the transition to single parenthood. Feelings of powerlessness relating to visitation, decision making, child support payments and interactions with their former partner can lead to frustration, rage and a sense of isolation (Erera and Baum, 2009). There is a need for support and counseling services to ease the transition to single parenting. Such services are traditionally delivered in a face to face setting. However, in Australia, a distributed population across vast distances can mean that some individuals find it difficult to access face to face counseling and support. This indicates that there is an opportunity to supplement face to face support and counseling services with online services that can be accessed at any time and place.

As highlighted by Getz (2007), Canada is also a very large diverse country. For example, the population in British Columbia is sparsely distributed, with about 67 per cent of the communities in the province having 10,000 or fewer residents. At the same time, these communities have less than 10 per cent of the total population. People in many of these small communities, particularly those isolated by geography or distance, do not have good access to family mediation or other family justice services. The *Distance Mediation Project* — also known as the Technology-Assisted Family Mediation Project —

sought to provide these people with access to qualified family mediators with the help of information and communication technologies (Getz, 2007).

A range of support sites and services relating to parenting and separation is available online (e.g. (Erera and Baum, 2009, Hall and Irvine, 2009, Sarkadi and Bremberg, 2005)). However, individuals may find it difficult to ascertain the credibility of providers. This has prompted face to face support and counseling providers such as Relationships Australia Victoria (RAV) to investigate the introduction of online support and counseling sites for their client base. It would allow their clients to access support and counseling at a distance, with the assurance of quality support and expert counseling.

The provision of accessible online support and counseling services in Australia has been made possible by recent upward trends in computer access and internet connectivity. In 2003 35 per cent of households had access to the internet. By 2006 the percentage had almost doubled to 63 per cent (Australian Bureau of Statistics, 2008). Following the Australian federal elections of 2010, the Australian government has commenced the roll-out of a National Broadband Network. The 2008-9 Multi-Purpose Household Survey indicated that 72 per cent of Australian households had internet access, the majority of which were broadband connections and 78 per cent of households had computer access (Australian Bureau of Statistics, 2009). This increase in uptake means that more Australian households have access to the information and services provided online than ever before.

The authors have been invited to evaluate the online support and counseling site that, at the time of writing, is under development by RAV. This paper focuses on identifying key considerations for developing and enhancing online support and counseling web sites and reviews how such sites are being evaluated at present. The aim is to move toward an approach for evaluating one such support and counseling site to determine its efficacy in supporting individuals through matters that otherwise might result in Family Dispute Resolution.

2 Negotiation support systems for Family Dispute Resolution

This section introduces negotiation support systems and illustrates how they have been used in Family Dispute Resolution. The goal of our research is to supplement current online family decision support systems (as described in Wilson-Evered et al. (2011)) with online support and counseling to provide separated men with both important post-separation parenting advice as well as the opportunity to communicate with other men undergoing similar traumas.

2.1 A Model for Online Dispute Resolution

In their development of a three step model for Online Dispute Resolution, Lodder and Zeleznikow (2010) evaluated the order in which online disputes are best resolved. They suggested the following sequencing:

1. First, the negotiation support tool should provide feedback on the likely outcome(s) of the dispute if the negotiation were to fail – i.e. the Best Alternative to a Negotiated Agreement (BATNA).
2. Second, the tool should attempt to resolve any existing conflicts using dialogue techniques.
3. Third, for those issues not resolved in step two, the tool should employ compensation/trade-off strategies in order to facilitate resolution of the dispute.
4. Finally, if the result from step three is not acceptable to the parties, the tool should allow the parties to return to step two and repeat the process recursively until either the dispute is resolved or a stalemate occurs.

If a stalemate occurs, arbitration, conciliation, conferencing or litigation (or indeed any other Alternative Dispute Resolution technique) can be used to reach a resolution on a reduced set of factors. This action can narrow the number of issues in dispute, reducing the costs involved and the time taken to resolve the dispute.

Lodder and Zeleznikow’s (2010) model, in suggesting providing advice about BATNAs, facilitating dialogue and suggesting trade-offs, focuses upon E-Commerce applications. They claimed that their research assumes that disputants focus upon interests.

Whilst Family Dispute Resolution in Australia also focuses upon the interests of the parents, its main goal is to meet the paramount interests of the children. Abrahams et al. (2010) discuss how negotiation support systems can be constructed to meet issues of fairness. In law, the concept of fairness equates to the notion of justice. This is quite different from Brams and Taylor's (1996) concept of fairness in a two-party dispute which requires both parties interests to be equally met.

3 Online Family Dispute Resolution

Bickerdike et al. (2009) note that approximately 400,000 Australian men do not live with their children.

- 77 per cent of those children reside with their mother alone.
- For 92,000 men their children live with their mother and step or blended family.
- 26 per cent see their fathers less than once a year.

They suggest that separated men:

a) Make sure they have time to grieve the loss of the relationship.
b) Join a men's separation group to reflect, learn and grow.
c) Give them time to re-establish their own independent interests, pastimes and social networks.

Online Family Dispute Resolution services offer the opportunity for disputants to read reliable information and participate in discussion and support groups. The process of divorce/separation and developing new parenting patterns is traumatic. Nevertheless, 40 per cent of Australian parents go through this process, without preparation to support them. Clearly, comprehensive educational programs with realistic previews of Family Dispute Resolution scenarios that focus on what is in the best interests of children promise a potentially positive impact that is yet to be realized in Family Dispute Resolution. In addition, self-help groups and networked separated parenting sites can provide invaluable support and help as parents share their experiences and learning going through this major life change.

The online Family Dispute Resolution situation provides a very promising avenue for wide spread public as well as specialist education on family agreements focusing upon the best interests of children. An added advantage is the development of problem solving skills and decision making so that learning is disseminated among the community, increasing societal competences in the care of children. Much can be learned from other online platforms such as those used in counseling and tertiary education to inform the broader platform of online Family Dispute Resolution.

Pre-Family Dispute Resolution education type programs typically take one of two approaches – *pre-mediation orientation programs* that are designed specifically to prepare clients for their mediation sessions and/or *parent education programs* that are designed simply to educate or improve parenting and conflict skills (Lehner, 1994). Both programs share one common goal and that is to make sure the parents focus on the best interests of the child/children and minimize any adverse post separation conflict (Saposnek, 2004)[2].

Dr. Andrew Bickerdike and others at RAV believe that online support and counseling can be gainfully used to minimize the feelings of isolation and lack of support those parents undergoing a divorce face. Their first target group is divorcing fathers who are not primary care-givers for dependent children. Online counseling and support services can provide very important education and networking support for divorcing parents within the context of online Family Dispute Resolution.

4 Examining Online Support and Counseling for Parents and Children

In this section several examples of online support and counseling sites are summarized. Evaluation approaches are then examined and contrasted.

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[2] Thanks to Professor Elisabeth Evered-Wilson of the School of Management and Information Systems at Victoria University for advice about these issues.

4.1 Kids Help Line

Urbis Keys Young (2002) evaluated an online support and counseling service, Kids Help Line. Kids Help Line is an Australian support service for children aged 5-18 who can contact counselors via email, chat or via a telephone service to discuss any issue of concern. The study used an online survey (n=45[3]) to explore quality of service and client satisfaction. The survey questions were informed by previous internally developed evaluation instruments used by Kids Help Online and another Australian provider, Care Ring. The survey also used a five question quality of life indicator, EQ-5D (EuroQol, 2011). Over half of respondents were satisfied with the service. Respondents who were not satisfied reported response delays (to emails) and feeling they were not understood by the counselor. Clients reported decreased feelings of anxiety and depression (measured by the EQ-5D) post session. Approximately 60 per cent of respondents indicated that they had been referred to another service.

4.2 Kindertelefoon

A Dutch study by Fukkink and Hermanns (2009) evaluated a children’s support service, Kindertelefoon, comparing the efficacy of the one on one web chat and telephone services provided. Children aged 8-18 can ring a toll free number or access web chat online and converse with trained volunteers about issues of their choosing. The methodology used pre and post support web chat interviews, as well as a follow up online survey one month post contact. The evaluation focused on outcomes of the session including sense of well-being and relief of burden (instrument based on the 1965 Cantrill ladder), as well as durability of benefit. The study found that children experienced positive outcomes and they were satisfied with the service provided. Results indicated the strength of outcomes was increased for children using the web based service (as opposed to telephone). However, the study indicated that serious issues were being discussed by children with volunteer counselors requiring development of a referral service to ensure children could get specialized medical treatment where necessary.

4.3 alt.dads-rights

A study by Erera and Baum (2009) examined and classified 450 postings in an online discussion group, alt.dads-rights, about issues concerning non-custodial fathers. Themes in posting indicated that visitation, decision making, child support payments and interactions with their former partner can lead to frustration, rage and a sense of isolation in non-custodial fathers. The study concluded that it was essential that non-custodial fathers have access to a support site to voice their concerns with. However, the level of distress reflected in the postings led the researchers to content that provision of an open professionally moderated support site may assist the posters with self-reflection and achieving more constructive outcomes.

4.4. e-Mothers

A Canadian study by Hall and Irvine (2009) examined group emails from a group (n=40) of mothers of small children who lived in the same local area. Emails were classified so themes in communications could be identified and a better understanding of how mothers used the service could be attained. The study found that mothers used the service to share information about events, products and services. The giving and receiving of social support was also a major activity in the group. The study concluded that online support sites provide a way for mothers, whose caring commitments restrict their opportunity for face to face interaction, to reduce isolation and develop supportive connections with others in similar circumstance.

4.5 The Parents Network

A study by Sarkadi and Bremberg (2005) examined perceptions of support provided by an online support site known as The Parents Network in investigating social bias. The discussion board is aimed at parents of children of any age and discussion covers a range of topics including illness, adoption, bullying

[3] The sample dropped to 25 as some later questions were unanswered.

and divorce. Over 2000 self-selected users completed an anonymous online survey. Perceptions of social support were examined using the *appraisal support* and *self-esteem* sub-scales of the Interpersonal Support Evaluation List (ISEL) adapted from Cohen et al. (1985) which was selected because it was appropriate and validated. Additional questions related to site and internet usage and demographic information.

Respondents were predominantly female (86.5 per cent) and over 70 per cent were under 35 years of age. The study found that respondents perceived a strong sense of support from participating in the site and reported a strong sense of self-esteem. Contrary to their hypothesis, the sample indicated a lack of social bias, with 68 per cent of respondents reporting income below the national average.

4.6 Evaluation Approaches

Preece (2001) proposes a metric based approach to evaluating the sociability and usability of web sites around design criteria including: *purpose, people, policy, dialogue and social support, information design, navigation and access.* This metric based approach is useful as it captures valuable usage data such as the number and type of messages, demographics and descriptions of policy governing usage and usability of a site can be ascertained. However, as noted by Preece (2001), it only tells part of the story in evaluating the success of a social support and counseling site, where the benefit of interaction to a users' well-being must be central in determining the sites efficacy.

Research from Griffiths and Cristensen (2002) investigates the DISCERN scale as a means to evaluate the quality of health information on treatment options. DISCERN is described as giving non subject matter experts insight into the validity of information by rating aspects of a publication including description of treatment options, benefits and risks, and bias. Their work in 2002, used the instrument to evaluate 15 Australian depression web sites, comparing the ratings to reference scores developed by subject matter experts using a standard protocol. They found that DISCERN ratings aligned with quality of the sites reviewed.

The approaches to evaluating the support and counseling sites identified in this paper vary. Real time text based chat interviews were used in one study by Fukkingk and Hermans (2009). Message analysis and classification is used to better understand issues and themes in support discussions in two others by Erera and Baum (2009) and Hall and Irvine (2009).

The majority of studies cited use an online survey to engage respondents (Fukkink and Hermanns, 2009, Sarkadi and Bremberg, 2005, Urbis Keys Young, 2002). Some craft a survey around the stated goals of the site and evaluate success in achieving the articulated goals (e.g. (Urbis Keys Young, 2002)). However, where improvement in a sense of well-being and perceptions of support are concerned, others use validated instruments to enhance the reliability of results (e.g. (Sarkadi and Bremberg, 2005)). In the case of counseling, administering such instruments pre and post consultation may assist in evaluating benefits received from participation. Durability of benefit was evaluated in one study by Fukkink and Hermans (2009) via a follow up survey (one to several months later) evaluating respondent perceptions well-being.

Some survey instruments explored the usability of the site, while others did not evaluate site construction, though several evaluations did review usage data. Adoption of metric based approaches to evaluating site design such as the one proposed by Preece (2001) would ensure that usability and sociability are considered in an evaluation and a complete picture of the user experience can be obtained.

Validity of information and resources can be ascertained via review from subject matter experts. However, in the case of health related resources the DISCERN instrument presents an interesting alternative to assessing health care information resource quality (Urbis Keys Young, 2002).

5 Themes in Online Support and Counseling

We now signpost important considerations in the development of support and counseling sites for Family Dispute Resolution.

5.1 Online Communication Issues

While there have been recent advances in video based online communication tools such as Skype™, the majority of the sites and services discussed in this paper used text based platforms. The absence of visual cues can challenge a counselor (Gedge, 2002, Barak, 2004, Urbis Keys Young, 2002, Beattie et al., 2006), or member of an online support site (Pfeil et al., 2009, White and Dorman, 2001) when interpreting the mood and emotions of participants. The modern online lexicon uses text abbreviations (e.g. LOL – laugh out loud) and emoticons in part to overcome this challenge and participants and counselors alike must be aware of such conventions to engage fully in the online environment.

Impersonation or dishonesty is possible where identity is not validated online (Gedge, 2002, Pfeil et al., 2009, White and Dorman, 2001, Barak, 2004). Dishonest behavior has the potential to negatively impact on the trust developed in an online support group or client/counselor relationship.

Online communication can reduce inhibitions and speed up the process of self-disclosure and group bonding and in some cases reduce barriers to aggressive or negative expression (i.e. flaming) (Barak et al., 2008, Barak, 2004). Online support groups and counseling sites need formal and informal methods, such as published netiquette guidelines, for establishing communication and participation standards and handling cases of inappropriate behavior to minimize negative impact on the support and counseling experience. In the case of isolated men, such as those to be supported by the RAV online support and counseling site, some sort of prior education and monitoring is necessary to avoid any posting that would inflame rather than inform online support discussions.

5.2 Validity of Information

Given that information seeking and becoming better informed is a primary motivation for many visiting support web sites (van Uden-Kraan et al., 2009), the validity of the information that they find there is important (Abdullah and Zakaria, 2010), especially when it concerns matters of health and well-being. Certified professionals do not supply or moderate much of the advice and information provided through support sites giving rise to concerns about the validity of the information (White and Dorman, 2001). Bickerdike et al. (2009) stress that it is important to find both counselors and networks that you can trust. Online Family Dispute Resolution Services should also provide commentary on recent changes in the law (e.g. a presumption of shared parenting and mandatory mediation) and links to the law and cases (to the few who might want to read these).[4]

5.3 Trust, Privacy and Confidentiality

The support and counseling sites discussed in this paper include sites aimed at helping children, parents and non-custodial parents. Disclosure of thoughts relating to such personal matters requires trust in the group members in the case of social support sites (Pfeil et al., 2009), and trust and certainty of confidentiality in cases of counseling sites (Gedge, 2002, Urbis Keys Young, 2002).

The potential for confidential counseling sessions to be recorded and re-transmitted presents new challenges for providers and patients alike (Gedge, 2002). Professional advice is tailored for the individual and may not be accurate if shared and applied to others (Gedge, 2002). Personal communications revealing details of illness or personal circumstance can have potentially harmful impact if communicated inappropriately or shared outside the confines of the client/counselor relationship (Gedge, 2002).

However, having a record of the counseling session provides opportunities for counselor and client alike. Both are able to review the discussion and reflect back on earlier exchanges during and after a session (Barak, 2004, Beattie et al., 2006).

[4] For example see http://australia.gov.au/topics/law-and-justice/family-law and http://www.austlii.edu.au/au/cases/cth/FamCA/ both last accessed December 4 2011

5.4 Usability and Sociability

It is essential that a support and counseling web site be perceived as easy to use by people who access it (Preece, 2001, Abdullah and Zakaria, 2010, Andrews et al., 2001). While the technology needs to be error free and intuitive, it also needs to afford social interaction or sociability (Abdullah and Zakaria, 2010, Andrews et al., 2001, Preece, 2001). Preece (2001) identifies a three component framework to support web site sociability comprising purpose, people and policies. *Purpose* denotes the shared interest and sense of belonging of the participants. *People* denote the participants and their roles and interaction within the site. Finally, *policies* denote the documented or understood rules governing participation in the site. Professional support and counseling sites can enhance their chances of engagement by focusing and acting on Preece’s (2001) three P model.

5.5 Accreditation, Ethical Standards and Professional Credentials

Many of the support sites discussed in this paper do not explicitly mention professional accreditation and qualification of moderators. Rather, supportive communication is provided from people who have experienced similar illnesses and life situations (Erera and Baum, 2009, van Uden-Kraan et al., 2009, Welbourne et al., 2009). However, accreditation, ethical standards, and professional credentials of counseling and moderation staff are important for government endorsed and fee for service counseling and support sites (Gedge, 2002, Urbis Keys Young, 2002, Barak, 2004). Clear communication of accreditation, ethical standards, and staff or volunteer credentials provides a surety to potential clients relating to quality of service.

The Australian Attorney-General accredits Family Dispute Resolution practitioners. Essentially they require an appropriate undergraduate degree in law or the social sciences, a Vocational Graduate Diploma of Family Dispute Resolution and continuing professional development. Ideally, any online family support and counseling services should be monitored by qualified Family Dispute Resolution practitioners.

5.6 Emergent Themes

The themes presented in this section are drawn from multi-disciplinary sources that focus on online support sites, online counseling sites, and the emerging area of online support and counseling sites, including those featured in section four. Figure 1 draws these themes together as building blocks or considerations for those who aim to develop or enhance such sites.

Support and Counseling Sites						
Counseling Sites	Accreditation, ethical standards and professional credentials	Privacy and confidentiality	Online communication issues	Validity of information	Trust	Usability and sociability
Support Sites	Moderation					

Fig 1. Building blocks to consider when developing and enhancing support and counseling web sites.

There are a range of support sites available on the internet on a variety of topics, some of which are captured in this paper. The ease with which sites can be created, and the relatively low cost of creating them contributes to the diverse array of options available to the user. However, primary interactions in support sites are sharing of information and support. The validity of information provided from such sites can be difficult for some to ascertain.

Professional support and counseling sites can address the need for accurate information by providing reputable information resources based on the latest research. Professional moderation of discussion boards can provide users with an added sense of security and assurance when coupled with clearly communicated standards of behavior and interaction. Support services can be complemented by secure and reliable real time counseling provided by trained, qualified and available counselors who can recognize serious issues and refer as required to additional professional service providers. Adoption and clear communication of relevant ethical standards can enhance service quality and reassure potential participants.

In addition to providing accurate information, supportive groups and quality counseling, professional sites need to be usable and reliable. Designing and implementing sites that promote sociability through usable features can boost engagement and interaction. It is critical that online counseling tools be reliable and secure to ensure confidentiality and promote a sense of stability and trust between client and counselor.

6 Conclusion and Future Work

Extensive research has been conducted upon the development of BATNAs and interest based negotiation for the development of online Family Dispute Resolution systems. However there has been minimal research on the use of online support and counseling sites to assist divorcing parents undergoing conflict upon how to determine the future care of their children.

Support web sites can play a key role in improving the well-being of participants. They provide an accessible, flexible means for people to share experiences, access and give support, gather information and network with people with similar interests or concerns. The addition of online counseling to support sites can provide a complementary service for participants, allowing them to seek personalized feedback in a more private online setting. Health care providers, non-government organizations or not for profit organizations and governments can play a key role providing credible and timely information and secure, trustworthy support and counseling services online.

The benefits that participation in online support and counseling sites bring, such as reduction of stress and anxiety and enhancement of well-being in participants, indicate they have the potential to assist in a family mediation setting. Specifically, participation in support and counseling sites may provide a positive intervention for participants who might otherwise need to pursue mediation and litigation in family/parenting disputes. Future research will draw on the online support and counseling building blocks presented and the approaches to evaluation identified in this paper to further develop and evaluate a site that will provide support and counseling for male non-custodial parents in Australia.

References

Abdullah, N. A., Zakaria, N. (2010), Sociability Aspects in E-Health Community: A Review. In*: Information Technology (ITSim), 2010 International Symposium*, 972-976.

Abrahams, B., Bellucci, E., Zeleznikow, J. (2010), Incorporating Fairness into Development of an Integrated Multi-Agent Online Dispute Resolution Environment. *Group Decision and Negotiation*, 1-26.

Andrews, D., Preece, J., Turoff, M. (2001), A Conceptual Framework for Demographic Groups Resistant to Online Community Interaction. In*: System Sciences, 2001. Proceedings of the 34th Annual Hawaii International Conference on*, 10 pp.

Australian Bureau of Statistics. *Patterns of Internet Access in Australia*, http://www.abs.gov.au/ausstats/abs@.nsf/mf/8146.0.55.001, (last accessed on 6 May 2011)

Australian Bureau of Statistics. *Household Use of Information Technology, Australia, 2008-09*, http://www.abs.gov.au/ausstats/abs@nsf/mf/8146.0, (last accessed on 6 April 2011 2011)

Barak, A. (2004), Internet Counseling. *Encyclopedia of Applied Psychology*, 2, 369-378.

Barak, A., Boniel-Nissim, M., Suler, J. (2008), Fostering Empowerment in Online Support Groups. *Computers in Human Behavior*, 24, 1867-1883.

Beattie, D., Cunningham, S., Jones, R., Zelenko, O. (2006), I Use Online So the Counsellors Can't Hear Me Crying: Creating Design Solutions for Online Counselling. *Media International Australia Incorporating Culture and Policy*, 118, 43-52.

Bellucci, E., Macfarlane, D., Zeleznikow, J. (2010), How Information Technology Can Support Family Law and Mediation. In: Abramowicz, W., Tolksdorf, R. & Węcel, K. (eds.), *Business Information Systems Workshops.* 243-255, Springer Berlin Heidelberg.

Bickerdike, A., Gee, T., Ilgauskas, I., Melvin, T., Hearn, J. (2009), *Men and Separation: Navigating the Future*, http://relationshipsvictoria.com.au/pub/file_manager/files/men_and_separation.pdf, last accessed on December 5 2011.

Brams, S., Taylor, A. (1996), *Fair Division, from Cake Cutting to Dispute Resolution,* Cambridge, UK, Cambridge University Press.

Cohen, S., Mermelstein, R., Kamarck, T., Hoberman, H. M. (1985), Measuring the Functional Components of Social Support. In: Sarason, I. B. & Sarason, B. R. (eds.), *Social Support: Theory, Research and Applications.* 73-94, Martinus Njhoff Publishers, Dordrecht.

Erera, P. I., Baum, N. (2009), Chat-Room Voices of Divorced Non-Residential Fathers. *Journal of Sociology & Social Welfare*, 36, 63-83.

Euroqol. *What Is Eq-5d?*, http://www.euroqol.org/eq-5d/what-is-eq-5d.html, (last accessed on 12 May 2011)

Fukkink, R. G., Hermanns, J. M. A. (2009), Children's Experiences with Chat Support and Telephone Support. *Journal of Child Psychology & Psychiatry*, 50, 759-766.

Gedge, R. (2002), Online Counselling Services in Australia –the Challenges of a New Vehicle for an Old Art. In*: AusWeb 02: The Eighth Australian World Wide Web Conference*. AusWeb/Southern Cross University.

Getz, C. (2007), *Evaluation of the Distance Mediation Project: Report on Phase 1 of the Technology-Assisted Family Mediation Project*, http://mediatebc.com/PDFs/1-2-Mediation-Services/Closing_Distance.aspx last accessed on December 4 2011.

Griffiths, K. M., Christensen, H. (2002), The Quality and Accessiblity of Australian Depression Sites on the World Wide Web. *Medical Journal of Australia*, 176.

Hall, W., Irvine, V. (2009), E-Communication among Mothers of Infants and Toddlers in a Community-Based Cohort: A Content Analysis. *Journal of Advanced Nursing*, 65, 175-183.

Lehner, L. (1994), Education for Parents Divorcing in California. *Family and Conciliation Courts Review*, 32, 50-54.

Lodder, A., Zeleznikow, J. (2010), *Enhanced Dispute Resolution through the Use of Information Technology* Cambridge, United Kingdom, Cambridge University Press.

Mickelson, K. D. (1997), Seeking Social Support: Parents in Electronic Support Groups. In: Keisler, S. (ed.) *Culture of the Internet.* 157-178, Lawrence Erlbaum Associates, Mahwah, New Jersey.

Pfeil, U., Zaphiris, P., Wilson, S. (2009), Older Adults' Perceptions and Experiences of Online Social Support. *Interacting with Computers*, 21, 159-172.

Preece, J. (2001), Sociability and Usability in Online Communities: Determining and Measuring Success. *Behaiviour and Information Technology*, 20, 347-356.

Rosen, D., Stefanone, M. A., Lackaff, D. (2010), Online and Offline Social Networks: Investigating Culturally-Specific Behavior and Satisfaction. In*: 2010 43rd Hawaii International Conference on System Sciences (HICSS)*, 1-10.

Saposnek, D. (2004), Commentary: The Future of the History of Family Mediation Research. *Conflict Resolution Quarterly*, 22, 37-53.

Sarkadi, A., Bremberg, S. (2005), Socially Unbiased Parenting Support on the Internet: A Cross-Sectional Study of Users of a Large Swedish Parenting Website. *Childcare and Health Development*, 31, 43-52.

Smyth, B. *Parent-Child Contact and Post-Separation Parenting Arrangements*, http://www.aifs.gov.au/institute/pubs/resreport9/main.pdf, (last accessed on December 4 2011)

Smyth, B., Ferro, A. (2002), When the Difference Is Night & Day: Parent-Child Contact after Separation. *Family Matters*, 63, 54-59.

Thoits, P. A. (1986), Social Support as Coping Assistance. *Journal of Consulting and Clinical Psychology*, 54, 416-423.

Tixier, M., Gaglio, G., Lewkowicz, M. (2009), Translating Social Support Practices into Online Services for Family Caregivers. In*: GROUP '09: Proceedings of the ACM 2009 international conference on supporting group work*. ACM.

Urbis Keys Young (2002), *National Review of Tele Counselling and Web Counselling Services*, http://www.health.gov.au/internet/main/publishing.nsf/content/E82FC46AF0BBE758CA2570DB0082CD66/$File/tele.pdf, last accessed on

Van Uden-Kraan, C. F., Drossaert, C. H. C., Taal, E., Seydel, E. R., Van De Laar, M. a. F. J. (2009), Participation in Online Patient Support Groups Endorses Patients' Empowerment. *Patient Education and Counseling*, 74, 61-69.

Welbourne, J. L., Blanchard, A. L., Boughton, M. D. (2009), Supportive Communication, Sense of Virtual Community and Health Outcomes in Online Infertility Groups. In*: C&T '09 The fourth international conference on communities and technologies*. ACM.

White, M., Dorman, S. M. (2001), Receiving Social Support Online: Implications for Health Education. *Health Education Research: Theory and Practice*, 16, 693-707.

Wilson-Evered, E., Mcfarlane, D., Zeleznikow, J., Thomson, M. (2011), Towards and on-Line Family Dispute Resolution Service in Australia. In: Poblet, M. (ed.) *Mobile Technologies for Conflict Management.*

Wood, R. T. A., Griffiths, M. D. (2007), Online Guidance, Advice, and Support for Problem Gamblers and Concerned Relatives and Friends: An Evaluation of the Gamaid Pilot Service. *British Journal of Guidance & Counselling*, 35, 373-389.

Context-aware Environments for Online Dispute Resolution

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Abstract: Virtual environments, such as Online Dispute Resolution, don't have the rich context of traditional environments do. We are developing a computational environment that can better support the decision-making process of experts by providing access to meaningful context information, allowing the intervenor to take better supported decisions. The resulting system is able to transparently acquire information about user's state, including stress or conflict resolution style.

Keywords: Online Dispute Resolution, Negotiation, Context-awareness.

1 Introduction

Personality traits, conflict resolution styles and emotional intelligence are some of the key determinants of how conflicts are resolved. Hence one may wonder how information technology can support the dispute resolution process (Lodder and Zeleznikow, 2010). Traditionally, conflicts have arisen between individuals in the geographical proximity of each other, after some kind of personal interaction (e.g. trade agreement, work relationship). However, nowadays conflicts can emerge between individuals located virtually anywhere in the world and may even involve non-human intervener and some kind of automated contracting process. This represents a significant change in the whole paradigm of conflict emergence and resolution. In that sense, conflict resolution is nowadays also a field of research in the Computer Science discipline.

The main consequence of this shift in the paradigm is that courts, shaped after the industrial revolution and still paper-based, are slow to deal with both the amount and the characteristics of these new disputes. In that sense, new approaches independent of concepts like geographical location or nationality and of paper based resources are needed.

The field of Online Dispute Resolution (ODR) (Katsh and Rifkin, 2001) emerged as a group of methods or techniques that allow the resolution of conflicts partially or wholly under an electronic environment and with the support of technological solutions (Lodder and Zeleznikow, 2010). Technology assumes such an importance that is seen as the fourth party in the conflict resolution process, together with the two opposing parties and the neutral (Rifkin, 2001). In that sense, ODR can be classified as first or second generation, according to the degree of autonomy of technology (Peruginelli and Chiti, 2002). First generation ODR describes systems in which technology is merely a facilitator of the contact between the parties or a document manager. It has no autonomy and doesn't play an important role. Second generation ODR comprises systems in which technology has the autonomy to make give advice or make decisions and may even be able to argue, to analyze complex information or to define strategies and plans. This is typically based on artifacts from Artificial Intelligence, including decision support systems or expert systems (Lodder and Thiessen, 2003).

In this paper we look at a very specific issue in Online Dispute Resolution: the implications of interacting and solving conflicts under virtual settings. In fact, as Rifkin puts it, in face to face mediation, the spoken word and the visual cues sparked by body language are the primary elements in the communication process. In opposition, in the "screen to screen" of ODR, the written word and the visual dimensions of the computer screen constitute these elements (Rifkin, 2001). This may have its advantages but certainly has disadvantages too, namely concerning the amount of contextual information (e.g. body language, emotions) that is absent in ODR.

In this paper, we make an analysis of the implications of the lack of context information in current ODR approaches and we present our approach, based on the concept of Ambient Intelligence

(Aarts and Grotenhuis, 2011). Ambient Intelligence refers to the combined use of Ubiquitous Computing, Ubiquitous Communication and Intelligent User Interfaces to develop context-aware computational environments that are able to seamlessly acquire information from its users and take actions that aim at the maximization of some goal (e.g. user comfort or safety, efficiency at performing a task). Two main modules can be identified here: data acquisition from the environment and decision-making.

We are developing a context-aware conflict resolution environment to support the traditional model of Online Dispute Resolution by providing important information about the parties and their context (Carneiro et al., 2011). The main aim of this approach is to increase the amount of context information available so that parties and neutrals can take more realistic and weighted decisions. In that sense we are developing a framework that aims at interpreting the state of the parties (e.g. levels of stress, emotional state, conflict resolution style) and sharing that information with the conflict resolution platform. In the first stage we want to empower the neutral so that he can better decide on how to guide the process (e.g. make a pause when a party is too stressed, temporarily interrupt direct contact between parties, inform a party that their lack of cooperativeness is jeopardizing the process). In a posterior phase we aim at developing mechanisms that can efficiently inform parties about each other's states (e.g. animated avatars), making the conflict resolution process more human and closer to traditional ones in which people communicate face-to-face and are fully aware of the consequences of their acts.

2 Limitations of Communication in Virtual Environments

The fact that ODR takes place in a virtual environment, without all the richness of face-to-face interaction, is seen as a serious drawback (Larson, 2007). And this is true not only in the conflict resolution field but in any other field in which virtual environments are used. Virtual environments are frequently regarded as "cold", with emotions and other traces of our complex interaction means playing little to no role at all. One could argue that the use of audio or video links between the parties would, to some extent, address this problem. However, there are cases in which the use of video/audio has negative effects (such as the cases in which people do not stand to see each other or in histories of abuse of a dominant personality). Moreover, the approach presented can provide additional information on the context of the parties or it will, at least, formalize the information that is already unconsciously present.

One of the most important aspects here is that of body language. In our day-to-day interactions we (unconsciously) rely on body language to express ourselves in a richer way. Mehrabian concludes that in a face-to-face communication there are three key elements: the words, the tone of voice and the nonverbal behavior (Mehrabian, 2009). The author also concludes that the non-verbal elements are particularly important for communicating feelings and attitudes, stating that they account for the majority of the information transmitted. i.e., the way that words are said is more important than the words themselves. The problem is that this information is lost in a virtual setting and makes it hard for the intervenient parties (e.g. mediators, disputants) to understand the emotional state of each other.

In a related line of research, Trevor et al. conclude that the lack of gestural information from both speaker and listener limits successful communication in virtual environments (Trevor et al., 2011). To support this conclusion, the authors created a communication game in which a player had to describe the meaning of a word to a partner so that she could guess the word. In this interaction, the partners could only communicate through animated avatars. These avatars could remain static, perform according to pre-record gestures or could be controlled by virtual reality suits worn by the first player. The results achieved prove that not only is body language very important for transmitting information but it is also used to perceive feedback from that transmission, i.e., to perceive if the communication is being successful or a different approach should be followed. Both the lack of feedback from the environment and the lack of meaningful content are pointed out as a drawback by other researchers (Campbell, 1997; Costalli et al. 2001).

When communicating online people tend to forget that there is another person behind the screen on the other side. In that sense, there is a disinhibiting effect and people tend to forget about the other's feelings and simply don't worry that much about the consequences of the words they utter and the actions they commit. Thus it is often easier to offend people online. This may constitute an important obstacle to the successful resolution of the conflict as a relation of trust is of utmost importance.

It is thus evident that the lack of the context of personal interactions constitutes a drawback in a virtual conflict resolution process. Context information is needed not only for parties to take better and more realistic decisions but also to interpret how others are being affected by the issues and to keep in mind that in the other end of the screen there are people with feelings, desires and fears. With this motivation in mind, in the next section we present our approach in which we aim to empower virtual conflict resolution mechanisms with the provision of context information in real-time about the parties and the interaction environment.

3 Building a Context-aware Conflict Resolution Environment

The main objective of this research is to build a transparent computational environment that can support the conflict resolution system with the provision of meaningful context information. In that sense, we are extending the traditional model of negotiation/mediation with two new components: an intelligent environment and an adaptation phase.

On the one hand, we are including the notion of an intelligent environment as an entity built on devices and sensors. Ideally, this entity would be invisible to the eye of the user and the user would not be aware of being monitored, as the simple fact of knowing it might be enough to change his behavior. Nevertheless, the fact that this environment surrounds the users and constantly acquires information about them and their context of interaction, by means of regular devices with computational power (e.g., touch screens, video cameras, accelerometers, PDAs) brings along legal requirements concerning the consent of the users and the finalities of the use of the collected data. These issue is addressed in (Andrade et al., 2011).

On the other hand, we include an adaptation phase. This phase occurs whenever the mediator notices a significant change in the context of interaction that calls for a rethinking of the strategies defined. The main objectives of this phase are to re-orient the focus of the conflict resolution process in order to keep the parties interested in its resolution and to find more suitable ways of achieving an outcome.

Thus, we define a dynamic context-aware conflict resolution model as depicted in Figure 1. The process starts with the generation of useful knowledge that will support the decisions of the disputant parties and allow for the mediator and other tools (e.g. expert systems, decision support systems) to make better decisions. With the support of this knowledge, the mediator will build the strategies that will guide the negotiated process. Whenever the mediator feels that it is necessary, he may choose to adapt these strategies. In order to decide when and how to perform this adaptation, the mediator interprets the information provided by an intelligent environment about the context of interaction, including the levels of escalation, the attitudes, the personal conflict styles, the emotional state or the levels of stress. This process goes on until a party leaves the process or a successful agreement is reached. In the following sub-sections we depict some of the information that the intelligent environment provides and how it acquires it.

3.1 The Automated Classification of Personal Conflict Resolution Styles

Each individual has a different style of dealing with a conflict. This so-called personal conflict style is a result of our personality traits, our past experiences and many other issues. One's personal conflict style is one of the most important issues influencing our decisions in a conflict resolution process and, consequently, its outcome. In that sense, knowledge about how each party behaves in a conflict scenario is of utmost importance for the mediator. Moreover, detecting, interpreting and even inducing changes in this personal conflict style may be a very powerful weapon for the mediator in order to achieve a successful outcome. Thus, understanding personal conflict styles should be regarded as essential in a conflict resolution process.

In the 1970s behavioral scientists Kenneth Thomas and Ralph Kilmann classified the way we respond to conflict scenarios in five different modes, in terms of the individual's assertiveness and cooperativeness (Thomas and Kilmann, 1974)[1]:

- Competing - A competing individual will have as its main purpose the achievement of the highest gain possible. In order to achieve it, the individual may use his ability to argue, his rank, economic sanctions or whatever power seems appropriate. This style is highly uncooperative;
- Accommodating – An individual showing an accommodating conflict style will show the openness necessary to accept another's point of view and may even evidence selflessness, generosity or

[1] Also known as the *Thomas-Kilmann Conflict Mode Instrument*

charity. In fact, the individual may even neglect his own gain to maximize the gain of the other. In that sense, there is an underlying element of self-sacrifice in this cooperative style;

- Avoiding – When an individual evidences an avoiding style of dealing with the conflict he will most likely try to not deal with the conflict at all, i.e., he will not try to satisfy his interests nor the ones of the opposing party. This style might be visible through behaviors such as the sidestepping or postponing of an issue or withdrawing from a threatening situation;
- Collaborating – A collaborating individual is willing to explore a disagreement to learn from others' insights. This style is the complete opposite of the avoiding one in the sense that it is cooperative and the individual tries to satisfy the interests of both parties, placing effort on discovering the underlying desires and fears of the other.
- Compromising – A compromising individual will try to split the differences between the two positions, exchange concessions or seek a quick middle-ground solution. Basically, he will try to find some expedient and mutually acceptable solution that partially satisfies both parties. This style can be seen as an intermediate one between the competing and accommodating ones.

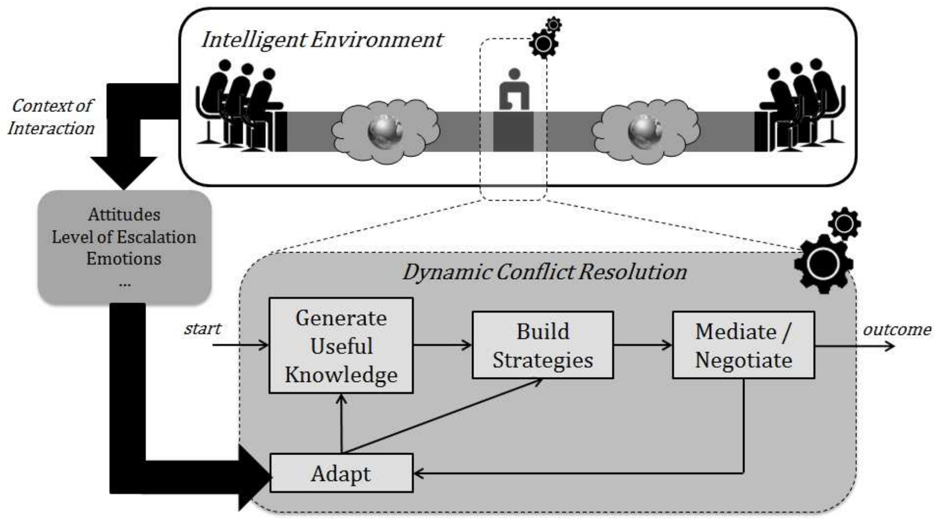

Fig. 1. High level view of the proposed context-aware conflict resolution model.

Although the authors argued that disputants tend to focus upon one specific conflict style, depending on the situation, they might use different styles. The styles the parties use can be determined following two different approaches:

A) On the one hand, parties can be questioned about how they would behave in certain scenarios. This provides information before the actual start of the process, allowing the mediator to plan ahead. However, this information may not be reliable as people tend to behave differently when they are under stress and it is fairly easy to give wrong information in questionnaires. Moreover, people will most likely change their conflict resolution style during the process, making the initial information outdated.

B) On the other hand, the behavior of the parties may be analyzed while they interact. Although this process may require more time to gather enough information about the parties, it will not only be more reliable information but it will also reflect eventual changes in the style, and in real time.

In this work, we focus on the interpretation of conflict styles during the negotiated process, by analyzing the behavior of the parties in real time, allowing us to infer the conflict resolution style of the parties while they interact. Specifically, we analyze the actions that parties take during the negotiation, in which parties can ignore, accept, refuse, exit, reply with a new proposal or reply with a counterproposal. The simple fact of performing a task has its specific meaning: a party that is simply refusing or ignoring a proposal is probably in an avoiding style while a party that replies with a counterproposal addressing the original proposal is often cooperating. However, the action by itself is not enough. In fact, the utility of the proposals that are constructed by the parties must be analyzed. This allows the mediator to determine to which extent the party is just being greedy (he cooperates by proposing solutions that encompass only his personal gain, and does not propose unrealistic solutions) or to which extent he is willing to propose middle ground solutions (he proposes to lose part of the possible gains in order to achieve an outcome). The analysis of this utility is central.

In order to correctly interpret each action, the utility of the proposal it encapsulates must be analyzed and compared with boundary values. In that sense, the utility is analyzed in comparison with the values of the BATNA, WATNA and ZOPA. BATNA and WATNA represent the Best and Worst Alternative to a Negotiated Agreement and depict the best and worst case scenarios in court, i.e., if the alternative method fails what are the chances in court? (De Vries et al., 2005). The ZOPA, on the other hand, represents the Zone of Possible Agreement and, as the name indicates, describes the range of possible outcomes (Raiffa, 2005). The way that these values are computed in the context of this work is further described in (Andrade, 2010). This analysis is performed under the assumption that a value of utility near the BATNA of the party stands for a greedy behavior (a more competitive style) whereas a value near the WATNA represents a more compromising one (Figure 2). This analysis is performed in each round of the negotiation process, in which parties exchange proposals and counterproposals.

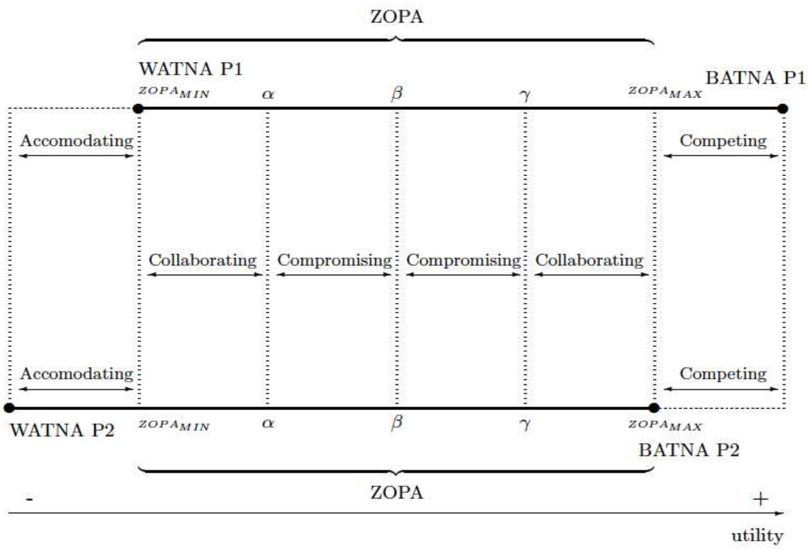

Fig. 2. The space that defines the personal conflict styles in function of the utility of the proposals and the values of the BATNA, BATNA and ZOPA.

In each round, each party will perform actions which will contribute to the overall characterization of its personal conflict style. This is thus the result of an ongoing process, i.e., a single action is not enough to accurately classify the style of the party. In this process of classifying styles two main scenarios are possible: the party ignores the proposal or the party answers to the proposal. If the party ignores the proposal, in that round his behavior is classified as *Avoiding*. On the other hand, if the party answers, the utility of the answer is analyzed.

First of all, a legitimate and valid answer evidences a cooperative behavior. However, we must determine what the real intentions of the party are. If the utility of the proposal is near the BATNA of the party, he is clearly showing a *Competing* style as he is trying to maximize his own gain. He might even be doing this in an unrealistically way, completely disregarding the other party. On the other hand, if the utility of the proposal is near the WATNA, the party may be neglecting his own gain or even maximizing the gain of the other. In such a scenario, it is reasonable to state that the party is showing an *Accommodating* behavior. If the utility of the proposal falls within the range of the ZOPA, the party is being reasonable and proposing a solution that may comprise losses on both sides but is certainly reasonable. In this case, style is determined in function of the distance to the mean point of the ZOPA, as defined in equation 1.

$$\beta = \left(\frac{ZOPA_{MIN} + ZOPA_{MAX}}{2}\right) \qquad (1)$$

Additionally, two intermediary points are defined that allow to classify the remaining conflict styles, equations 2 and 3. Specifically, when the utility belongs to $[\alpha, \gamma]$, it denotes a party negotiating in intermediary points of the ZOPA. That is, the party is trying to work out compromise that implies a loss from both parties. In such a scenario, it may be said that the party is evidencing a *Compromising* behavior. On the other hand, if the value of the utility belongs to $[ZOPA_{MIN}, ZOPA_{MAX}]/[\alpha, \gamma]$

The party is making proposals that are closer to the limits of the ZOPA. This means that the party is trying to work out a solution but may also mean that the party is trying to explore some weakness of the other party, trying to force him to accept a more extreme solution. In this case, the style of the party is classified as *Collaborating.*

$$\alpha = \left(ZOPA_{MIN} + \frac{\beta - ZOPA_{MIN}}{2}\right) = \left(\frac{ZOPA_{MIN} + \beta}{2}\right) \qquad (2)$$

$$\gamma = \left(ZOPA_{MAX} - \frac{ZOPA_{MAX} - \beta}{2}\right) = \left(\frac{ZOPA_{MAX} + \beta}{2}\right) \qquad (3)$$

However, given that we might use several styles at the same time and that a value that is near the limit of the interval should have a different meaning from a value that is in the middle, we propose a more accurate approach in which a main conflict style is inferred, together with a so-called trend style. This can be interpreted as a party showing a given behavior but with a trend to another one. The following notation is used to denote a main conflict style with a trend to a secondary one: $Main_{\rightarrow secondary}$.
Let φ be the value of the utility of a proposal. The following personal conflict styles are defined:

$$Collaborating_{\rightarrow Accomodating} \qquad if\ \varphi \in [ZOPA_{MIN}, \frac{ZOPA_{MIN} + \alpha}{2}[$$

$$Collaborating_{\rightarrow Compromising} \qquad if\ \varphi \in [\frac{ZOPA_{MIN} + \alpha}{2}, \alpha[$$

$$Compromising_{\rightarrow Collaborating - Accomodating} \qquad if\ \varphi \in [\alpha, \beta[$$

$$Compromising_{\rightarrow Collaborating - Competing} \qquad if\ \varphi \in [\beta, \gamma[$$

$$Collaborating_{\rightarrow Compromising} \qquad if\ \varphi \in [\gamma, \frac{ZOPA_{MAX} + \gamma}{2}[$$

$$Collaborating_{\rightarrow Collaborating - Competing} \qquad if\ \varphi \in [\frac{ZOPA_{MAX} + \gamma}{2}, ZOPA_{MAX}]$$

Doing this in each round allows us to analyze the evolution of the conflict resolution styles in a temporal perspective (Figure 3), in an attempt to try to identify some pattern or trend (e.g. an apprehensive party starts out showing and avoiding behavior and then evolves towards a more collaborative or compromising one). With access to this kind of information, the mediator may better decide on when and how to adapt strategies.

3.2 A Non-invasive Estimation of the Level of Stress of Disputants

Stress is an abnormal condition that disrupts the normal functions of the body or mind. In other words, human stress is a state of tension that is created when a person responds to demands and pressures. It can affect the body, thoughts, feelings, and the behavior of a person (Selye, 1956). In that sense, its analysis in a conflict resolution scenario is of utmost importance. However, when the conflict resolution process takes place in an online environment, information about the underlying stress is not available. As a consequence, the intervener loses access to important interaction information that may allow him to assess how each issue effects each party and to what extent this occurs. In this line of research, we aim to empower ODR settings with estimated information about the levels of stress of the parties.

Stress has spawned a vast body of research in the health literature (Jones and Kinman, 1988). In fact, some research areas on the topic of stress can be identified, namely: (1) stressors (the environmental causes of stress), (2) intervening variables and (3) strains (the outcomes of stress). Moreover, these areas are interlinked and these categories are not mutually exclusive, which has led to misunderstanding in academic and popular writing on stress.

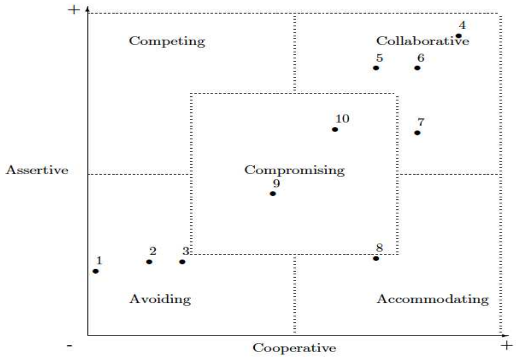

Fig. 3. Representation of the evolution of the personal conflict style of a party in 10 rounds.

It is a rather challenging task to develop a practical human stress monitoring system. Several difficulties arise from this task, namely: (1) the expression and the measurements of human stress are very much person-dependent and even time or context dependent for the same person; (2) the sensory observations are often ambiguous, uncertain, and incomplete; (3) the user stress is dynamic and evolves over time; (4) the lack of a clear criterion for feasible stress states greatly increases the difficulty of validating stress recognition systems.

The ability to recognize common stress symptoms and, furthermore, the underlying causes, is crucial to understand the factors that conduct the user's performance to perform an action or evidence a behavior. Our current work focuses on modeling a system that is able to estimate the level of human stress from its external symptoms. We are developing a non-invasive real-time system that monitors human stress in a task-specific environment. This approach is based on the use of handheld devices that are used to interact with the conflict resolution system. These handheld devices are equipped with sensors that can provide useful information in real-time about how the users interact with the platform, in a transparent way.

Currently, our solution considers the following inputs:

- Touch patterns – The touch pattern encodes the specific way of the user touching the handheld device. Stressed and calm users show different touch patterns;
- Touch accuracy – The accuracy of the touch refers to the precision with which the user touches or fails to touch the controls. Lower levels of accuracy are related to increased levels of stress;
- Touch intensity – The touch intensity depicts the pressure of the touch. Generally, a stressed touch has a higher maximum value of intensity than a calm touch;
- Acceleration – Information from the accelerometer placed in the handheld device can allow to determine the level of agitation of the user: stressed users tend to move more and in more abrupt ways than calm users;

Concerning touch patterns, each user has a specific touch pattern. However, these touch patterns are affected by stress in similar ways, even for different users (Grundlehner et al., 2009). Touch patterns can vary in length and in the variation of the intensity during the touch (Figure 6b). Generally, a touch performed in a calm state starts in or near a maximum value of intensity and then decreases until the finger releases the screen. On the other hand, a touch performed under stress tends to last longer, with its intensity increasing until a maximum value (that is higher than the maximum value of a calm touch) is reached. After this point, the intensity decreases until the finger releases the screen. In that sense, even for different users, it is possible to develop an algorithm that is able to distinguish between a more stressed and a more relaxed touch. Still, better results are achieved with a prior phase of training, in which the system adapts to the specific touch pattern of the user.

To make this distinction between stressed and calm touches we look at the intensity curves of the touches. Given that the usual shape of the intensity of a touch is similar to a quadratic function, we use a least-squares fit to obtain the curve that best fits the touch pattern. Figure 6a shows a touch pattern (orange line) and the corresponding curve generated by the least-squares fit (in blue). Thus, after being processed, the touch is no longer represented as a list of points of intensity but as a quadratic function of type

$$f(x) = ax^2 + bx + c\ , a \neq 0.$$

This allows us to compare touches by comparing their respective curves (e.g. similar curves denote similar touch patterns). We thus use machine learning techniques to classify each touch. Specifically, we trained a J48 algorithm to be able to distinguish between a stressed and non-stressed touch, using a dataset of 349 touches. The resulting tree is used to distinguish between stressed and non-stressed touches (Figure 4).

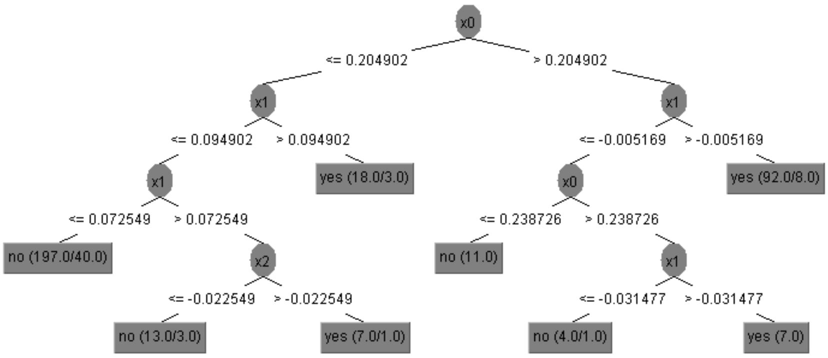

Fig. 4. The tree created by the J48 classification algorithm. This tree is used to distinguish between a stressed and a non-stressed touch.

The algorithm shows interesting results, with 271 out of 349 correctly classified instances (around 78%) (Figure 5).

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=== Stratified cross-validation ===
=== Summary ===

Correctly Classified Instances         271               77.6504 %
Incorrectly Classified Instances        78               22.3496 %
Kappa statistic                          0.5457
Mean absolute error                      0.2876
Root mean squared error                  0.4155
Relative absolute error                 58.1595 %
Root relative squared error             83.5666 %
Total Number of Instances              349

=== Detailed Accuracy By Class ===

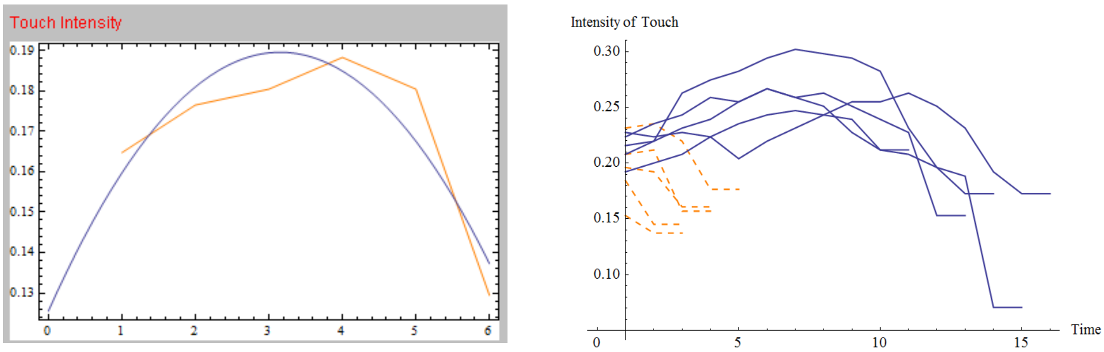
               TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
                 0.724     0.181      0.764     0.724     0.743      0.807    yes
                 0.819     0.276      0.786     0.819     0.802      0.807    no
Weighted Avg.    0.777     0.233      0.776     0.777     0.776      0.807

=== Confusion Matrix ===

   a   b   <-- classified as
 113  43 |   a = yes
  35 158 |   b = no
```

Fig. 5. Summary of the model used to classify touches.

After building this model, the system is ready to classify touches as stressed or not stressed. Evidently, a single touch is not enough to accurately classify the user’s state. In that sense, we follow a temporal approach in which each touch contributes to the overall estimation of the level of stress. Together with this information, we also analyze the accuracy and maximum intensity of the touch. The accuracy represents the amount of touches in active areas (e.g. buttons, text fields) versus touches in passive areas (areas without controls, thus without the need to be touched). A touch in a passive area can be the evidence of a stressed state as the user has most likely touched it while trying to touch an active area. Thus, the lower the accuracy is, the higher the contribution to the overall level of stress. Similarly we use the maximum value of the intensity of each touch. This is supported by the fact that touches performed by stressed users show a higher maximum value of intensity. Thus, the level of stress associated to this input is higher when the maximum intensity is higher.



(a) (b)

Fig. 6. Intensity of a touch over time (orange line) and corresponding quadratic curve (blue line) (a) and plot of calm (orange) and stressed (blue) touch patterns.

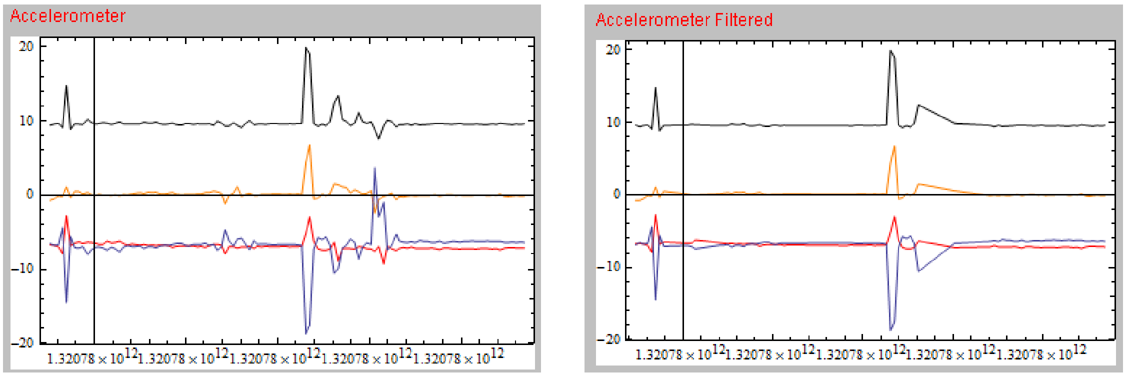
Finally we also perform an analysis of the acceleration sensed on the handheld device under the assumption that a stressed user will be more agitated, making more sudden movements, and this can be measured by the accelerometer. Nevertheless, a filter is applied to the accelerometer placed on the handheld device so that the variations of the acceleration that correspond to touches are removed (i.e. a variation in the acceleration is expected when we touch the device and this has no relation with level of stress). This way we make sure that the acceleration is an independent variable. Figure 7 shows two plots of the accelerometer data for the same time interval, with the raw data (a) and the data after applying the filter (b). The filtered data can thus be analyzed and contribute to the evaluation of the level of agitation, thus stress, of the user. Putting together all this information, the proposed monitoring framework is able to produce, in real-time, an estimation of the state of the user in terms of stress.

4 Conclusion and Future Work

Current trends in Online Dispute Resolution focus on developing tools that can help parties make contact and share information and proposals for problem resolution. This is expected to result in faster and more efficient conflict resolution processes. Moreover, virtual environments are being created that facilitate this interaction. However, the human side of conflict resolution is being left aside, as pointed out by the literature. Consequently, we must keep in mind that there is the risk of exclusion of important context information, considered vital by expert human mediators for making informed decisions, but unavailable in the online context. As a result, conflict resolution processes might ignore the human element and focus only on objective information, putting aside context information that may be quite important in order to perceive feedback from the parties and assess how they are being effected.

The approach presented has as its main objective the desire to enrich conflict resolution platforms by providing access to this kind of context information. Specifically, in this paper we focused on how to classify personal conflict resolution styles in an automated way and on estimating the level of stress of the users utilising non-invasive methods. This information can then be used by the platform or even by a mediator who is conducting the process, to perceive how each issue or event is effecting each party. This, we believe, will increase the success rate of conflict resolution procedures and bring ODR closer to the rich communicative environment that we have, when we communicate face-to-face.

Current research is now incorporating additional components that will contribute to the characterization of the stress, so that we can provide more acceptable advice. Namely, we are working on analyzing the patterns of movement of the users. This research is based on image processing. In a later phase, we intend to work with the School of Medical Sciences at University of Minho to use electroencephalograms that will be useful not only for validating this approach but also to more accurately calibrate it.



(a) (b)

Fig. 7. Information from the accelerometer corresponding to a user interacting with the touch screen (a) and the same information with the data corresponding to the touches filtered (b). The upper line represents the module of the acceleration while the three other lines represent acceleration in the three axes.

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References

Aarts, E., Grotenhuis, F. (2011), Ambient Intelligence 2.0: Towards Synergetic Prosperity. In: *Journal of Ambient Intelligence and Smart Environments*, volume 3, pp. 3-11. IOS Press.

Andrade F., Novais P., Carneiro D., Zeleznikow J., Neves J. (2010), Using BATNAs and WATNAs in Online Dispute Resolution, in New Frontiers in Artificial Intelligence, Kumiyo Nakakoji, Yohei Murakami and Eric McCready (Eds), (JSAI-isAI 2009 Workshops, LENLS, JURISIN, KCSD, LLLL, Tokyo, Japan, 2009, Revised Selected Papers), Springer - LNAI 6284, ISBN 978-3-642-14887-3, pp. 5-18.

Andrade F., Costa A., Novais P. (2011): Privacy and Data Protection in Elderly Healthcare (*Privacidade e Proteção de Dados nos Cuidados de Saúde de Idosos*), Proceedings of the XV Congreso Iberoamericano de Derecho e Informática.

Campbell, D.A. (1997). Explorations into Virtual Architecture: A HIT Lab Gallery. IEEE Multimedia, 4(1), 74–76.

Carneiro, D., Novais, P., Neves, J. (2011), Toward Seamless Environments for Dispute Prevention and Resolution, International Symposium on Ambient Intelligence, In: *Advances in Intelligent and Soft Computing*, Volume 92/2011, 25-32, DOI: 10.1007/978-3-642-19937-0_4, Springer.

Costalli, F., Marucci, L., Mori, G., & Paternò, F. (2001), Design Criteria for Usable Web-Accessible Virtual Environments. Cultural Heritage and Technologies in the Third Millennium Conference, Milan Italy.

De Vries BR., Leenes, R., Zeleznikow, J. (2005), Fundamentals of providing negotiation support online: the need for developping BATNAs. Proceedings of the Second International ODR Workshop, Tilburg, Wolf Legal Publishers pp. 59-67.

Dodds, T., Mohler, B., Bülthoff, H. (2011), Talk to the Virtual Hands: Self-Animated Avatars Improve Communication in Head-Mounted Display Virtual Environments. PLoS ONE, volume 6 (10).

Grundlehner, B., Brown, L., Penders, J., Gyselinckx, B. (2009), The design and analysis of a realtime, continuous arousal monitor.Wearable and Implantable Body Sensor Networks, International Workshop on 0, 156–161.

Jones, F., Kinman, G. (2001), Approaches to Studying Stress. In: F. Jones & J. Bright (Eds.), Stress: Myth, Theory and Research. Harlow: Pearson Education.

Larson, D. (2007), Technology Mediated Dispute Resolution. In *Proceeding of the 2007 Conference on Legal Knowledge and Information Systems* - JURIX 2007: The Twentieth Annual Conference. IOS Press, Amsterdam, The Netherlands.

Lodder, A., Thiessen, E. (2003), The Role of Artificial Intelligence in Online Dispute Resolution. In Workshop on Online Dispute Resolution at the International Conference on Artificial Intelligence and Law, Edinburgh, UK.

Lodder, A. R., Zeleznikow, J. (2010), Enhanced Dispute Resolution Through the Use of Information Technology. Cambridge Unversity Press, ISBN: 978-0521515429.

Mehrabian, A. (2009), Silent Messages – A Wealth of Information about Nonverbal Communication. In: *Personality & Emotion Tests & Software*. Los Angeles.

Peruginelli, G., Chiti, G. (2002), Artificial Intelligence in Alternative Dispute Resolution. In: *Proceedings of the Workshop on the law of electronic agents* – LEA.

Raiffa, H. (1982), The art and science of negotiation: how to resolve conflicts and get the best out of bargaining, Cambridge, The Belknap Press of Harvard University Press.

Rifkin, J. (2001), Online dispute resolution: theory and practice of the fourth party. In: *Conflict Resolution Quarterly*, volume 19, number 1, Fall 2001.

Selye, H. (1956), The stress of life. No. vol. 5 in McGraw-Hill paperbacks, McGraw-Hill.

Thomas, K. W., Kilmann, R. (2002), Thomas-Kilmann conflict mode instrument, CPP.

Inherited Stability Properties in Perceptual Graph Models

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Abstract: Perceptual graph models and stability analysis are presented to account for the roles of emotions and lack of consistent perceptions among decision makers in conflict. The inherited stability properties of Nash and symmetric metarationality solution concepts and the consistency of different stabilities observed across perceptual graph models are demonstrated through various theorems. This research highlights the importance of accounting for decision makers' perceptions when constructing conflict models, and the importance of being cautious when drawing conclusions from these models.

Keywords: Negative emotion, perceptual graph model systems, perceptual stability analysis, Nash stability, symmetric metarationality.

1 Introduction

As omnipresent social phenomena, dispute and confrontation exemplify contentions between adversaries who battle to attain objectives that are not collectively compatible. Whether these contentions are mild disagreements or deadly clashes, conflicts cause people to experience bewilderedness and negative emotions. The experienced emotions depend on how people appraise a situation with respect to accountability (who did what?), significance (how much it is important?), and incongruence to own goals and beliefs (Lazarus, 2001a,b). Obeidi et al. (2005) highlight the inextricable association of negative emotions to adversaries' relational dynamics during confrontation. For example, the perception that someone premeditated an action that is incongruent with individual's goals will likely make a person angry, while the perception of an imminent risk, especially if the perpetrator is unknown or powerful, will likely engender complex emotions where fear is dominant.

If conflict is not resolved or not properly managed from the onset, the initially experienced emotion will continue to spiral into a complex array of destructive emotions, which would further fuel the conflict. As conflict escalates, involved parties, or decision makers (DMs), perceive the structure of conflict differently. Partly because of asymmetry in information and partly because of individual differences in information processing and biases in judgment (Pinkley et al., 2005; Carnevale, 2007. Negative emotions intensify any incompatibility in DMs' perceptions of the conflict and any biases in information processing and coping strategies.

Formal techniques that have been developed to analyze situations characterized by conflict of interest are founded upon or inspired by game theory (Von Neumann and Morgenstern, 1953). *Metagame Theory* (Howard, 1971), *Conflict Analysis* (Fraser and Hipel, 1984), *Hypergame Analysis* (Bennett, 1977, 1980; Wang, Hipel, and Fraser, 1988), the *Graph Model for Conflict Resolution* (Fang, Hipel, and Kilgour, 1993), and *Drama Theory* (Bennett and Howard, 1996; Bryant, 2003) are all formal tools that conceive conflict and negotiation as multi-party-multi-objective decision making situation, or strategic conflict (Obeidi et al., 2005). The structure of strategic conflict are: two or more DMs, each with some ability to choose between alternatives or courses of action, each available alternative is fully known to every DM, each DM has preferences over outcomes, and each DM makes choices conducive to her own self-interest and expect the opponents to do likewise.

These conflict analysis techniques focus on finding outcomes that are stable with respect to choices made in decision makers' interests. A number of stability analysis procedures that capture human behavior under conflict have been used within these techniques for assessing the stability of outcomes in strategic conflicts (Nash, 1950, 1951; Howard, 1971; Brams and Wittman, 1981; Fraser and Hipel, 1984; Zagare, 1984; Kilgour, 1985). These procedures represent each DM's readiness and strategic approach to behavior in the conflict, assuming all DMs have the same view of the conflict and each is acting in accordance to one's self-interest. Of interest here is Nash and symmetric metarationality solution concepts.

Perceptual graphs and stability analysis (Obeidi et al., 2009a,b) are developed to include salient interpersonal issues in conflict. These theoretical structures incorporate the effect of affective reactions (emotion, feelings, and impulses) on DMs' inconsistent perceptions of possible outcomes during conflict. Discrepancy in the perception of outcomes among DMs necessitates changing the way a conflict is modeled and analyzed for stability. Each DM, under perceptual graph assumption, may have a limited view of other DMs' model. Hence, analyzing a perceptual model require modifying traditional stability analysis. Perceptual stability analysis takes into account awareness of DMs of any inconsistency in perceived outcomes.

The following sections give a general overview of perceptual graph model systems and perceptual solution concepts. Then Nash and symmetric metarationality are defined for both standard and perceptual modes. The paper is concluded by showing how Nash and symmetric metarationality are persistent from standard to any submodel in a perceptual graph model system.

2 Perceptual Graph Model System

Perceptual graph system (Obeidi et al., 2009a) is founded upon the graph model for conflict resolution (Fang et al, 1993) but it extends the application to situations where DMs have different perceptions of possible outcomes.

2.1 Standard Graph Model

Constructing a Graph Model for a strategic conflict requires determining the set of key DMs ($N; |N| \geq 2$), states ($s \in S; |S| \geq 2$), and each DM *i*'s relative preferences among states $(\succeq_i)_{i \in N}$. A state represents a distinguishable feasible outcome, and it enables the representation of DMs' course of actions. Possible moves from state to state are modeled using a directed graph for each DM *I*, (S, A_i), in which vertices represent states and arcs indicate state transitions, $A_i \subset S \times S$, controlled by focal DM *i*. $(s_1, s_2): s_1,\ s_2 \in S$ and $s_1 \neq s_2$, is an arc in DM *i*'s directed graph, if DM *i* can reach, in one-step move, state s_2 from state s_1. All DMs' strategic interactions represent the evolution of the conflict from a *status quo state* as DMs jockey for positions via state transitions until some stable state is reached. If attained, this stable state represents a resolution of the conflict. Formally, a *standard* Graph Model is an integration of all DMs' directed graph, and is expressed by a quartet of components:

$$G = \left[N, S, (A)_{i \in N}, (\succeq_i)_{i \in N} \right] \qquad \textbf{(1)}$$

2.2 Perceptual Graph Model

Inconsistent perceptions among DMs is commonly observed because of the prevalence of negative emotions and impulses as adversaries experience unjust, perceive the attainability of their goals hindered, or being physically or mentally hurt by other individuals' self-interest actions. Accounting for the effect of emotions in conflict by modifying the set of feasible states perceived by each DM according to DMs' emotions upsets an important assumption in the Graph Model, which is all DMs share a unified view of the conflict. Using a perceptual model, each DM is allowed to have its *own* graph, which consists of an integration of all DMs' perceived directed graphs. A DM's perceived directed graph is the DM's apprehension of its own recognized states, state transitions, pairwise comparisons of the recognized states, and an index of awareness. A perceptual graph model for DM $k \in N$ is an integration of all $k's$ perceived directed graphs using $k's$ set of recognized states, which reflects DM $k's$ perception and awareness of other DMs' perceptions. Using such perceptual lens each DM's viewpoint defines a conflict model.

A perceptual graph model defined for each DM $k \in N$, using *k*'s set of *recognized states*, S_k, is obtained by eliminating states not recognized by DM k. S_k reflects DM $k's$ perception, where $S_k \subseteq S$ and $S_k \neq \phi$. It is also assumed that the *status quo* state $s_0 \in S_k$. For DMs $i,k \in N$, S_i^k is defined as DM *k*'s perception of *i*'s set of state, where $S_i^k \subseteq S_k$. Notice that if the focal DM is the owner of the perceptual graph, then $k = i$ and $S_i^i \subseteq S_i$.

A perceptual graph model for DM *k* requires defining *k*'s state transitions and preferences among the recognized states as well as *k*'s perception of opponents' state transitions and preferences. Hence, Thus, for $i,k \in N,$, where *k* is the owner of a perceptual graph model, G_k, is based upon S_k; DM *k*'s perception of DM *i*'s state transitions, A_i^k, that are wholly contained within S_k; and DM *k*'s perception of DM *i*'s relative preferences among states, $\succeq_i^k$.

Furthermore, *k*'s perceptual graph model must reflect whether or not DM k is aware that other DMs recognize states in S_k. An index of awareness, $\alpha_k = 1$, is used in a perceptual graph model if DM *k* knows that some states in S_k are not recognized by opponents, and $\alpha_k = 0$ is used if DM *k* thinks all DMs share the same view of the conflict. Formally, *k*'s perceptual graph model is expressed as:

$$G_k = \left[N, \left(S_i^k\right)_{i \in N}, \left(A_i^k\right)_{i \in N}, \left(\succeq_i^k\right)_{i \in N}, \alpha_k \right] \quad (2)$$

3 Solution Concepts

Within the standard graph model structure, procedures have been established to assess the stability of states using various solution concepts (stability definitions), which are designed to reflect DMs strategic behavior under conflict. A solution concept is a mathematical model, which consists of a set of rules for identifying a state which a DM would choose to stay at given that the state has been attained. These rules describe calculations that measure a rational DM's expected success to attain a more preferred outcome as DMs jockey for positions via moves and countermoves. A state is stable if and only if (iff) a DM decides not to move away from it when the state is attained. The incentive to stay at a state is determined by the lack of a unilateral improvement from the state, or the prospects of a sanction that could be levied by an opponent should the DM decide to move away from the state. A sanction is an opponent's countermove to every UIs by a focal DM that would move the conflict to an equally or less preferred state for the focal DM. A state that is stable under a solution concept becomes equilibrium if the DM also believes that other DMs prefer to stay at that state.

In the Graph Model the set of all states that DM *i* can unilaterally reach from state $s \in S$ in one step is the *reachable list*, $R_i(s)$. In a 2-DM model, let $N = \{1,2\}$ and either $i = 1$ and $j = 2$ or $i = 2$ and $j = 1$. Assuming that DM *i* seizes the initiative and moves first, then *i* is called the *focal* DM and DM *j* is *i*'s opponent. Based on a focal DM's preference, the set of feasible states, S, can be partitioned relative to a particular state $s \in S$ into two sets: $\Phi_i^+(s)$ and $\Phi_i^{\leq}(s)$. $\Phi_i^+(s) = \{s_m \in S : s_m \succ_i s\}$ is the set of all states that DM *i* prefers to state s; and $\Phi_i^{\leq}(s) = \{s_m \in S : s \succeq_i s_m\}$ is the set of all states that DM *i* finds equally or less preferred to state s. Furthermore, for DM *i*, $R_i(s)$ can be further partitioned into two subset: $R_i^+(s) = R_i(s) \cap \Phi_i^+(s)$ is the set of *unilateral improvements* from state s and $R_i^{\leq}(s) = R_i(s) \cap \Phi_i^{\leq}(s)$ is the set of *unilateral disimprovements* from state s. The followings are Nash and symmetric metarationality formal solution concepts for the case of 2-DMs.

3.1 Standard Nash and Symmetric Metarationality Stabilities

Nash stability. For $i \in N$, a state $s \in S$ is Nash stable for DM i, denoted by $s \in S^{\mathrm{Nash}_i}$, iff $R_i^+(s) = \varnothing$.

In other words, DM *i* has no possible unilateral improvements. A DM who is acting according to Nash stability will move to a more preferred state only if it is possible without regard to opponents' preferences and any possible countermoves. The (myopic) underlying assumption of Nash stability is that DM i expects that the other DMs, $|N-i|$, would not move away from the state reached after i's move.

Symmetric Metarationality Stability (SMR). For $i \in N$, a state $s \in S$ is symmetric metarational stable for DM i, denoted by $s \in S^{\mathrm{SMR}_i}$, iff for every $t \in R_i^+(s)$, $R_j(t) \cap \Phi_i^{\leq}(s) \neq \varnothing$, and for all $h \in R_j(t) \cap \Phi_i^{\leq}(s)$, $R_i(h) \cap \Phi_i^{+}(s) = \varnothing$.

A state s is symmetric metarational stable for DM i iff for every UI i can take advantage of from state s, DM j can countermove the UIs to a state that is at most as good for DM i as the original state s and there is no unilateral counter-response by DM i can leave it better off than the original state s. In other words, there is an inescapable sanction to every possible UI by DM i. Notice that Nash stability, under SMR the DM contemplates three moves ahead.

3.2 Perceptual Nash and Symmetric Metarationality Stabilities

A perceptual graph mode permits DMs to have different apprehensions of the underlying decision problem, which violates a fundamental assumption of the Graph Model methodology—that all DMs' directed graphs have identical sets of vertices (states). Nonetheless, a perceptual graph model inherits most of its components from a standard graph model. Inherited components include the DMs, states, state transitions and DMs' relative preferences for states. Inconsistencies in apprehending outcomes necessitate modification of the set of feasible states to reflect each DM's perception. Consequently, perceived state transitions and preferences regarding the perceived states may vary among DM's perceptual models. Hence, every perceptual graph model is created for every DM through a mapping function $G_k = \xi_k(G)$, each consists of sub-models that share many properties with the standard graph model.

Analyzing a perceptual graph mode is unlike the way a standard graph model is being analyzed. Because of the possibility of apparent inconsistency in perceptions, any conclusions drawn by analyzing a conflict model depends on both the owner of a perceptual graph model, DM *k*, and the focal DM—the one that takes initiative and makes first move. Whether to use standard or perceptual stability depends on DM *k*'s index of awareness—whether DM *k* is aware that other DMs do not apprehend some of S_k. If DM *k* is unaware, $\alpha_k = 0$, of inconsistent perceptions among DMs then standard Nash and symmetric stabilities is used to analyze *k*'s model. Here DM *k* believes $G_k = G_i, \forall i \in N-k$. While, if DM *k* is aware, $\alpha_k = 1$, that other DMs perceive only partial view of G_k then perceptual solution concepts (defined below) are used to analyze *k*'s model (Obeidi et al., 2009b).

The set S^c is the set of commonly perceived states by all DMs in N. This set of states represents distinguishable feasible outcomes that are conspicuous to DMs. Similarly, DMs k and j, and $S_{kj}^P = S_k \cap \overline{S}_j$ to be the set of states recognized by k but not j, where $\overline{S}_j$ is the complement of S_j in S. Also, the set of states *private* to DM *k* is $S_k^P = S_k \cap \overline{S}_1 \cap \overline{S}_2 \cap ... \cap \overline{S}_k \cap \overline{S}_{k+1} \cap ... \cap \overline{S}_n$. If the index of awareness of DM *k* is $\alpha_k = 0$, then *k* will not be aware of these private states, i.e., $S_k^P = \varnothing$.

Similar to earlier convention, in a 2-DM model let DM *k* refer to DM who owns the graph model, G_k, and DM *i* refer to the focal DM who seizes the initiative and makes the first move from a state, and let DM *i*'s opponent be DM *j*. Either $k = i$ or $k = j$ but not both. When $k = i$, DM *i* analyzes the stability of states in G_i twice. First, when *i* is the focal DM while *j* is the opponent, and second, when *j* is the focal DM while *i* is the opponent. The outcomes of DM *i*'s stability analysis represent *i*'s perception of the stability of states in G_i using a particular solution concept. Similarly, when $k = j$, DM *j* analyzes the stability of the states in G_j for DMs i and j.

Perceived Nash Stability. For $i, j \in N$ and $k = i$ or $k = j$, a state $s \in S_k \cap S_i$ is perceived by *k* to be

Nash stable for DM *i*, denoted by $s \in S_k^{\text{Nash}_i}$, iff $R_i(s) \cap S_k \cap S_i \neq \emptyset$ and $R_i^+(s) \cap S_k = \emptyset$.

In G_k the standard Nash stability is reformulated to take into account a DM's inability to perceive more preferred states. Under perceived Nash stability, DM k perceives a state to be Nash stable for the focal DM i whenever k believes that there is no preferred state in S_k that i can move to.

Perceived Symmetric Metarationality Stability. For $i, j \in N$ and $k = i$ or $k = j$, a state $s \in S_k \cap S_i$ is perceived by k to be SMR stable for DM *i*, denoted by $s \in S_k^{\text{SMR}_i}$, iff $R_i^+(s) \cap S^C \neq \emptyset$ and for every $t \in R_i^+(s) \cap S^C$, $R_j(t) \cap \Phi_i^{\leq}(s) \cap S^C \neq \emptyset$, and for all $h \in R_j(t) \cap \Phi_i^{\leq}(s) \cap S^C$, $R_i(h) \cap \Phi_i^+(s) \cap S_k = \emptyset$.

According to this definition, DM *k* perceives a state to be symmetric metarational stable for a focal DM *i* whenever *k* believes for every unilateral improvement *i* can make, there is an inescapable sanction by DM *j*. That is the focal DM has no counter response to opponent's sanctions.

4 Consistency of Nash and SMR across Perceptual Graphs

Mapping a standard graph model to a perceptual graph model may affect the stability of a state under standard solution concepts. The stability of a state for a focal DM may change because the state is not recognized by the owner of a graph model, or because some state transitions controlled by a DM in the standard graph model become invisible to that DM in the perceptual graph. In the former case, the stability of the state is irrelevant, because it cannot be assessed for stability by the owner of the graph model. But in the latter situation, either the stability status of the state under a particular solution concept is altered (i.e., stable state becomes unstable and unstable state becomes stable), or the state cannot be assessed for stability under the same solution concept because the DM cannot or has no desire to unilaterally move away from it; thereby the stability of the state is limited to perceived default or Nash stability for the focal DM. A state is perceived default for a focal DM if the DM has no ability to move away from the state.

Hence, a state that is stable for a DM in the standard graph model may or may not be stable in a perceptual graph model system, from the viewpoint of the DM who perceives it. Nonetheless, some solution concepts are resilient to DMs' inconsistent perceptions of the conflict; in that their stability properties are preserved as the standard graph model is mapped into sub-models. Understanding these inherited qualities, moreover, may expedite a perceptual stability analysis. Most notably, Nash and SMR stability in a perceptual graph model system can be inferred from a stability analysis of the standard graph model.

The rules embedded in a solution concept identify a current state that a DM may tend to stay at, given that the state is attained. In Nash stability, the basic rule examines whether a focal DM can move unilaterally to a more preferred state. Thus, the absence of unilateral improvements (UIs) indicates that the state is Nash stable. Consequently, the lack of a UI in a standard graph model must be preserved in a perceptual graph model. Hence, if a state is Nash stable for a DM in the standard graph model, the state cannot be unstable in any sub-model for that DM.

Theorem 1: Persistence of Nash Stability. A state $s \in S$ that is Nash stable for a DM in a standard graph model maintains its stability in any perceptual graph model for any DM who perceives it.

Proof (by contradiction):

Suppose that $s \in S_k \cap S_i$ for $i, j \in N$, that $k = i$ or $k = j$, and that the state *s* is Nash stable in G for DM *i*. Therefore, $R_i^+(s) = \emptyset$. Assume that the state *s* is *not* Nash stable for DM *i* in a perceptual graph model. Then, either $R_i^+(s) \neq \emptyset$ is true if $\alpha_k = 0$ or $R_i^+(s) \cap S_k \neq \emptyset$ is true if $\alpha_k = 1$. In either case, this contradicts the assumption (in the second case, because $R_i^+(s) \cap S_k \subseteq R_i^+(s)$). Hence, $R_i^+(s) = \emptyset$ must be true if $\alpha_k = 0$ and $R_i^+(s) \cap S_k = \emptyset$ must be true if $\alpha_k = 1$.□

In a 2-DM model, if a state is Nash stable for DM *i* in the standard graph model, then, in DM *k*'s perceptual graph ($k = 1$ or $k = 2$), it will remain Nash stable for DM *i* provided that *k* perceives the state and it is not default stable. Conversely, a state that is not Nash stable for a DM in standard graph model may or may not be stable in a perceptual graph system from the viewpoint of the DM who perceives it.
In the SMR stability definition, the rules for identifying the stability of a state for a DM examines available escapes from sanctions imposed by opponents to all focal DM's UIs. A perceptual graph model system inherits the inescapability property of sanctions from the standard graph model. In other word, the absence of escapes to all opponents' sanctions must be preserved in all sub-models. Hence, a state that is SMR stable in standard graph model cannot be SMR unstable in a perceptual graph model system.

Theorem 2: Persistence of SMR Stability. A state $s \in S$ that is SMR stable for a DM in a standard graph model maintains its stability in any perceptual graph model for every DM who perceives it.

Proof (by contradiction):
Suppose that $s \in S_k \cap S_i$ for $i, j \in N,$ that $k = i$ or $k = j,$ and that the state *s* is Nash stable in G for DM *i*. Therefore, for every $t \in R_i^+(s),$ $R_j(t) \bigcap \Phi_i^{\leq}(s) \neq \emptyset,$ and for all $h \in R_j(t) \bigcap \Phi_i^{\leq}(s),$ $R_i(h) \bigcap \Phi_i^+(s) = \emptyset.$ Assume that the state s is GMR stable but *not* SMR stable for DM *i* in some perceptual graph model. Then, $R_j(t) \bigcap \Phi_i^{\leq}(s) \neq \emptyset,$ and $\forall t \in R_i^+(s), \forall h \in R_j(t) \bigcap \Phi_i^{\leq}(s),$ either $\alpha_k = 0$ and $R_i(h) \bigcap \Phi_i^+(s) \neq \emptyset$ is true or $\alpha_k = 1$ and $R_i(h) \bigcap \Phi_i^+(s) \bigcap S_k \neq \emptyset$ is true. In either case, this contradicts the assumption (in the second case, because $R_i(h) \bigcap \Phi_i^+(s) \bigcap S_k \subseteq R_i(h) \bigcap \Phi_i^+(s)$). Hence, $R_i(h) \bigcap \Phi_i^+(s) = \emptyset$ must be true when $\alpha_k = 0$ and $R_i(h) \bigcap \Phi_i^+(s) \bigcap S_k = \emptyset$ must be true when $\alpha_k = 1$. If the state s is not GMR stable in a perceptual graph model, s cannot be assessed for SMR stability in the perceptual graph model.□

In a 2-DM model, if a state is SMR stable for DM *i* in the standard graph model, then, in DM *k*'s perceptual graph ($k = 1$ or $k = 2$), it will remain SMR stable for DM *i* provided that *k* perceives the state and the state is GMR stable for *i*. To paraphrase, the following two conditions must be satisfied to preserve SMR stability: (1) the DM who owns the perceptual graph model must recognize the current state and at least one UI from it, and (2) the UI and any possible sanction must be recognized by all DMs. A state that is SMR unstable for a DM in the standard graph model may or not be stable in perceptual sub-models from the viewpoint of the DM who perceives it.

On the other hand, an inference can be made about the stability of a state in the standard graph model from its stability in perceptual sub-models. If a state is recognized in all perceptual graph models and stable for a DM for all $\alpha_k = 0$ and $\alpha_k = 1$, then the state must be stable in the standard graph model for that DM.

Theorem 3. For all $k \in N,$ a state $s \in S_k$ that is stable in G_k for DM $i \in N,$ under a particular solution concept, must be stable in a standard graph model for DM *i* under that solution concept.

Proof (by contradiction):
A state $s \in S_k$ for $\forall k \in N,$ implies that $s \in S^C.$ Suppose that the state s is stable in G_k for DM $i \in N.$ Then s is perceived by every DM k to be stable for DM i. Assume that s is not stable in the standard graph model for DM i. Thus s is not perceived by all DMs to be stable for DM i, which contradicts the initial assumption. Hence, state s must be stable in the standard graph model for DM i. □
Thus, if a state is recognized in all perceptual graph models and the state is unstable for a DM in all variants of awareness, then the state must be unstable in the standard graph model.

5 Conclusions

A perceptual graph model for a conflict inherits its basic ingredients from a standard graph model, but with some modifications. Thus, a DM's perceptual graph model is based upon the set of states recognized by the DM; the state transitions that are wholly contained within these recognized states; and the DM's perception of all DMs' relative preferences among states. In addition, a perceptual graph model must reflect the DM's knowledge of other DMs' awareness of his or her recognized states Hence, a graph model system compiles all DMs' perceptual graph models, and expresses the perspective used by every DM in viewing and analyzing the conflict.

Formally, the above research shows that Nash and SMR stabilities are immune to lack of perception among DMs (Theorems 1 and 2). These stabilities are passed down from standard to any perceptual sub-model. On the other hand, inference can be made about the stability of a state in a standard graph model (perception-free model) by observing the stability of the state in all perceptual models. If the state is consistently stable under any solution concepts in all perceptual graph models the state that must be stable in the standard graph model.

An important point must be made about the above research. Despite the fact that in conflict DMs may have inconsistent perceptions because of emotions or any other reason, it is assumed that all are rational; in the sense all predictably behave in self-interest. However, the reality is DMs who are affected by emotions not only they may have different subjective perceptions they also possess different coping strategies where rationality suppressed. Therefore, we should be careful in drawing conclusions about real-life conflict when applying descriptive analysis, like the one in this research.

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References

Bennett, P. G. (1977), Toward a Theory of Hypergames. *Omega*, 5(6), 749-751.

Bennett, P. G. (1980), Hypergames: Development a Model of Conflicts. *Futures*, 12(6), 489-507.

Bennett, P. G. and Howard, N. (1996), Rationality, Emotion, and Preference Change: Drama-Theoretic Models of Choice. *European Journal of Operational Research*, 92, 603-614.

Brams, S. J. and Wittman, D. (1981), Nonmyopic Equilibria in 2x2 Games. *Conflict Management and Peace Science*, 6, 39-62.

Bryant, J. (2003), *The Six Dilemmas of Collaboration: Inter-organisational Relationships as Drama*. John Wiley, Chichester, England.

Carnevale, P.J. (2007), Positive Affect and Decision Frame in Negotiation. *Group Decision and Negotiation*, 17(1), 51-63.

Fang, L., Hipel, K. W., and Kilgour, D. M. (1993). *Interactive Decision Making: The Graph Model for Conflict Resolution.* Wiley, New York.

Fraser, N. and Hipel, K. W. (1984), *Conflict Analysis: Models and Resolutions*. North Holland New York.

Howard, N. (1971). *Paradoxes of Rationality: Theory of Metagames and Political Behavior*. MIT Press Cambridge, Massachusetts.

Kilgour, D. M. (1985), Anticipation and Stability in Two-Person Noncooperative Games. In U. Luterbacher and M. D. Ward (eds.), *Dynamic Models of International Conflict. Boulder*, Lynne Rienner Publishers, CO.

Lazarus, R. S. (2001a), Progress on Cognitive-Emotional-Relational Theory of Emotion. *American Psychologist*, 46, 819-834.

Lazarus, R. S. (2001b), Relational Meaning and Discrete Emotions. In K. R. Scherer, A. Schorr, A., and T. Johnstone (eds.), *Appraisal Processes in Emotion*. Oxford University Press, New York.

Obeidi, A., Hipel, K. W., and Kilgour, D. M. (2005, The Role of Emotions in Envisioning Outcomes in Conflict Analysis. *Group Decision and Negotiation*, 14(6), 481-500.

Obeidi, A., Kilgour, D. M., and Hipel, K. W. (2009a), Perceptual Graph Model Systems. *Group Decision and Negotiation*, 18: 261-277.

Obeidi, A., Kilgour, D. M., and Hipel, K. W. (2009b), Perceptual Stability Analysis of a Graph model System. *IEEE Transactions on Systems, Man, and Cybernetics—Part A: Systems and Humans.* 18: 261-277.

Pinkley, R.L., Gelfand, M.J., Duan, L. (2005), When, Where and How: The Use of Multidimensional Scaling Methods in the Study of Negotiation and Social Conflict. *International Negotiation*, 10(1), 79-96.

Nash, J. F. (1950), Equilibrium Points in n-Person Games. In: *Proceedings of National Academy of Sciences,* 36, 48-49.

Nash, J. F. (1951), Noncooperative Games. *Annals of Mathematics*, 54(2), 286-295.

Von Neumann, J. and Morgenstern, O. (1953). Theory of Games and Economic Behavior. 3rd ed., Princeton University Press, Princeton, N.J.

Wang, M., Hipel, K. W., and Fraser, N. M. (1988), Modeling Misperception in Games. *Behavioral Science*, 33(3), 207-223.

Zagare, F. C. (1984), Limited-Move Equilibria in 2x2 Games. *Theory and Decision*, 16(1), 1-19.

GDN Models and Applications

Collaborative Dominance: an experimental study

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Abstract: In this paper we experimentally studied three aspects of 2x2 games with collaboratively dominant strategies: the mixed equilibrium; the collaborative equilibrium; and the burning money mechanism. First, we detected that players do not seem to play according to the mixed equilibrium and that the collaborative equilibrium does not seem to have focal point properties. Finally we detected that a burning money mechanism only helps players to collaborate when it transforms a collaborative profile of strategies into a collaborative equilibrium.

Keywords: Collaborative Dominance; Mixed Equilibrium; Burning Money; Experiments.

1 Introduction

In recent studies, Souza and Rêgo (2010a,b) developed some critics on the mixed Nash equilibrium in 2x2 normal form games, especially for games where both players have a strict preference for one of the other player pure strategy, regardless their own strategies. In a 2x2 game, when a player has a pure strategy which is strict preferred by the other player, the authors define this strategy as a *strongly collaboratively dominant strategy*; and when an equilibrium profile is composed only by collaboratively dominant strategies, they say that the equilibrium is a *collaborative equilibrium*.

Initially, supported by those two ideas, the authors argument that for games with a collaborative equilibrium and at least one mixed equilibrium in the non-degenerated sense, playing according to a mixed equilibrium should not be considered as a rational behavior. For example, imagine the Stag-Hunt game, in which a collaborative equilibrium exists and still the mixed equilibrium is recommended as a rational behavior for the players. However, by playing according to the mixed equilibrium (making the other player indifferent), players are contradicting their original preferences and, furthermore, are achieving inefficient outcomes, what can be considered an irrational behavior.

Furthermore, Souza and Rêgo (2010a,b) developed an approach that shows when a burning money behavior by the players can improve their expected utility in a given game. First, Souza and Rêgo (2010a) proved that a burning money mechanism can be used by the player to transform a profile of strategies composed only by collaboratively dominant strategies in a collaborative equilibrium and, therefore, improve players' payoff. In a second work, Souza and Rêgo (2010b) proved that burning money for some specifics strategies profile can improve the collaboration likelihood and, consequently, the players' expected payoffs in the mixed equilibrium if and only if, players have collaboratively dominant strategies.

In this paper we propose to study experimentally three main issues of 2x2 one-shot games with collaboratively dominant strategies: the mixed equilibrium; the collaborative equilibrium as a focal point; and the burning money mechanism as a collaboration incentive. Thus, the remainder of the paper is organized as follows: in Section 2, we make a brief review of the experimental and empirical literature about mixed equilibrium and burning money games; in Section 3, we present the design of the experimental and the main hypothesis that we will test; in Section 4, we discuss the results of the experiment and, in Section 5, we present the final remarks of the paper.

2 A brief review of the literature

In developing a theory about human behavior from an economic standpoint, two main ideas may coexist, i.e., we want to create a theory that explains how individuals should behave in a given situation or we wish to create a theory that explains how individuals actually behave? The experimental method and the empirical research reduce the gap between these two ideas, because they can assist in the validation of standard theories and/or provide evidences for new theories. Now we present a brief review of some experimental and empirical studies that inspired our research, starting with an analysis of the mixed equilibrium.

Ochs (1995) experimentally tested three variations of the game shown in Figure 1 in order to assess if the players behave according to what is suggested by the mixed Nash equilibrium.

		Player 2	
Player 1		*A*	*B*
	A	*(a, 0)*	*(0, b)*
	B	*(0, b)*	*(c, 0)*

Fig. 1. Testing the mixed equilibrium (OCHS, 1995).

In this game, the payoffs *a*, *b* and *c* were all positive and, therefore, the game has a unique mixed equilibrium in the form $E = ((½, ½), (c/(a+c), a/(a+c)))$. Initially, Ochs studied how the players behave if $a=b=c$; and after he analyzes what changes in players' behavior when the payoff *a* increases and the other payoffs remain constants.

As his main results, Ochs found that almost all players 1 respond to increases in *a* by playing strategy *A* more frequently, fact that is contrary to the mixed equilibrium theory. In contrast, he observed that when the payoff *a* increases, player 2 chose strategy *A* less frequently, result that corroborated with the mixed equilibrium theory.

Even the major contribution on the test of standard theories are realized by experimental studies, recently, empirical studies are getting more space in literature once they make use of base of date collected by the observation of the human behavior in real world situations, especially in sports competitions. Walker and Wooders (2001) assessed the probability of a tennis player draw on the left side or the right side of his opponent based on historical data of the Wimbledon Championship. Chiappori, Levitt and Groseclose (2002) evaluated the probability of a soccer player kick a penalty on the left, on the right or on the center, based on historical data of the Italian and the French soccer championships that encompassed a period of approximately three years. In both studies, the authors found empirical evidence that supported the mixed equilibrium theory.

Now, making a pause from studding the mixed equilibrium and passing for the study of burning money games, we can highlight the work of Huck and Müller (2005), which evaluated the theoretical prediction introduced by Van Damme (1989) and Ben-Porth and Dekel (1992). Ben-Porth and Dekel (1992) proved that in games in which a player has a strict preference for an equilibrium point, and if this player can self-sacrifice (burning utility), then, based on the forward induction rationality and iterative elimination of weakly dominated strategies, such player will achieve his (or her) most preferred outcome.

To test this theoretical prediction Huck and Müller divided their experiment in three main parts. In the first part, the participants played the Battle of the Sexes game, as show in Figure 2. In this game, the authors observed that the frequency that strategy X and W are played does not stay far from the theoretical prediction of the mixed equilibrium.

		Player 2	
Player 1		*W*	*Z*
	X	*(3, 1)*	*(0, 0)*
	Y	*(0, 0)*	*(1, 3)*

Fig. 2. The Battle of the Sexes Game.

The second part of the experiment consisted of a sequential game where Player 1 should choose between two payoff matrix, one in winch the payoffs were identical to the original Battle of the Sexes (i.e.

without burning money) and another in which all payoffs of the Player 1 were reduced (i.e. a game with burning money). Furthermore, Player 2 observes the initial choice made by Player 1 and, thereafter, both choose their strategies simultaneously. With this experiment the authors test the hypothesis that the opportunity of burning money will bring an advantage for Player 1, which would result in the fact that Player 1 would chose not to burn money and then his favorite strategy profile will be achieved. This hypothesis was confirmed statistically. However Huck and Müller make an advertence that even the results being statistically significant, indicating the advantage of Player 1, the observed frequency is still lower than the one expected by the theory, which completely solves the coordination problem between the players.

In the third experiment, the hypothesis tested was the same as the second, with the only difference that instead of a sequential form representation, the game was exposed in the reduced normal form representation. In this case, the result was very different, i.e., Player 1 was able to reach his favorite strategy profile in only 6.5% of the cases. As an explanation for this divergent result, the authors suggest that the participants were unable to perform the iterative elimination of weakly dominated strategies. However by the sequential character of the burning money, it is possible to infer an advantage for Player 1. Other discussions and similar results on forward induction rationality and elimination of dominated strategies can be found in Brandts and Holt (1995).

3 Experimental design

There is a growing literature (both theoretical and, specially, experimental) that seeks to explain the individual behavior in strategic situations by means of reciprocity, indirect reciprocity, reputation, altruism and many others aspects. Such studies are often supported by evolutionary game theory, where, for example, it is assumed that players can learn during a sequence of games. Because of the evolutionary aspect of learning, Maskin (2011) states that the Nash equilibrium (both pure and mixed) provides a good prediction of individual behavior, at least when the players acquire sufficient experience in the game in question. In contrast, Rey-Biel (2009) indicates that it does not occur when individuals play a game for the first time. Thus, in our experiment, we will follow the Rey-Biel line, i.e., we analyze the individual behavior when the players are faced with a strategic situation for the first time, excluding the possibility of learning by repetition.

Our experiment was design in three basic parts: In Part I, we test if players behave according to the mixed Nash equilibrium; In Part II, we test if the collaborative equilibrium can be seen as a focal point (or if the mixed equilibrium behavior prevails); In Part III, we test if the burning money behavior by the players can make cooperation (collaboration) more likely. Furthermore, in each part of the experiment, players shall express their beliefs about the other player's behavior.

In Parts I and II, the participants were asked how many times they would choose a particular strategy if they were to play the game 15 times. The game chosen to evaluate the behavior of the participants in Part I was the Chicken game (also known as Hawk-Dove game) shown in Figure 3. This game was selected because it is a coordination game with two pure equilibriums (asymmetric), (Y, W) and (X, Z), and a mixed equilibrium, E=((1/3, 2/3), (1/3, 2/3)), what lead theories of equilibrium selection (such as Harsanyi and Selten (1988)) to indicate the mixed equilibrium as the solution of the game. Nevertheless, in the Chicken game, both players have collaboratively dominant strategies, Y is collaborative dominant for Player 2 and Z is collaboratively dominant for Player 1. The existence of such a pair of collaborative dominant strategies could lead the players to collaborate, even if this strategy profile not being an equilibrium. So, if players acted according to the mixed equilibrium, then the expected number of times that they would have chosen their collaborative dominant strategies (Y and Z) is 10. Thus the hypothesis to be tested is:

H_0: The average number of times that participants collaborate (choose strategy Y or Z) is equal to 10.
H_1: The average number of times that participants collaborate (choose strategy Y or Z) is different from 10.

		Player 2	
Player 1		*W*	*Z*
	X	*(10, 10)*	*(90, 50)*

	Y	*(50, 90)*	*(70, 70)*

Fig. 3. The Chicken Game – PART I.

The game chosen to evaluate the participants' behavior in Part II was the Stag-Hunt game shown in Figure 4. This game has two pure (symmetric) equilibriums, (*X, W*) and (*Y, Z*), and one mixed equilibrium, *E*=((2/3, 1/3), (2/3, 1/3)).

	Player 2		
Player 1		*W*	*Z*
	X	*(90, 90)*	*(10, 70)*
	Y	*(70, 10)*	*(50, 50)*

Fig. 4. The Stag-Hunt Game – PART II.

In addition, the pure equilibrium (*X, W*) is payoff dominant (and is a collaborative equilibrium) while the equilibrium (*Y, Z*) is risk dominant. Thus, as stated by Goldman and Page (2010), any of the pure equilibrium of the game could be selected as the solution of the game depending of the selection criterion invoked by the players. Furthermore, Rankin, Van Huyck and battalion (2000) argue that when more than one equilibrium selection criterion can be used, players must find a way to focus on the same criterion, or the coordination problem will remain. Thus, in Part II, we will test the idea that the collaborative equilibrium could be seen as a focal point (because of its efficiency properties) which would eliminate the coordination problem, and could also prevent the players to play according to the mixed equilibrium. Therefore, like in Part I, we test:

H_0: The average number of times that participants collaborate (choose strategy X or W) is equal to 10.
H_1: The average number of times that participants collaborate (choose strategy X or W) is different from 10.

In Part III, players were given the option to choose between two given games and then they had to answer the same questions of Parts I and II. The games that the players had to choose from are shown in Figure 5. This approach intends to verify if the participants recognize the burning money opportunity as a mechanism that helps them to achieve a better result in the game (when compared with the original mixed equilibrium of the games in Parts I and II). Then, we test two main hypotheses:

H_0: The proportion of individuals who chose to play the game with the highest payoff is equal to 1/2.
H_1: The proportion of individuals who chose to play the game with the highest payoff is different from 1/2.

And,

H_0: The average number of times that players collaborate when chose to burn money is equal to the average number of times that players collaborate when chose not to burn money.
H_1: The average number of times that players collaborate when chose to burn money is different from the average number of times that players collaborate when chose not to burn money.

A total of 167 subjects participated in the experiment, 82 classified as Player 1 and 85 classified as Player 2. All the subjects were undergraduate volunteers from the Economic and Accounting fields of a Brazilian university. They were told that, for each type of player, the participant who had obtained the highest expected score in the sum of all games would win a prize of R$250.00. To calculate the expected score, the performance of each participant was measured considering the sum of their score against the choice of all others participants classified as the other type of player. In the event of a tie, they were told the prize would be divided equally among the winners.

Game 1

( )

		Player 2	
Player 1		*W*	*Z*
	X	*(10, 10)*	*(90, 50)*
	Y	*(50, 90)*	*(70, 70)*

( )

		Player 2	
Player 1		*W*	*Z*
	X	*(10, 10)*	*(70, 50)*
	Y	*(50, 70)*	*(70, 70)*

Game 2

( )

		Player 2	
Player 1		*W*	*Z*
	X	*(10, 10)*	*(90, 50)*
	Y	*(50, 90)*	*(70, 70)*

( )

		Player 2	
Player 1		*W*	*Z*
	X	*(10, 10)*	*(80, 50)*
	Y	*(50, 80)*	*(70, 70)*

Game 3

( )

		Player 2	
Player 1		*W*	*Z*
	X	*(90, 90)*	*(10, 70)*
	Y	*(70, 10)*	*(50, 50)*

( )

		Player 2	
Player 1		*W*	*Z*
	X	*(80, 80)*	*(10, 70)*
	Y	*(70, 10)*	*(50, 50)*

Fig. 5. Burning Money Games – PART III.

4 Results

Below we summarize the main results of the experiment.

4.1 Part I and II

In Part I, the average number of collaboration was approximately 6.74, the mode was ‘not collaborate’ (i.e. collaborate 0 times) with 57 observations (approximately 34%) and the standard deviation was approximately 5.84. When we analyze the participants’ belief about the behavior of the other player we observe that the average number of collaboration was approximately 7.93, the mode was ‘not collaborate’ with 45 observations (approximately 27%) and the standard deviation was approximately 5.66. Furthermore, the correlation between these two variables was approximately of 0.52.

Moreover, making the t-test of means against the reference constant of 10 (the expected number of collaboration if players are behaving according the mixed equilibrium) we have strong statistical evidence (p-value=0.000000) that the players do not behave as expected by the mixed equilibrium theory. In fact, there is statistical evidence that the participants collaborate less than the expected by the mixed equilibrium theory.[1] A possible explanation for this result is the competitive character of the Chicken game, i.e. to collaborate when the other player is to collaborate too is not a Nash Equilibrium.

In Part II, the average number of collaboration was approximately 7.11, the mode was ‘not collaborate’ with 49 observations (approximately 29%), closely followed by 15 collaborations, with 47 observations (28%) and the standard deviation was approximately 6.01. When we analyze the participants’ beliefs about the behavior of the other player, we observe that the average number of collaboration was approximately 7.61, the mode was ‘always collaborate’ with 51 observations (approximately 30.5%) and the standard deviation was approximately 5.95. Furthermore, the correlation between these two variables was approximately of 0.65.

Making the t-test of means against the reference constant of 10 (the expected number of collaboration if players are behaving according the mixed equilibrium) we have strong statistical evidence (p-value=0.000000) that the players do not behave as expected by the mixed equilibrium theory. In fact, there is statistical evidence that the participants collaborate less than the expected by the mixed

[1] Making the same test to evaluate players’ belief, there is also significant evidence (p-value=0.000005) that the participants believe that the other will collaborate less than the expected by the theory.

equilibrium theory.[2] A possible explanation for this result is that even though a collaborative equilibrium exists in the Stag-Hunt game, this equilibrium is riskier and, therefore, the players may chose not to collaborate as a defense mechanism, since they do not know the other player's behavior very well and do not have the opportunity to learn.

The main descriptive statistics of Part I and II are summarized in Table 1.

Table 1. Descriptive statistics of Part I and II.

Variable	Mean	Median	Mode	Std. Deviation
Part I:Collaboration	6.74251	7	0	5.842268
Part I: Belief about collaboration	7.928144	9	0	5.660654
Part II: Collaboration	7.113772	7	0	6.010452
Part II: Belief about collaboration	7.610778	7	15	5.945384

4.2 Part III

In Game 1 of Parte III, 119 subjects (approximately 71.26%) chose the game without burning money; in Game 2, 111 subjects (approximately 66.47%) chose the game without burning money; and, finally, in Game 3, this number rose to 134 subjects (more than 80%).

In Game 1, for those who chose the game without burning money, the average number of collaboration was approximately 6.24, the mode was 'not collaborate' with 47 observations (approximately 39.5%), and the standard deviation was approximately 6.06. When we analyze the participants' belief about the behavior of the other player we observe that the average number of collaboration was approximately 6.78, the mode was 'not collaborate' with 43 observations (approximately 36%) and the standard deviation was approximately 5.95. On the other hand, for those who chose the game with burning money, the average number of collaboration was, approximately 8.52, the mode was 'always collaborate' with 14 observations (approximately 29%) and the standard deviation was approximately 5.87. When we analyze the participants' belief about the behavior of the other player we observe that the average number of collaboration was approximately 10.19, the mode was again 'always collaborate' with 18 observations (approximately 37,5%) and the standard deviation was approximately 5.13. The main descriptive statistics of Game 1 are summarized in Table 2.

First, making a t-test of means against the reference constant of 0,5 (representing that half of players opt to burn money) we observe a p-value=0.000000, statistically indicating that players do not split themselves equally in both types of games (with or without burning money). In fact, the participants rarely (less than 30%) opt for the burning money game, however, when it happens, they seem to be more willing to collaborate. This conjecture is confirmed by the Mann-Whitney U Test. First, comparing the collaboration inclination of the two groups we have a p-value=0.025193; and comparing the two groups' beliefs we have a p-value=0.000916. Thus, there is statistical evidence that the burning money mechanism may help players to collaborate, by turning (collaborate, collaborate) into an equilibrium.

In Game 2, for those who chose the game without burning money, the average number of collaboration was approximately 6.47, the mode was 'not collaborate' with 42 observations (approximately 37.8%) and the standard deviation was approximately 6.11. When we analyze the participants' belief about the behavior of the other player we observe that the average number of collaboration was approximately 7.79, the mode was 'not collaborate' with 34 observations (approximately 29%) and the standard deviation was approximately 5.93.

[2] Making the same test to evaluate players' belief, there is also significant evidences (p-value=0.000001) that the participants believe that the other will collaborate less than the expected by the theory.

Table 2. Descriptive statistics of Part III – Game 1.

Game 1	N	Variable	Mean	Median	Mode	Std. Deviation
Without burning money	119	Collaboration	6.235294	5	0	6.060019
		Belief about collaboration	6.781513	7	0	5.950587
With burning money	48	Collaboration	8.520833	9.5	15	5.874538
		Belief about collaboration	10.18750	11.5	15	5.130867

On the other hand, for those who chose the game with burning money, the average number of collaboration was, approximately 6.48, the mode was 'not collaborate' with 15 observations (approximately 27%) and the standard deviation was approximately 5.41. When we analyze the participants' belief about the behavior of the other player, we observe that the average number of collaboration was approximately 8.1, the mode was again 'not collaborate' with 12 observations (approximately 21%) and the standard deviation was approximately 5.4. The main descriptive statistics of Game 2 are summarized in Table 3.

Table 3. Descriptive statistics of Part III – Game 2.

Game 2	N	Variable	Mean	Median	Mode	Std. Deviation
Without burning money	111	Collaboration	6.468468	6	0	6.112312
		Belief about collaboration	7.792793	9	0	5.931606
With burning money	56	Collaboration	6.482143	5.5	0	5.407036
		Belief about collaboration	8.107143	9	0	5.402621

Making a t-test of means against the reference constant of 0,5 we observe a p-value=0.000013, which indicates that players do not split themselves equally in both types of games. In game 2, participants opt for the burning money game in approximately 1/3, but cooperation seems not to emerge even with the possibility of burning money. This conjecture is confirmed by the Mann-Whitney U Test. First, comparing the collaboration inclination of the two groups we have a p-value=0.813747 and comparing the two groups' beliefs we have a p-value of 0.853428. Thus, there is statistical evidence that burning money just for some specific payoffs does not help players to collaborate. This is not a surprising result, once collaboration would only increase if players behave according to the mixed equilibrium; but, as discussed in Part I, this is not the case.

In Game 3, for those who chose the game without burning money, the average number of collaboration was approximately 8.02, the mode was 'always collaborate' with 47 observations (approximately 35%); and the standard deviation was approximately 6.17. When we analyze the participants' belief about the behavior of the other player, we observe that the average number of collaboration was approximately 7.21, the mode was 'not collaborate' with 41 observations (approximately 31%) and the standard deviation was approximately 6.12. On the other hand, for those who chose the game with burning money, the average number of collaboration was, approximately 5.15, the mode was 'not collaborate' with 12 observations (approximately 36%); and the standard deviation was approximately 5.85. When we analyze the participants' belief about the behavior of the other player we observe that the average number of collaboration was approximately 4.48, the mode was again 'not collaborate' with 14 observations (approximately 42%) and the standard deviation was approximately 5.06.The main descriptive statistics of Game 3 are summarized in Table 4.

Again, as well as it was detected in the earlier games, participants do not split themselves equally in both types of games (p-value=0,000000). In fact, they rarely (less than 20%) opt for the burning money game, and when it happens, they seem to be less willing to collaborate. This conjecture is confirmed by the Mann-Whitney U Test. First, comparing the collaboration inclination of the two groups we have a p-value=0.016715; and comparing the two groups' beliefs we have a p-value=0.01917. Thus, there is statistical evidence that burning money just for some specific payoffs do not help players to collaborate. One possible explanation for this result is that the Stag-hunt game has a collaborative equilibrium, (X, W)

and once the players do not opt for burning money in the payoffs of the profile (X, W) they could be more tempted to collaborate, even if the other player does not know his first option.

Table 4. Descriptive statistics of Part III – Game 2.

Game 3	N	Variable	Mean	Median	Mode	Std. Deviation
Without burning money	134	Collaboration	8.022388	8	15	6.169859
		Belief about collaboration	7.208955	7	15	6.116752
With burning money	33	Collaboration	5.151515	2	0	5.858334
		Belief about collaboration	4.484848	4	0	5.056686

5 Final Remarks

In this paper we experimentally studied three main aspects of 2x2 one-shot games with collaboratively dominant strategies: the mixed equilibrium; the collaborative equilibrium as a focal point and the burning money mechanism as a collaboration incentive. First we detected that players do not seem to play according to the mixed equilibrium and that the collaborative equilibrium seems not to have focal point properties when compared with a less risk equilibrium (even an inefficient one). Finally, we detected that a burning money mechanism only helps players to collaborate when it turns a collaborative profile of strategies in a collaborative equilibrium. The other mechanisms do not seem to have an improvement effect in collaboration since players do not behave according to the mixed equilibrium predictions.

References

Ben-Porath, E., Dekel, E. (1992), Signaling future actions and the potential for sacrifice, *Journal of Economic Theory*, 57, 36-51.

Brandts, J; Holt, A. (1995), Limitations of dominance and forward induction: Experimental evidence, *Economics Letters*, 49, 391-395.

Chiappori, P.-A.; Levitt, S.; Groseclose, T. (2002), Testing mixed-strategy equilibria when players are heterogeneous: the case of penalty kicks in soccer. *The American Economic Review*, 92, 4, 1138-1151.

Golman, R.; Page, S. E. (2010), Individual and cultural learning in stag hunt games with multiple actions, *Journal of Economic Behavior & Organization*, 73, 359-376.

Harsanyi, J. C.; Selten, R. (1988), *A General Theory of Equilibrium Selection in Games*. London: MIT Press.

Huck, S; Müller, W. (2005), Burning money and (pseudo) first-mover advantages: an experimental study on forward induction, *Games and Economic Behavior*, 51, 109–127.

Ochs, J. (1995), Games with unique mixed strategy equilibria: an experimental study. *Games and Economic Behavior*, 10, 200-217.

Maskin, E. (2011), Commentary: Nash equilibrium and mechanism design. *Games and Economic Behavior*, 71, 9-11.

Rankin, F. W.; Van Huyck, J. B.; Battalio, R. C. (2000), Strategic Similarity and Emergent Conventions: Evidence from Similar Stag Hunt Games. *Games and Economic Behavior*. 32, 315-337.

Rey-Biel, P. (2009), Equilibrium play and best response to (stated) beliefs in normal form games. *Games and Economic Behavior*, 65, 572-585.

Souza, F. C.; Rêgo, L. C. (2010a). Collaborative Dominance: When Doing Unto Others as You Would Have Them Do Unto You Is Rational. In Second Brazilian Workshop of the Game Theory Society in honor of John Nash, São Paulo, SP.

Souza, F. C.; Rêgo, L. C. (2010b). Mixed equilibrium: When Burning Money is Rational. In Second Brazilian Workshop of the Game Theory Society in honor of John Nash, 2010, São Paulo, SP.

Van Damme, E. (1989), Stable equilibria and forward induction, *Journal of Economic Theory*, 48, 476-496, 1989.

Walker, M.; Wooders, J. (2001), Minimax Play at Wimbledon. *American Economic Review*, 91, 1521-1538.

Group Decision and Negotiation Models in Brazil

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Abstract: This paper presents an overview of models and applications conducted on group decision and negotiation in Brazil. Main areas of applications found are water management, supplier selection, participatory budget and computer systems for production planning. Development of new approaches are related to voting procedure, veto procedure for additive group aggregation models, fuzzy for expert group aggregation models and a range of computational tools proposed from computer science area.

Keywords: Voting procedures; Group decision aggregation with veto; fuzzy models for expert aggregation Water management; supplier selection.

1 Introduction

There is a huge opportunity for developments of group decision and negotiation (GDN) models and applications in Brazil. A growth demand for GDN models in order to overcome a variety of problems has been notice in daily business life. Many researchers and practitioners have been concerned with applications related to multi-agent decision making process. Although, an increasing number of studies related to GDN models in Brazil have been found in recent years, there is still a large opportunity to produce research related to relevant literature, when one focuses on most relevant journals, mainly those indexed in ISI database. Similar situation is found GDN models in Latin America (Almeida and Costa, 2012). This unbalance between society demand and relevant research produced shows clearly an opportunity for new developments and applications in the field related to this environment.

Although a number of researchers and practitioners can be found working on GDN, isolated or in most cases in collaboration with other researches around the word, not much work has been found as a research produced in loco, taking into account contextual issues, such as: cultural aspects and peculiarities of applications itself.

This work presents a selection of research conducted on GDN in Brazil with emphasis to those work produced by teams developing research focused rather on the contextual issues of those applications than just bringing out and applying methods and models worked out for a diverse situation.

2 A Selection of models and studies carried out in Brazil

As previously explained the work selected and subsequently presented is related to research effectively worked out on GDN by research teams in Brazil. Also, a particular problem on participatory budgeting is presented due to its demand and applicability for the contextual issues experienced by the society in recent years.

2.1 Water management

The involvement of multiple decision makers is an inherent characteristic of water resources management and it is considered the possibility of conflicts amongst the stakeholders and the influence of powerful members over the preference of others. There are some group decision making models developed in Brazil in order to facilitate this decision situation, as follows:

Silva et al (2010a) presented a tool to support the committee responsible for the management of the watersheds in Brazil with the purpose of promotes decentralization and the participation of all involved in the water resources management. The tool provides a ranking of alternatives for the environmental recuperation of the watershed through the use of the multicriteria method PROMETHEE II. For each decision maker, the alternatives were ranked and then the individual rankings were combined into a global ranking which contained the preferences of the whole group.
Morais and Almeida (2007) studied the leakage problem in water supply system, which requires actions drawn from different aspects of water network management. They proposed a group decision-making model based on PROMETHEE V method to aim a leakage management strategy, considering the points of view of four stakeholders to select feasible options, in view of the available budget as constraint. Thus, this strategy is the combination of options that will efficiently meet technical, socio-economic and environmental criteria to achieve sustainable development.
Morais and Almeida (2009) proposed an integrated model of problem structuring and multicriteria group decision making to analyze water sustainable projects. As problem structuring approach, they applied SSM (soft system methodology), to facilitate and to share information from a participative approach as a way to generate alternatives of solution and to improve the learning process among all the involved members. After the applied a multicriteria evaluation to find a group solution for the problem, incorporating the points of view of all members involved in the decision process.
Other model for water management can be found (Morais et al, 2010; Silva et al; 2010b; Morais and Almeida, 2006a and 2006b).

2.2 Supplier selection

Alencar and Almeida (2010) discuss how complex multi-criteria group decision making problem a selection of a project team could be. They propose a model based on a multi-criteria evaluation of the preferences of a client's representatives whose preferences diverge little. The methodology of PROMETHEE VI is adopted for the selection of a project team for a construction engineering company. A study considering a huge divergence among the preferences of decision makers can be found on Alencar and Almeida (2008). The latter model is based on two stages: the first one makes use of the ELECTRE IV methodology for ranking the criteria and on a second stage, a partial information method is considering for select a project team.
Considering aggregation of individual priorities, Alencar et al (2010) proposes a multi-criteria group decision model to be used in situations where absence of information regard with the relative importance of the decision makers. A three stage model is proposed where on the first stage the ELECTRE II method is applied to identify the individual rankings, follow by the construction of a global matrix of alternatives versus the individual preferences of the decision makers. On the third stage the ELECTRE IV is considered to aggregate the individual preferences and a final collective recommendation is undertaken.
Baccarin et al (2011) present a negotiation protocol for electronic multi-party contracts, built on the YAWL Workflow Management System. This protocol is implemented on Web services.

2.3 Participatory budget

Participatory budget (PB) is a social and political process that enables participation of the citizens, especially at local level, to be part of the decision of how fraction of a public budget is spent. PB can be understood as a budget allocation taking into account citizens' preferences, which sometimes diverges from the representatives' preferences.
In Brazil there are several variants of studies regarding PB:
Santos BS (1998) presented the case of Porto Alegre, a city in the south of Brazil, where the PB was organized through three steps: first, citizens receive basic information about the city budget in meetings at district level and a list of priorities for projects in the forthcoming budget is built. After that, they vote to assign priorities to projects. The available budget is distributed among thematic categories, and citizens vote, in regional assemblies, on thematic priorities. When this step is finished, the available budget is distributed among the thematic categories proportionally to the total points received. In a second step, the budget allocated to each specific thematic category is distributed among the regions according to a formula combining three criteria: the total population, the lack of services or infrastructures and the

thematic priority that has been given by citizens in each region. At the end of the process, the Investment Plan is subject to approval by the Municipal Council.
Fontana and Morais (2011) proposed to use a multicriteria method in the second step of PB in order to find a portfolio of feasible alternatives compatible with the city's goal. Nonetheless, it is not intended to eliminate the negotiation phase, but, the decision making process can be more transparent when it is used an appropriated method. They presented a case in Recife, a city in northeast of Brazil, applying Promethee multicriteria method which considers the actors' preferences, the problem constraints, and also facilitates the understanding process to conduct negotiations in the PB.
Silva and Morais (2011) presented a voting procedure based on fuzzy sets theory where voters can reveal their preferences among alternatives using linguistic terms that represent the common language used by the community daily.
PB is a remarkable way to promote citizens participation in the city's budget allocation and its success is widely acknowledged not only in Brazil but also internationally. The demand to use PB is increasing since the society is changing the way to think about politics and wants to be part of it. Nevertheless, this is a research field that needs to grow. According to Alfaro et al (2010) there are some reasons to make use of participatory processes, such as increase of legitimacy, acceptance and transparency in decisions made; approaching decisions to citizens; taking advantage of the local knowledge that citizens might have; educate politicians, remembering them that they are elected to represent citizens and mitigate patronage; educate citizens to make them understand that decisions entail both benefits and costs that need to be somehow balanced; enhance diversity, including additional perspectives on a problem; and, reduce the apathy which causes the above mentioned democratic deficit.

2.4 Voting procedures

In order to establish a collective preference based on the aggregation of different individual preferences, Morais and Almeida (2010) proposed a voting procedure based on analysis of individual priorities. The procedure is defined in four exploration phases (filter 1 and 2, veto and choose), as shown in Fig. 1, based on ranking the alternatives that have been constructed by each group member. The filter phase consists of creating two sets of alternatives considered as an upper and lower order, through separation by quartiles. In the veto phase, a positional count of the alternatives is performed, attributing a value corresponding to each position in the ranking per quartile. The intention is to eliminate the alternatives classified as worst by most decision makers through analyzing the strength and the weakness of the alternatives; in other words, a positional analysis is made of the alternatives that are in the upper and lower quartiles. The last phase of the exploration is to choose the alternative. The procedure is concluded when the alternative that has the largest number of points is selected.
Morais and Almeida (2010) proposed a group decision making model based on this voting procedure with the aim of choosing an appropriate alternative for water network rehabilitation which is the best compromise of the points of view of the actors involved in the decision problem. Morais and Almeida (2012) also applied this voting procedure in a real world application of a group decision problem to support the choice of an alternative to control the degradation of the hydrographic basin of Jaboatão River, located in the state of Pernambuco, Brazil.

2.5 Veto procedure for additive group aggregation models

The inherent compensatory effect of additive models is one of the major problems for aggregating group decisions using this kind of approach whereas the result may represent none of the individual decision makers' opinions. This problem is discussed in Daher and Almeida (2012) and a group decision model based on a ranking veto on additive models is proposed.
A preference group aggregation is obtained by introducing a utility reduction factor into the traditional formula of the global utility value. The model consider that decision makers are able to express their preferences by means of a ranking of selected alternatives and are also enable to make an informed veto of a ranking by their clear information about undesirable or unacceptable ranking position of some alternatives. Furthermore the combination of individual veto information may define to decision makers extra data regarding decision zones where agreement and disagreement are expected (Daher and Almeida 2012).

2.6 Fuzzy Approach for expert group aggregation models

In some studies, the group decision process is rather related to aggregation of experts' knowledge than the aggregation of decision maker' preferences (Almeida and Costa, 2012).
The term consensus scheme may used to denote a process where experts discuss a decision problem and a moderator work out to minimize discrepancy amongst individual experts' opinions. Ekel et al (2009). Parreiras et al (2010) deals with a group decision consensus scheme, related collective opinion, from information provided by each expert. The proposed consensus scheme is demonstrated by solving a hypothetical enterprise strategy planning problem, based on a Brazilian enterprise context.
Parreiras et al (2012) studied three aggregation procedures for the analysis of group decision making (aggregation of individual evaluations – AIA; aggregation of individual preferences per criterion - AIC; aggregation of individual results - AIR) and discussed some guidelines to choose an appropriate aggregation approach to be adopted depending on the decision context to construct a collective result. The presented schemes have been applied for solving an enterprise problem in order to distribute the labor across groups in such a way that the capabilities of each expert are efficiently exploited.
Krohling and Campanharo (2011) work out on a tool to support decision makers facing a contingency plan for oil spills, in an oil field located in Brazil. A fuzzy TOPSIS for group decision making is proposed to aggregate preferences of decision makers.

2.7 Negotiation and ethical issues

Volkema et al (2010) deals with negotiation and ethical issues. They examine negotiators' attitudes toward competitive and unethical tactics. They conducted an experiment with sixty-six graduate students from two business negotiation courses. The participants had a mean age of 25.6 years, and 60.6 percent were male. In 66.7 percent of cases of the experiment, both parties used a competitive-unethical behavior. The study presents and discusses implications found in this experiment.

2.8 Studies connected with computer science

A variety of studies may be found in literature related to either applications or methods concerned with group decision and negotiation processes in Brazilian context, which are connected with computer science.
Queiroz et al (2002) deals with systems that performs recommendations for groups of people, making connections with social choice and psychology. They use collaborative filtering and classification of alternatives based on fuzzy approach. Carvalho et al (2011) describes LaSca (from Large Scale), a system that supports decisions in large-scale groups, facilitating the decision-making process.
Daher and Almeida (2010) conducted a search with the objective of assimilating information from widely diverse sources of patent databases such as US Patent Office, European Patent Office, WIPO and the Japanese Patent Office to provide an overview regarding software and/or systems patented during a 5-year period (2005-2009) regarding group decision and negotiation theme. Some selected patents are commented. The authors noted that comparing with the numbers of academic studies published on important journals on the same period of time, the numbers of patents are very less than it could be and are in majority supported by enterprises.
Sordoni et al (2010) study the design of an artificial agent taking decisions combined with human agents. The system considers votes of stakeholders for final decision. Zattar et al (2010) use negotiation protocol for decision-making in a job-shop environment. The protocol has been changed for inclusion of multiple tasks and many-to-many negotiations. Enembreck et al (2009) deal with trade agents in multi-issue bilateral dynamic negotiations, using dynamic weighted majority algorithm.

3 Conclusions

It has been shown that a variety of models have been built in GDN studies conducted in Brazil. Most of these studies are related to water management, supplier selection, participatory budget and computer

systems for production planning. Also, new approaches have been developed in order to tackle contextual situations, normally found in real applications.
It has been notice that there is a clear opportunity for developments of GDN models and applications in several situations in order to meet an increasing demand for these kind models.

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References

Alencar, L.H.; Almeida, A.T. (2008). Multicriteria Decision Group Model for Suppliers Selection. *Pesquisa Operacional*, v. 28, p. 321-337.

Alencar, L.H.; Almeida, A.T. (2010). A model for selecting project team members using multicriteria group decision making. *Pesquisa Operacional*, v. 30, p. 221-236.

Alencar, L.H.; Almeida, A.T.; Morais, D.C. (2010) A multicriteria group decision model aggregating the preferences of decision-makers based on ELECTRE methods. *Pesquisa Operacional*, v. 30, p. 687-702.

Alfaro, C.; Gomez, J.; Lavin, J.M.; Molero, J.J. (2010) A configurable architecture for e-participatory budgeting support. JeDEM, 2(1): 39-45.

Almeida, A.T.; Costa, A.P.C.S. (2012). Research Developments of Group Decision and Negotiation in Latin America. *Group Decision and Negotiation*, v. 21, p. 129-132.

Baccarin, E.; Madeira, E. R. M.; Medeiros, C. B.; Van der Aalst, W.M.P. (2011) SPICA'S Multi-Party Negotiation Protocol: Implementation Using YAWL. International Journal of Cooperative Information Systems. 20(3): 221-259.

Carvalho, G; Vivacqua, A. S.; Souza, J. M.; Medeiros, SPJ (2011) LaSca: a Large Scale Group Decision Support System. Journal of Universal Computer Science. 17(2): 261-275.

Daher, S.F.D.; Almeida, A.T. (2010) Recent Patents Using Group Decision Support Systems: A Short Review. *Recent Patents on Computer Science*, v. 3, p. 81-90.

Daher, S.F.D.; Almeida, A.T. (2012) The Use of Ranking Veto Concept to Mitigate the Compensatory Effects of Additive Aggregation in Group Decisions on a Water Utility Automation Investment. *Group Decision and Negotiation*, v. 21, p. 185-204.

Ekel, P.Ya.; Queiroz, J. Parreiras, R.O.; Palhares, R.M (2009) Fuzzy set based models and methods of multicriteria group decision Making. *Nonlinear Analysis*, 71: e409-e419

Enembreck, F.; Tacla, C. A.; Barthes, Jean-Paul (2009) Learning Negotiation Policies Using Ensemblebased Drift Detection Techniques. International Journal on Artificial Intelligence 18(2): 173-196.

Fontana, M. E.; Morais, D.C. (2011) Selecting a Portfolio of Alternatives in Participatory Budgeting based on multicriteria method. In: IEEE SMC 2011 International Conference on Systems, Man, and Cybernetics, 2011, Anchorage, Alaska. IEEE SMC 2011, 2011. p. 3179-3183

Krohling, R. A.; Campanharo, V. C. (2011) Fuzzy TOPSIS for group decision making: A case study for accidents with oil spill in the sea. *Expert Systems With Applications*, 38(4): 4190-4197.

Morais, D.C.; Almeida, A.T. (2006a). Water supply system decision-making using multicriteria analysis. *Water SA*, v. 32, n. 2, p. 229-235.

Morais, D.C.; Almeida, A.T. (2006b). Modelo de Decisão em Grupo para Gerenciar Perdas de Água. *Pesquisa Operacional*, v. 26, n. 3, p. 567-584.

Morais, D.C.; Almeida, A.T. (2007). Group Decision-Making for Leakage Management Strategy of Water Distribution Network. *Resources, Conservation and Recycling*, v. 52, p. 441-459.

Morais, D.C.; Almeida, A.T. (2009) Integrated model of problem structuring and multicriteria group decision-making for social sustainable development. *Brazilian Journal of Operations and Production Management*, v. 6, p. 1-19.

Morais, D.C.; Almeida, A.T. (2010) Water network rehabilitation: A group decision-making approach. *Water S.A.*, v. 36, p. 487-494.

Morais, D.C.; Almeida, A.T. (2012) Group Decision Making on Water Resources based on Analysis of Individual Rankings. *Omega* (Oxford), v. 40, p. 42-45.

Morais, D.C.; Cavalcante, C.A.V.; Almeida, A.T. (2010). Priorização de Áreas de Controle de Perdas Em Redes de Distribuição de Água. *Pesquisa Operacional* (Impresso), v. 30, p. 15-32.

Parreiras, R. O. ; Ekel, P. Ya. ; Morais, D. C. (2012) Fuzzy Set Based Consensus Schemes for Multicriteria Group Decision making Applied to Strategic Planning. *Group Decision and Negotiation*, v. 21, p. 153-183.

Parreiras, R.O.; Ekel, P.Ya.; Martini, J.S.C.; Palhares, R.M (2010) A flexible consensus scheme for multicriteria group decision making under linguistic assessments. Information Sciences 180: 1075–1089.

Queiroz, SRD; de Carvalho FDT; Ramalho GL; Corruble, V (2002) Making recommendations for groups using collaborative filtering and fuzzy majority. In: Bittencourt, G; Ramalho, GL (Editors) Advances in Artificial Intelligence, Lecture Notes in Artificial Intelligence Vol: 2507, PP. 248-258

Santos, B.S. (1998) Participatory budgeting in Porto Alegre: toward a redistributive democracy. *Polit Soc*, 26, n. 4, p.461–510.

Silva, V.; Morais, D.C.; Almeida, A.T. (2010b) Prioritizing Complex Issues of Hydrographic Basin Committees by Group Decision Approach. *Brazilian Journal of Operations and Production Management*, v. 7, p. 123-139.

Silva, V.B.S.; Morais, D.C.; Almeida, A.T. (2010a) A Multicriteria Group Decision Model to Support Watershed Committees in Brazil. *Water Resources Management*, v. 24, p. 4075-409.

Silva, Vanessa B. S.; Morais, D. C. (2011) A new voting procedure to support participatory Budgeting. In: IEEE SMC 2011 International Conference on Systems, Man, and Cybernetics, 2011, Anchorage, Alaska. IEEE SMC 2011, 2011. p. 3184-3189.

Sordoni, A.; Briot, Jean-Pierre; Alvarez, I.; Vasconcelos, E; Irving, MA; Melo, G; (2010) Design of a Participatory Decision Making Agent Architecture Based on Argumentation and Influence Function - Application to a Serious Game About Biodiversity Conservation. RAIRO-OPERATIONS RESEARCH 44(4): 269-283.

Volkema, R.; Fleck. D.; Hofmeister, A. (2010) Predicting Competitive-Unethical Negotiating Behavior and Its Consequences. Negotiation Journal. 26(3): 263-286.

Zattar, I. C.; Ferreira, J. C. E.; Rodrigues, J.G.G.G.; de Sousa, C.H.B.; (2010) A multi-agent system for the integration of process planning and scheduling using operation-based time-extended negotiation protocols. International Journal of Computer Integrated Manufacturing. 23(5): 441-452.

Group decision support system and multiparty coordination system

PROMETHEE-GDSS: applications and new developments

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Abstract: The PROMETHEE method, developed by JP. Brans and B. Mareschal (Brans, 1982 and Brans and Mareschal, 1994) has been extended to be used in the group decision context (as described in Macharis, Brans and Mareschal (1998)). The aim of the paper is to analyze how PROMETHEE-GDSS has been applied and which further developments can enhance its applicability. The analysis is structured along a SWOT analysis (Strengths, weaknesses, opportunities and threats) and on the basis of this analysis recommendations are given.

Keywords: GDSS, GMCDA, PROMETHEE, Stakeholders

1 Introduction

Group decision support systems (GDSS) are a class of electronic meeting systems, a collaboration technology designed to support meetings and group work (Dennis et al., 1988). Within the last two decades several multicriteria analysis methods were adapted to be used in a group decision context (for an overview see Álvarez-Carrillo et al. 2010). They are called Group Multicriteria Decision Support System (GMCDSS) or Multicriteria Decision Support System (MCDSS). According to Banville et al. (1998), the groups of methods can be classified according to the moment the preferences of the stakeholders are introduced. This can be done *a priori* by using an aggregation procedure in which all potential actions are compared through their respective performance. This kind of aggregation can range from a single synthesis criterion approach such as used in the Multi Attribute Utility Theory (MAUT) and the Analytical Hierarchy Process (AHP) approach or a synthesis outranking approach such as in ELECTRE and PROMETHEE. It can also be done *a posteriori* by an efficient set determination method or *progressively* with interactive methods. The latter two approaches were developed largely within the framework of multi objective programming.

In most of these approaches a common hierarchy (or in other words a criteria set) for all the stakeholders is considered. The group is assumed to be homogeneous, which is a normal assumption for group decisions in an organizational context. Even if different departments have opposite views (marketing, operations…) at the end of the day they have an overall goal, namely to create more value for the firm. So even if there are opposite kind of views they can use the same hierarchy tree to start from. However, in social decision problem contexts it is clear that the group will not be homogeneous and have different and often conflicting points of view. Social multicriteria analysis (SMCA) as defined by Munda (2004) looks at decision problems within the society as a whole and puts itself in the domain of public choice. In this context, problems are multidimensional and the evaluation of public plans or projects has to be based on procedures that explicitly require the integration of a broad set of various and conflicting points of view (Munda, 2004). A common value tree/hierarchy/criteria set is in such a context not possible.

So the difference between the GMCDSS methods is mainly based on the extent to which the information is brought together. One could talk about input level aggregation or output level aggregation as Leyva-Lopez (2010) do. Or one can also make a difference between models with a same value tree for all stakeholders or with different value trees for each stakeholder (De Brucker et al. 2011). The same value tree corresponds mainly to input level aggregation where the group is asked to agree on a common set of criteria, weights and remaining parameters. If several individual value trees exist and are only aggregated in the end, we talk about output level aggregation. In the evaluation of transport projects it is important to distinguish the different points of view, hence different value trees and output level aggregation is most appropriate. The Multi Actor Multi Criteria Analysis developed by Macharis et al. (2009) allows working with different value trees per stakeholder group. A classification within the GMCDSS can be represented in the following way (Figure 1).

	One value tree	**For each actor a value tree**
Business	Most of the applications and methods	
Social	SMCA	**MAMCA**

Fig. 1. Classification of multi criteria group decision making (Source: Macharis et al. 2011)

This paper focuses on the PROMETHEE-GDSS method which belongs to the outranking methods. The PROMETHEE method has been developed since 1982 by JP. Brans and B. Mareschal (Brans, 1982 and Brans and Mareschal, 1994). In Macharis, Brans and Mareschal (1998) the PROMETHEE-GDSS method was developed. It was shown that the PROMETHEE net flow can be used to represent the arguments of the different actors involved in the decision making process and that this can also be displayed in the GAIA plane (see section 2). Initially it was developed to be used in organizational setting, but later on also social applications were executed. The method allows using different value trees within one larger model and so it can be used in the MAMCA methodology.

The aim of the paper is to analyze how PROMETHEE-GDSS has been applied and which further developments can enhance its applicability. First an overview the importance of stakeholders is discussed in the framework of a generic GMCDSS process (section 2). Secondly, the presentation of the PROMETHEE-GDSS method (section 3) and of its different applications (section 4) is given. The analysis is structured along a SWOT analysis (Strengths, weaknesses, opportunities and threats) in section 5 and on the basis of this analysis recommendations are given (section 6).

2. The importance of stakeholders in GDSS-MCDA process

A generic GMCDSS process involves 9 steps not necessarily in a linear path: (1) problem setting and stakeholder mapping; (2) alternative listing; (3) translating concerns and issues into criteria; (4) choosing measurement indicators and scales; (5) weighting criteria according value systems; (6) evaluating all alternatives against all criteria; (7) choosing and implementing an aggregation procedure (in our cases PROMETHEE); (8) deliberating, negotiating and recommending solutions; (9) decision.

Within the context of GMCDSS it is very important to remind that the decision process is a scene involving many actors about complex societal problems. The promoter is the one that initiate an action (a project or a strategic proposal and alternatives). Often, assessment of the options is made under a regulatory institution or organization which can be called an authority in charge or responsible for managing the decision process and thus allowing financial and human resources into a timeframe. The group of people which participate in the decision process can be composed by stakeholder representatives from civil society, institutions or ministries, economic sector and organized expertise. The decision process can also benefit from supporting experts in different fields as participatory processes, decision aiding, communication, and diverse sectorial issues. At the end, even the decision process encompasses many intermediate decisions; one or more decision makers will make the final decision by authorizing the implementation by the promoter of the chosen alternative. Each actor has specific role and responsibilities through the process. We can have a better understanding these roles by focusing on the concept of stakeholders.

The concept of stakeholders was introduced in the research field of strategic management (Williamson, 1991). These stakeholders needed to be taken into account due to the fact that firms were focusing more and more on corporate social responsibility (Donaldson and Preston, 1995; Buysse and Verbeke, 2003). Freeman (1984) defines a stakeholder as an individual or a group of individuals who can influence the objectives of an organization or can be influenced themselves by these objectives. So this definition is very organizational/business oriented. For Banville et al. (1998) who makes a very convincingly plea for the inclusion of stakeholders within MCDA, a stakeholder is everyone who has a vested interest in a problem in any of the three following ways: 1° by mainly affecting it, 2° by mainly be affected by it and 3° by both affecting it and being affecting by it. It seems that the stakeholder perspective of Banville is also inspired by a organizational setting, when he mentions among other things, that the choice of stakeholders depends on his/her role in the decision making process, i.e. those stakeholders whose potential for cooperation is low, will be less likely retained for participation. Within a social context, this kind of approach would be quite unethical, as all relevant points of view should be incorporated. Also Munda (2004) reacts on this definition as it only recognizes relevant organized groups, while he prefers to talk about social actors. This term is broader in the sense that it covers a societal perspective and not a business perspective and in addition incorporates also non-organized groups. Indeed, in societal contexts often the point of view of unorganized groups should be incorporated, such as the vision of future generations, groups that are unable to organize themselves or come together on the discussion table. In the definition of Grimble and Wellard (1997), this is in our opinion well incorporated: "Stakeholders are any group of people, organized or not organized, who share a common interest or stake in a particular issue or system". A stakeholder should be rather defined based on his/her stake in the issue as this determines whether he/she can affect or will be affected by the ultimate outcome. Grimble and Wellard (1997) call the ones who affect, the active stakeholders and those who are affected, the passive ones. Another useful distinction can be made according to the relative influence (the power certain stakeholders have over the success of a project) and importance of the stakeholders (those whose needs and interests are the priorities of aid) (Grimble and Wellard, 1997). At the strategic level, it is not manageable to involve directly individuals from the general public. Stakeholders should then be representative from organized or non-organized groups.

So although the notion of stakeholders is always somewhere there within GMCDSS it is not always well used in practice.

3. PROMETHEE-GDSS

The PROMETHEE method can be used to analyze multicriteria problems including a finite set of n alternatives and k criteria. The basic data are an evaluation table where the alternatives are evaluated on the different criteria. Quantitative as well as qualitative criteria can be considered. Besides this, additional information is required to model the preferences of the decision-maker.

First, for each criterion f_j (j=1,...,k) a specific preference function $P_j(a,b)$ has to be defined to translate the deviation between the evaluations of any two alternatives a and b into a preference degree ranging from 0 to 1. This preference function is a non-decreasing function of the deviation $d=f_j(a)-f_j(b)$ between the evaluations of the alternatives on the considered criterion , as shown in formula 1. In order to facilitate the selection of a specific preference function, six possible shapes of preference functions are proposed to the decision-maker by Brans et al. (1986) (usual shape, U-shape function, V-shape function, level function, linear function and Gaussian function).

$$P_j(a,b) = G_j\{f_j(a) - f_j(b)\} \qquad (1)$$

Second, information on the relative importance of the criteria (weights) is required. PROMETHEE assumes that the decision-maker is able to weigh the criteria appropriately, at least when the number of criteria is not too large. For larger numbers of criteria, weights can be determined according to several methods: direct rating, point allocation, trade-off, pairwise comparisons via the AHP method, among others (Macharis et al. 2004). This information is used to compute an multicriteria preference index $\pi(a,b)$ taking into account all the criteria (see formula 2).

The multicriteria preference index is the basis for the computation of the positive $\varphi^+(a)$ and negative $\varphi^-(a)$ preference flows that measure how each alternative (a) is outranking (see formula 3) or outranked (see formula 4) by the other alternatives. The difference between these two preference flows is the net preference flow $\varphi(a)$ (see formula 5), which is a value function whereby a higher value reflects a higher attractiveness of alternative *a*.

$$\begin{cases} \pi(a,b) = \sum_{j=1}^{k} w_j \, P_j(a,b) & (2) \\ \varphi^+(a) = \dfrac{1}{n-1} \sum_b \pi(a,b) & (3) \\ \varphi^-(a) = \dfrac{1}{n-1} \sum_b \pi(b,a) & (4) \\ \varphi(a) = \varphi^+(a) - \varphi^-(a) & (5) \end{cases}$$

Several PROMETHEE procedures can be used to analyze the multicriteria decision problem. Among them the most often used are the PROMETHEE I partial ranking, the PROMETHEE II complete ranking and the GAIA plane. In PROMETHEE I, a partial ranking is obtained from the positive and negative preference flows (see formulas 3 and 4). In this respect, alternative *a* is preferred to alternative *b* if it has a higher positive flow and a lower negative flow. As a result PROMETHEE I allows incomparability between alternatives. PROMETHEE II produces a complete ranking of all the alternatives from the best to the worst one, based on the net preference flow (see formula 5). The GAIA (Geometrical Analysis for Interactive Aid) plane is a visual representation of the decision problem in which the alternatives and their contribution to the criteria are displayed. Additionally, a decision stick can be used to further investigate the sensitivity of the results as a function of weight changes (Brans and Mareschal, 1994).

In the context of group decision, the PROMETHEE method has been extended to PROMETHEE-GDSS: we suppose that R stakeholders (ST_r, r=1,...,R) are evaluating the same set of alternatives using PROMETHEE. As each stakeholder has specific preferences a different net flow is obtained for each of them:

$$\phi^r\left(a_i\right) \qquad i = 1,2,\ldots n,\ r = 1,2,\ldots R \tag{6}$$

According to (2) to (5) it is easy to show that:

$$\phi^r\left(a_i\right) = \sum_{j=1}^{k} \phi_j^r\left(a_i\right) w_j \tag{7}$$

with

$$\phi_j^r\left(a_i\right) = \sum_{x \in A} \left\{ P_j^r\left(a,x\right) - P_j^r\left(x,a\right) \right\} \tag{8}$$

where $\phi_j^r\left(a_i\right)$ is the single criterion net flow obtained by considering only criterion $f_j(.)$ for ST_r.

If appropriate different weights (ω_r) can be assigned to the stakeholders, otherwise equal weights are used:

$$\omega_1, \omega_2, \ldots \omega_r, \ldots \omega_R \quad \left(\sum_{r=1}^{R} \omega_r = 1 \right) \tag{9}$$

The net flows (7) are representative of the preferences of each stakeholder. The higher the net flow, the better the corresponding alternative for ST_r. Moreover these net flows directly define the PROMETHEE II ranking for each ST_r. We therefore consider them as criteria summarizing the point of view of each stakeholder (Macharis et al., 1998). They form a new evaluation table that can be analyzed by PROMETHEE. For this purpose a special "0-option" preference function is used to simply calculate the weighted sum of the individual net flows (10). Indeed no preference function is required at this level as individual preferences have been taken into account for each stakeholder.

$$\Phi^G\left(a_i\right) = \sum_{r=1}^{R} \phi^r\left(a_i\right)\omega_r \tag{10}$$

This global net flow provides the PROMETHEE II ranking of the alternatives according to the global preference of the group. A GAIA-plane analysis can also be performed. The axes then represent the points of view of the stakeholders and show the amount of consensus or conflict within the group (see Figure 2).

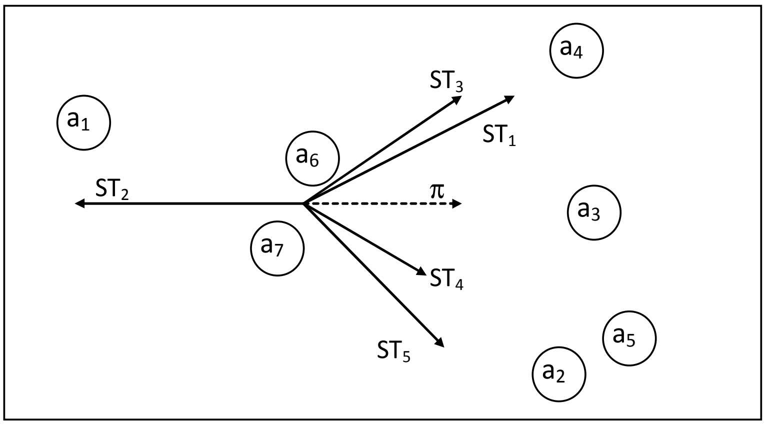

Fig. 2: GLOBAL GAIA PLANE

The PROMETHEE VI procedure makes it possible to perform a sensitivity analysis showing the level of conflict between the stakeholders. In Figure 3, the polygon shows the location of the tip of the decision axis when the weights are modified within a +/- 50% interval. In this example 3 it seems that a consensus can easily be reached as the polygon lies on one side of the GAIA plane.

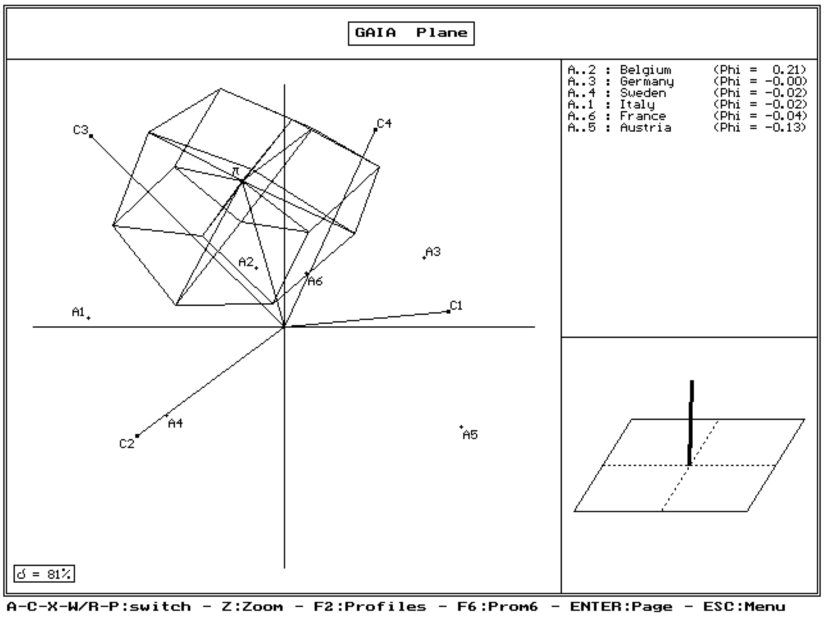

Fig. 3: PROMETHEE VI with 50% margin on the weights (Source: Macharis et al., 1998)

Different software have been developed for the PROMETHEE method: PROMCALC, Decision Lab, D-Sight and the new Visual PROMETHEE software available for download on www.promethee-gaia.net.

4. Overview of applications

Recently, an extensive literature review on PROMETHEE methodologies and applications has been performed by Behzadian et al. (2010). It showed that PROMETHEE is increasingly used in a variety of domains such as environmental and natural resources management, logistics and transportation, energy planning, and so on.

Specific within PROMETHEE-GDSS we found the following chronological applications (table 1).

Publication	Subject	Actors
Macharis (2000; 2004)	Location of intermodal terminals	The users of the terminal, the operators/investors and the community as a whole
Martin, St-Onge, Waaub (2000)	Watershed management, Quebec city metropolitan area	Round table with stakeholders such as planning authorities, environmental and riverside residents NGOs
Côté et al. (2002)	Land use planning, biodiversity management, waste management siting for Outaouais administrative region in Quebec province	Land use planners, promoters, civil servant from relevant ministries belonging to a regional association for managing territorial electronic information
Harahambopoulos and Polatidis (2003)	Renewable energy projects	Local authorities, potential investors, central government and public pressure groups
Waaub et al. (2005a; 2005b)	Strategic environmental assessment of First Nation forest management scenarios, Quebec, Canada	Territorial representatives, fauna and forest management representatives, elders, civil servants from Nation Council

Kourouma (2005) and Kourouma, Waaub (2004)	Strategic environmental assessment of energy system in Maritimes Guinea	Civil servants from involved ministries, NGO's representatives
Wotto, Waaub (2003; 2006)	Strategic environmental assessment of transportation planning scenario in metropolitan Montreal	25 representatives from various sector involved in transportation planning
Vaillancourt, Waaub (2006)	GHG emission permit allocation at world level	Simulation of group of countries
Samoura, Bouvier, Waaub (2007)	Planning Mangrove Ecosystems in Guinea	People from mangrove communities, representative from ministries
Morais and Teixeira de Almeida (2007)	Leakage management strategies of a water network of a city	The water company representative, the consultant-engineer, the environmental agency and a community representative
Samoura (2010)	Strategic environmental assessment of hydroelectric dams development in Guinea	Civil servants from involved ministries, NGO's representatives
Alancar and Teixaira de Almeida (2010)	Project team for a civil construction project	Technical engineer, a quality engineer, a security and environment engineer, a budget manager and a contract manager

Table 1: PROMETHEE-GDSS applications

The first application for which the PROMETHEE-GDSS method is incorporated in the MAMCA methodology is the choice of location for intermodal terminals. The so called LAMBIT-model (Location Analysis Model for Belgian Intermodal Terminals) provided the framework for the decision-making process on the location of new intermodal terminals (Macharis, 2000; Macharis, 2004). Interesting in this application is the combination with other socio-economic evaluation tools such as the cost-benefit analysis as one of the criteria.

Martin et al. (2000) presented the result of a pilot project conducted in a watershed management context in the Quebec City metropolitan area. A round table of stakeholders was at the core of the project. This took about 6 months which illustrates that the PROMETHEE-GDSS approach might need time for iterative work and discussion. The role of a supporting team and the need to integrate capacity building taking into account both the process and the tools were emphasized.

In Coté et al. (2002) the PROMETHEE-GDSS method is integrated in a larger integrated decision support system with GIS related tools. A multilevel GIS was designed, including ecological mapping for land use planning and socioeconomic databases. The idea was also to benefit from a more powerful decision aid tool than the classical weighted average sum embedded in most of GIS software and overlay approaches. A regional agency called LATINO (an agency coordinating the numerical information related to the full administrative Outaouais region in Quebec Province which is about 35 000 km2). Illustrative examples were simulated, dealing with locating waste management facilities and with consolidating regional biodiversity planning).

The paper of Harahambopoulos and Polatidis (2003) concluded that participation and discussion among the stakeholders is crucial to come to good results. In their application still a lot was done via computer interaction and not real live interaction which did not allow using all sensitivity tools that could help to come to a consensus.

A few applications conducted at GEIGER (Interdisciplinary Research Group in Geography and Regional Environment) under the supervision of Waaub are focusing on tiering PROMETHEE-GDSS approach to the decision process related to strategic environmental assessment (SEA) in different contexts. Among those projects, Waaub et al. (2005a; 2005b) reported challenges and results from adaptation to First Nation pilot project related to an endogenous territorial planning process facing the Quebec forest management planning process in a context of ongoing territorial Nation to Nation negotiation. This changes a lot the way stakeholders are involved. Instead of being involved through diverse sectorial consultation processes, an endogenous SEA process was adapted and designed to fit First Nation values and processes (ex.: schedule of meetings, way of conducting discussions, problem setting, use of traditional knowledge etc.).

Some applications were also about African cases such Kourouma and Waaub (2004) and Kourouma (2005) in energy planning in Guinea. The stakeholders involved are mainly from different ministries having competencies on the subject and also national NGOs. Considering the political and institutional context the use of a formal decision support tool is a significant improvement in the planning process. Most of the work about implementing the PROMETHEE-GDSS is done by a supporting team. There was no direct use of software during the meetings. Information and documentation about each step was prepared to be discussed by the stakeholders. A "translation" and adaptation was needed to face the specific needs of civil servants representative of their ministries. This problem was even important in Samoura et al. (2007) who used the PROMETHEE-GDSS to perform a Strategic Environmental Assessment (SEA) for Planning Mangrove Ecosystems in Guinea which involved people having very contrasted level of knowledge, some of them were even analphabetic. They conclude that participation is essential and that the approach followed was interesting to be used in Africa. The approach was then used at the river basin management level in a 5 year projects (Samoura, 2010) dealing with SEA of cumulative hydroelectric development plan alternatives. This application was combining GIS, hydrology modeling and PROMETHEE-GDSS to assess the alternatives at strategic level. It illustrated the need for inter ministries cooperation in SEA. In all those cases, main contributions from stakeholders relied on building their own weight set according their priorities and values and on negotiation once they completed appropriation phase of their own results (ranking and others, see section 3). They all found the set-up of preference functions too complicated, leaving the task to the supporting team after having given the appropriate insights.

Wotto and Waaub (2003; 2006) conducted a pilot project about transport planning for the Montreal metropolitan area. The duration of the project was about 18 months and involved 25 real stakeholders. This project tested a PROMETHEE-GDSS design to be managed on the Web. For the definition of the problem setting a mini policy Delphi approach on the Web was used. MCDA was done in the lab using data collected through a secure Web site. Lessons from this project is that it is always important to have some face to face meetings even if Internet can allow a better contribution by offering asynchronous and delocalized opportunities. Also, training and capacity building might be needed considering that people does not have similar skills to master Internet exchanges and communication processes.

In Vaillancourt and Waaub (2006), a simulation of international negotiations was performed. The case was on greenhouse gases allocation permit in contrasted climate control policies but extending the stakeholders involved beyond the Kyoto Protocol to all countries grouped into 15 regions. It included also two innovative issues: how to deal with different views of equity, and how to implement dynamic MCDA.

In Morais and Teixeira de Almeida (2007) a common criteria set was used for the whole group. Every stakeholder can choose however his/her own weights and preference functions. The judgment of the alternatives is done by the group in an open discussion phase. In order to get a group ranking, the procedure of the PROMETHEE-GDSS method is used and were they gave the different stakeholders a different weight according to their responsibility in the decision process. Also in Alancar and Teixaira de Almeida (2010) PROMETHEE GDSS the preference function were established in an interactive way between the stakeholders and the analyst and are thus also common for the whole group PROMETHEE VI (the brain, see Fig.3) is being used to see if changing the weights of the criteria (and not of the actors!) would change a lot the decision.

It is interesting to note that the PROMETHEE-GDSS approach can be use either with real stakeholders in complex societal controversies or to simulate stakeholder behaviors depending who are the "client".

In Turcksin et al. (2011) a combined AHP-PROMETHEE approach is being used for selecting the most appropriate policy scenario to stimulate a clean vehicle fleet. Although it is not a real PROMETHEE-GDSS procedure, it is worth mentioning here. In this application, the Analytical Hierarchy Process (AHP) method was used to obtain the weights for the different criteria. This allows involving the stakeholders in this step of the procedure. The stakeholders (being the car manufacturing industry, user-organizations and policy makers) gave their opinion about the weights and this was brought together with this geometric mean. These weights were then further used in the traditional PROMETHEE method. A discussion in group about the results of the PROMETHEE model was done during a workshop in order to find a consensus on the proposals that were evaluated.

5. SWOT analysis

From the examples above, one can see that PROMETHEE-GDSS has been used in several contexts and in different ways. Based on these experiences, a strengths, weaknesses, opportunities and threats analysis is executed. This SWOT takes the further development of the PROMETHEE-GDSS methodology as its focus.

5.1. Strengths

The PROMETHEE methodology and outranking methods in general have several advantages over the MAUT approach (see Macharis et al., 2004). With the PROMETHEE I method, trade-offs between scores on criteria (like in AHP) are avoided. As a result, the dominance relation is enriched rather than impoverished. However, when the partial ranking is forced into a complete ranking of the alternatives (PROMETHEE II), detailed information might also get lost. Moreover, with PROMETHEE a synthesis is achieved indirectly and only requires evaluations to be performed of each alternative on each criterion. Furthermore, outranking methods are better suited to perform extensive sensitivity analyses. PROMETHEE-GDSS is usually experienced as a very transparent method and one that can be used without too much interference with the supporting team, although some have difficulties in choosing the preference functions (see weaknesses). The good mathematical foundation together with its several analysis and graphical tools enable the user a thorough analysis of the problem at stake. Of course the possibility to include the stakeholders within the analysis is its main strength of the GDSS module of PROMETHEE. It is possible to switch easily from the individual to a common set of criteria and back. It gives a clear view of each stakeholder and of the group and is then a strong support for deliberation and negotiation. In such processes involving even conflicting issues, it is important that each stakeholder constructs its own appropriation of the problem and solutions that take into account their own preferences, priorities and values. It is also important to have a common space for negotiation.

5.2. Weaknesses

As said above, some actors have difficulties to choose the preference functions and to interpret the outcome of their decision. Although in theory you could say that PROMETHEE-GDSS can be used by any organization who would like to use it, in practice there is a clear need to have a facilitator and or an analyst to facilitate the process, certainly in a GDSS setting. This facilitator should also be able to handle conflicts and discussions about the final outcome of the analysis. More communication tools and guidance to help the facilitator in this task should be developed.

Another weakness of the PROMETHEE-GDSS tool, but that is common for most of the GMCDSS tools, is the problem of splitting bias. The structure of the value tree affects the weights (Hamalainen and Alaja, 2008) and by doing so the weight of a certain criterion can be diluted according to its place in the hierarchy. In a splitting bias, decomposing an objective into multiple attributes leads to a higher overall weight for that objective when compared to a direct assessment of the objective's relative importance (Jacoba and Hobbs, 2007). Also other experiments have shown the evidence of biases occurring with the use of value trees. Borcherding and Winterfeldt (1988), for example, demonstrated that weights for an objective tend to be higher when the objective is presented at a higher level in a value tree, while Stilwell et al. (1987) claim that hierarchically assessed weights tend to have a larger variance than weights assessed in a non-hierarchical way.

5.3. Opportunities

Stakeholder management in multicriteria will gain in importance as societal decision makers are facing an important class of problems that involve choices between conflicting objectives such as economic and environmental ones. By their inherent nature they are of interest of a diverse set of stakeholders (Gregory and Keeney, 1994). According to Gamper and Turcanu (2007) decision makers are more likely to choose tools as MCDA when they face decision coupled with uncertainty which is typically the case for sustainability decisions that concern the quality and quantity of future resources. If making wrong decisions, conflicts are likely to arise among the affected stakeholders and decision makers could be blamed by them.

Another opportunity for the PROMETHEE-GDSS method is the development of very user-friendly softwares for it such as D-Sight and the now freely available PROMETHEE. The fact that these softwares are easily available will make that more and more people will be using it. This emphasized also the need for training people at different levels. On the expert side, there is a need to know how to be a good facilitator, how to give better support to the process, how to manage stakeholders, how to communicate results etc. On the stakeholder side, there is a need for capacity building and social learning either about the involved processes or the different tools used (PROMETHEE-GDSS, GIS, Web interfaces etc.).

5.4. Threats

As noted by many authors, MCDA is often been used in a technocratic way, centered around the expert(s) and/or authorities (Gamper and Turcanu, 2007; Munda, 2004; Lotov, 2003; Banville et al. 1998, Bana e Costa and Oliviera, 2002). The experts have the tendency to be more sensitive to the mathematical rigor than to the relevance of the work (Banville et al., 1998). This technocratic (expert-oriented paradigm) is unable to take the points of various interest groups, mass media and even individual citizens into account which want to be involved in important societal decisions. This expert-oriented paradigm is confronted by its limits when protests and criticism alter or even stop the implementation of strategies and measures (Lotov, 2003). Munda (2003) speaks about a new paradigm, within post normal science, in which it is possible to deal with two crucial aspects in the policy domain, namely uncertainty and value conflict. It has been noted for the first point which is typically the case for sustainable decisions, that decision makers are more likely to choose tools as MCDA as it concerns the quantity and quality of future resources. It directly relates to the latter, as making wrong decisions in this case, conflicts are likely to arise among the affected stakeholders and the decision makers could be blamed by them (Gamper and Turcenu, 2007). An important issue is then, on how to incorporate these stakeholders within the decision process. If some decision makers might sometimes face temptation to manipulate the process as this has been illustrated by the Arnstein ladder of participation, it is better not using GMCDSS because once they will be involved in such participative and transparent approach it will be better to face the responsibility for the final decision.

Another threat is still the dominance of socio-economic evaluation tools as social cost-benefit analysis, cost-effectiveness, economic impact analysis (EIA), etc. These instruments have surely their utility, but fail to incorporate the points of view of the stakeholders and restrict the analysis to only specific criteria or monetary values. The latter becomes more and more problematic in the context of sustainability. Several objectives are difficult to quantify and certainly to monetize (for example quality of public transport, value of human life, etc.) (Damart and Roy, 2009; Tsamboulas et al., 1999, Scannella and Beuthe (2003)).

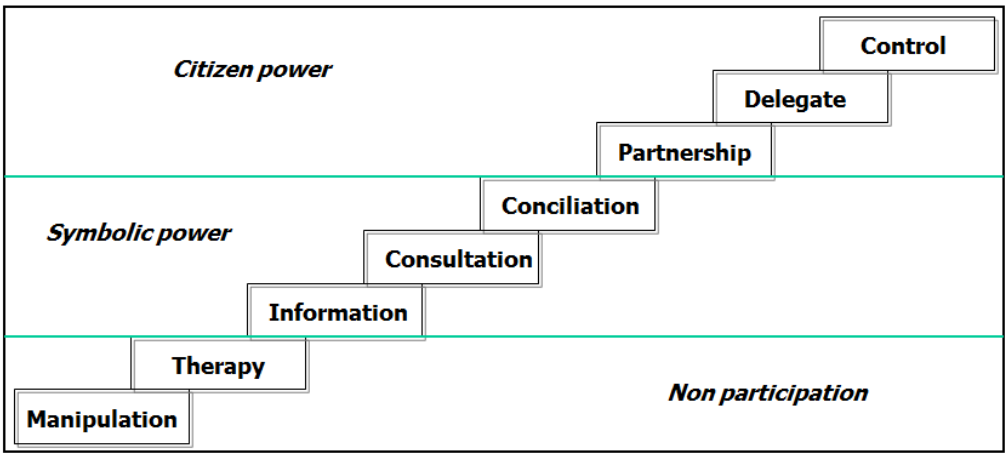

Fig. 4 Arnstein ladder of public participation

6. Recommendations

6.1. New communication tools

Most important in a multi actor setting is that good communication tools are in place so that the results of the analysis can be communicated but can also serve as a mean to structure the discussion. Within PROMETHEE-GDSS this is usually done with the GAIA plane, which is nice instrument. However when many actors are involved, the visualization might not be so clear. In addition, as the GAIA plane is a two dimensional representation of multidimensional data, some information is lost (as indicated by the delta parameter) and it can be more or less reliable depending on the size of the problem and on the degree of conflict. For this reason other GDSS tools have been implemented in the different PROMETHEE software.

As indicated in Macharis et al. (1998), PROMETHEE VI can be used to further analyze the group situation. PROMETHEE VI, also called the decision maker brain in a single stakeholder setting, shows the possible sensitivity of the result. This kind of analysis is possible in PROMCALC and D-Sight as well as in the newer Visual PROMETHEE software but not in Decision Lab.

Besides, the Visual PROMETHEE software introduces several new possibilities.

First it is possible to have a global overview of the stakeholder points of view by comparing side by side the individual PROMETHEE II net flows. An example is given in Figure 5, with four stakeholders and five alternatives (Site 1 to Site 5). It is a plant location problem whose data are available for download together with Visual PROMETHEE. Each column corresponds to one stakeholder and shows his/her PROMETHEE II ranking. From

, it is easy to see that Site 3 and Site 2 are the most preferred alternatives and that two coalitions of stakeholders can be identified: Industrial and Political stakeholders prefer Site 3 while Environmental and Social stakeholders prefer Site 2.

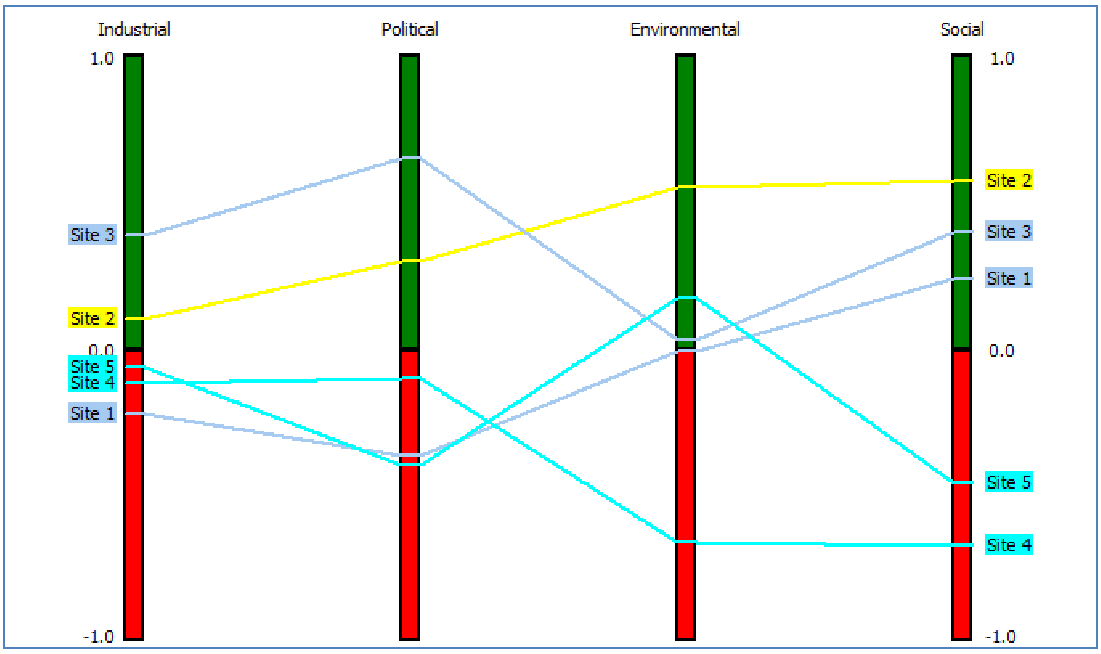

Fig. 5: Visual PROMETHEE: Multiple scenarios comparison

A next step is to identify the origin of the conflicts between the stakeholders. For this purpose, two additional GAIA analyses can be performed. First it is possible to compare the way the stakeholders have evaluated the alternatives on a single shared criterion. Such an analysis can be used to achieve a better definition of the criteria among the stakeholders and to solve misunderstandings or ambiguities about the definition of the criteria. Another GAIA analysis can be performed on a single alternative to compare the way it has been evaluated by the different stakeholders. This makes it possible to identify potential misunderstandings about the definition of the alternatives. These two analyses are of course only possible when the stakeholders use a shared set of evaluation criteria. They are implemented in Visual PROMETHEE.

Visual PROMETHEE also integrates a 3-dimensional GAIA analysis that can be useful when the GAIA plane has a lower quality (small delta value). The addition of a third dimension makes it possible to increase the quantity of information that is displayed by GAIA (Fig. 6).

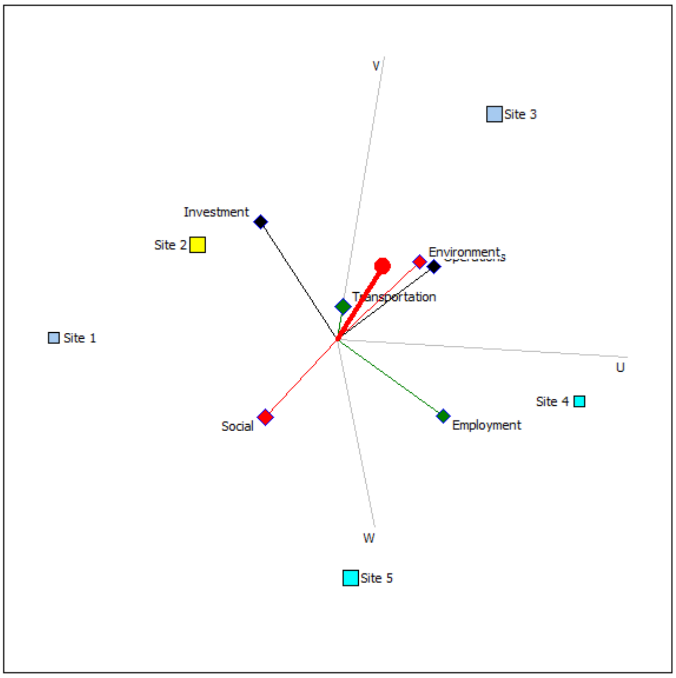

Fig. 6: GAIA 3D view in Visual PROMETHEE

6.2. New processes: how and when to include stakeholders in the process.

As said in section 2, the inclusion of stakeholders is a GDSS process is very important. However this is not always well organized. A good way to structure this involvement of the stakeholders can be by adopting the MAMCA methodology. MAMCA stands for multi actor multi criteria analysis. It allows evaluating different alternatives (policy measures, scenarios, technologies…) on the objectives of the different stakeholders that are involved. Unlike a conventional MCDA where alternatives are evaluated on several criteria, the MAMCA explicitly includes the points of view of the different stakeholders.

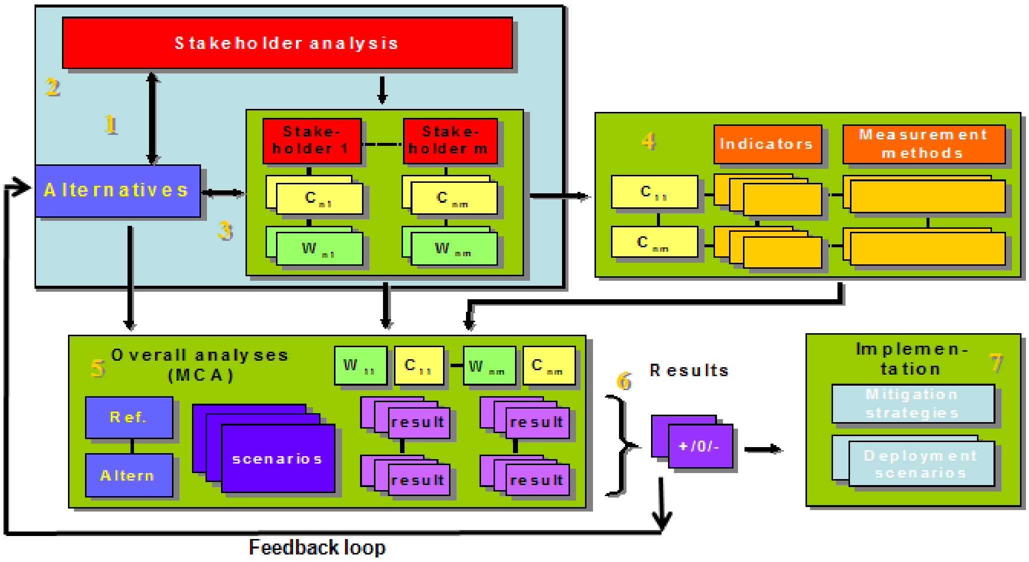

Fig. 7: The MAMCA methodology (Macharis et al, 2009)

The methodology consists of 7 steps (as shown in Fig. 7). The first step is the definition of the problem and the identification of the alternatives. These alternatives can take different forms according to the problem situation. They can be different technological solutions, different policy measures, long term strategic options, etc. Next, the relevant stakeholders are identified (step 2). Stakeholders are people who have an interest, financial or otherwise, in the consequences of any decisions taken. Thirdly, the key objectives of the stakeholders are identified and given a relative importance or priority (weights) (step 3). These first three steps are executed interactively and in a circular way. Fourthly, for each criterion, one or more indicators are constructed (e.g. direct quantitative indicators such as money spent, number of lives saved, reductions in CO_2 emissions achieved, etc. or scores on an ordinal indicator such as high/medium/low for criteria with values that are difficult to express in quantitative terms etc.) (step 4). The measurement method for each indicator is also made explicit (for instance willingness to pay, quantitative scores based on macroscopic computer simulation etc.). This permits measuring each alternative performance in terms of its contribution to the objectives of specific stakeholder groups. Steps 1 to 4 can be considered as mainly analytical, and they precede the “overall analysis”, which takes into account the objectives of all stakeholder groups simultaneously and is more “synthetic” in nature. The fifth step is the construction of the evaluation matrix. The alternatives are further described and translated into scenarios which also describe the contexts in which the policy options will be implemented. The different scenarios are then scored on the objectives of each stakeholder group. For each stakeholder group a MCDA is being performed. The different points of view are brought together in a multi actor view. This yields a ranking of the various alternatives and reveals their strengths and weaknesses (step 6). Afterwards, the stability of the ranking can be assessed through sensitivity analyses. The last stage of the methodology (step 7) includes the actual implementation. Based on the insights of the analysis, an implementation can be developed, taking the wishes of the different actors into account.

The MAMCA methodology has already proven its usefulness for several transport related decision problems (see for an overview Macharis et al., 2009). The application used the AHP method inside the MAMCA methodology or the PROMETHEE GDSS method. The advantage of the methodology is that it structures the different steps in the evaluation process and allows integrating the stakeholder opinions along the way. The degree in which participation will effectively be obtained depends on the way the different steps are executed. Step 2 and 3 should be done with a real participation of the stakeholders as here a consensus should exist on the list of stakeholders and each stakeholder group should formulate its set of criteria and the weights they are attaching to them. The evaluation itself is usually done by experts but also here the stakeholders can be involved. The discussion on the results (step 6) can also be done very openly and in consensus.

6.3. New knowledge: role of the facilitator and social learning process:.

A number of prerequisites related to the good will of the stakeholders to participate into a rational problem solving process involving other parties should be met before applying these approaches. On a collective basis, participants should be open to negotiate, recognize the multicriteria nature of the problem, be proactive to ensure the representativeness of different point of views, accept the help of a supporting team which in turn should not be invasive and focus on guaranteeing the legitimacy of the deliberations by the mean of a facilitator. The facilitator should not induce conformity to his own suggested framework but should be open to suggestions of all the actors. Each stakeholder should in turn be committed to the process until its end, given time availability, stay open to the results provided by the analysis, and accept that the final result might be counter intuitive or different from what he expected.

Stakeholders should always negotiate some conditions to their participation before the beginning of the process. Those conditions include: availability of training to the process and to the methodological tools used; adapted process to the cultural, political, institutional context; appropriate time frame, budget and human resources available; conflict resolution procedure; facilitator; the steps in which they will be involved; the way the process will influence the final decision (justification of the decision against convergences and divergences, written report etc.); and the follow-up planned.

It is also very important to define who is legitimate to participate. From the point of view of the decision makers, not only the “good ones” should participate. The process should be considered as giving opportunities for emerging solutions from conflict resolution and negotiation mechanisms. The problem setting is greatly influenced by the interactions between stakeholders. Some actors cannot participate because they are either absent (not in the area, future generations, etc.) or weak (poverty, disabled, etc.). How should they be taken into account? Is simulation acceptable?

As mentioned above, stakeholders can be involved directly in the assessment. Most of societal complex problems need to integrate, unite or find an equilibrium among different types of knowledge such as scientific, traditional (as First Nations), vernacular, contextualized etc.

Finally, it is important to be conscious that all actors are parts of a social learning process. Web 2.0 give many opportunities to exchange rapidly and efficiently (even sometimes the technology looks like creating “noise”). Some community of practice might be very helpful to overcome challenges.

7. Conclusions

PROMETHEE-GDSS has been applied in several applications. The applications show the potentiality of the approach and related methodological tools. PROMETHEE-GDSS has the ability to open up the decision process to all involved actors. An important strength of the methodology is that it enables yo includes several stakeholders within the decision process. This will become more and more important in the future which makes it directly an opportunity. A weakness is that a facilitator should always be there to facilitate the process. We advocate for new and good communication tools to help guide the discussions. In the recent software several new tools have been built in. In terms of involving the stakeholders, the Multi Actor Multi Criteria Analysis is a good methodology to integrate the stakeholders within the process in a structured way. The role of the facilitator and the social learning process should be given enough attention. Further research will be conducted on how to further strengthen the methodogy along the lines of the recommendations of this paper.

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References

Alencar, L.H. and A. Teixeira de Almeida (2010). “A model for selecting project team members using multicriteria group decision making”, Pesquisa Operacional, v.30, n.1, p.221-236.

Álvarez-Carillo, P.A., Duarte, A., Leyva-Lopez, J.C. (2010). “A Group Multicriteria Decision Support System for Rank a Finite Set of Alternatives.” Paper at the EURO XXIV, July 11-14, 2010. Lisbon, Portugal.

ARNSTEIN, Sherry R. 1969. « A Ladder of Citizen Participation ». *Journal of American Planning Association*, Vol. 35, no. 4, 216-224

Bana e Costa C.A., Oliveira R.C. (2002). “Assigning priorities for maintenance, repair and refurbishment in managing a municipal housing stock”, *European Journal of Operational Research*, vol. 138, no. 2, pp. 380-391.

Banville C, Landry M, Martel J-M, Boulaire C. (1998). “A Stakeholder Approach to MCDA”. *System Research*, 15: 15-32.

Borcherding, K. and von Winterfeldt, D. (1988). “The effect of varying value trees on multiattribute evaluations”. *Acta Psychologica, vol.* 68, pp. 153—170.

Brans, J.P., Vincke, Ph., Mareschal, B. (1986). “How to select and how to rank projects: The PROMETHEE method”. European Journal of Operational Research, 24, 228-238.

Brans, J.P. and Mareschal, B. (1994). “PROMCALC & GAIA decision support system for multicriteria decision aid”. Decision Support Systems, 12, 297-310.

Brans,J.P. (1982). L’ingéniérie de la décision. Elaboration d’instruments d’aide à la décision. Méthode PROMETHEE. In: Nadeau,R., Landry,M. (Eds.), L’aide à la décision: Nature, instruments et perspectives d’avenir, Presses de l’Université Laval, Quebec, Canada.

Buysse, K., Verbeke, A. (2003). “Proactive environmental strategies: a stakeholder management perspective.”‖ Strategic Management Journal 24(5): pp. 453-470.

Côté, M.-J., Poulin, G., Prévil, C., St-Onge, B., Waaub, J.-P. (2002). « Un système intégré d’aide à la décision pour gérer le territoire et mettre en œuvre le développement durable. Le cas du SIAD Outaouais.». *Géocarrefo*ur, 76 (3) Les territoires de la participation. pp.253-264.

Damart, S. and Roy, B. (2009). “The uses of cost–benefit analysis in public transportation decision-making in France”, *Transport Policy* 16, pp. 200–212.

De Brucker, K., Macharis, C., Wiethoff, M. and V. Marchau (2011). “A strategic analysis of stakeholder preferences regarding the design of innovative road safety measures. Results from the pan-European IN-SAFETY project regarding forgiving and self-explaining road environments”, submitted to Journal of Safety Research.

Dennis, A.R., George, J.F. ,Jessup, L.M., Nunamaker, J.F. , Vogel, D.R. (1988). Information technology to support electronic meetings. *MISQuarterly*, 591–624.
Donaldson, T.J., Preston, L.E. (1995). “The stakeholder theory of the corporation: concept, evidence and implications.” *Academy of Management Review* 20(1): 65-91.

Freeman, R.E. (1984). *Strategic Management: A stakeholder approach*. Boston: Pitman.

Gamper, C.D., Turcanu, C. (2007). “On the governmental use of multi-criteria analysis”. Ecol. Econ. 62 pp. 298-307

Grimble, R. and Wellard, K. (1997). “Stakeholder methodologies in natural resource management: a review of principles, contexts, experiences and opportunities”, *Agricultural Systems*, Volume 55, Issue 2, Socio-economic Methods in Renewable Natural Resources Research, 173-193.

Hamalainen, R.P. and Alaja, S. (2008). “The threat of weighting biases in environmental decision analysis”, *Ecological Economics*, 68, 1-2, 556-569.

Jacobi, S. K., Hobbs, B.F. (2007). “Quantifying and mitigating the splitting bias and other value tree induced weighting biases ». *Decision Analysis*, 4, 194-210.

Kourouma, D.L., Waaub, J.-P. (2004). « L’utilisation de l’analyse multicritère en ÉES du secteur de l’énergie: comparaison d’options énergétiques dans l’étude de cas de la Guinée maritime ». Actes du 9ème Colloque international des spécialistes francophones en évaluation d'impacts : De l’évaluation environnementale à l’évaluation du développement durable, (Ouagadougou, 20-25 septembre 2004). CD-Rom

Kourouma, D.L. (2005). *Approche méthodologique d’évaluation environnementale stratégique du secteur de l’énergie : Application à la dimension régionale de la politique énergétique guinéenne en Guinée Maritime*. Thèse présentée pour l’obtention du doctorat en sciences de l’environnement. Université du Québec à Montréal.

Leyva-Lopez, J.C. (2010). “A Consensus Model for Group Decision Support Based on Valued Outranking Relations.” EURO XXIV, July 11-14, 2010. Lisbon, Portugal.

Lotov, A.V. (2003). “Internet Tools for Supporting of Lay Stakeholders in the Framework of the Democratic Paradigm of Environmental Decision Making”, *Journal of Multi Criteria Decision Analysis*, 12, 145-162.

Macharis, C. (2000). “Strategische modellering voor intermodale terminals: Socio-economische evaluatie van de locatie van binnenvaart/weg terminals in Vlaanderen.” Phd, Brussels: Vrije Universiteit Brussel.

Macharis, C. (2004). “The optimal location of an intermodal bargeterminal”, in Beuthe, M.; Himanen, V. ; A. Reggiani and L. Zamparini (Eds.): *Transport Developments and Innovations in an Evolving World*, Springer-Verlag, 211-234.

Macharis, C., Brans, J., Mareschal, B. (1998). “The GDSS Promethee procedure”. *Journal of Decision Systems*, 7, 283-307.

Macharis, C., De Witte, A., Ampe, J. (2009). “The multi-actor, multi-criteria analysis methodology (MAMCA) for the evaluation of transport projects: theory and practice.”‖ *Journal of advanced transportation* 43(2), 183-202.

Macharis, C., Lebeau, K., Turcksin, L. (2011). “Multi Actor Multi Criteria Analysis (MAMCA) as a tool to support sustainable decisions: state of use.” Submitted for acceptance in *Decision Support Systems*.

Macharis, C., Springael, J., De Brucker, K. and Verbeke, A. (2003). “PROMETHEE and AHP: the design of operational synergies in multicriteria-analysis. Strengthening PROMETHEE with ideas of AHP”, *European Journal of Operational Research*, 153, 2, 307-317.

Martin, N., St-Onge, B., Waaub, J.-P. (2000). «An Integrated Decision Aid System for the Development of Saint-Charles River's Alluvial Plain, Québec, Canada». International Journal of Environmental Pollution, vol.12 no 2/3. 264-279

Morais, D.C.and A. Teixeira de Almeida (2007), “Group decision-making for leakage management strategy of water network”, *Resources, Conservation and Recycling*, 52, 441–459.

Munda, G. (2004). “Social Multi – criteria Evaluation (SMCE): Methodological foundations and operational consequences.” *European Journal of Operational Research* 158: 662-677.

Polatidis, H., Haralambopoulos, D.A. (2007). Renewable energy systems: A societal and technological platform. Renewable Energy 32, 329–341.

Samoura, K., Bouvier, A.-L. et J.-P. Waaub (2007). « Strategic environmental assessment for planning mangrove ecosystems of Guinea ». *Knowledge, Technology & Policy*. 19, 4, 77-93.

Samoura, K. (2010). Contributions méthodologiques à l’évaluation environnementale stratégique de l’exploitation du potentiel hydroélectrique des basins côtiers en milieu tropical : cas du Konkouré en Guinée. Thèse de doctorat en sciences de l’environnement, UQAM, 251p + annexes

Scannella G, Beuthe M. (2003). “Valuation of road projects with uncertain outcomes”. *Transport Reviews* 23, 1: 35-50.

Stillwell, W.G., von Winterfeldt, D., & John, R.S. (1987). “Comparing hierarchical and non-hierarchical weighting methods for eliciting multiattribute value models”. *Management Science*, 33, 442-450.

Tsamboulas, D., Yiotis, G., Panou, K. (1999). “Use of multicriteria methods for assessment of transport projects.” Journal of Transportation Engineering 25 (5): 404-414.

Turcksin, L., Bernardini, A., Macharis, C. (2011). A combined AHP-PROMETHEE approach for selecting the most appropriate policy package to stimulate a clean vehicle fleet. 14th EWGT Meeting, 26th Mini-EURO and 1st ESC RH conference, September 5-9, Poznan (Poland).

Vaillancourt, K., Waaub, J.-P. (2006). “A decision aid tool for equity issues analysis in emission permit allocations”. *Climate Policy*, 5, 487-501.

Williamson, O.E. (1991). ”Strategizing, economizing, and economic organization.” *Strategic Management Journal* 12(2): 75-94.

Waaub, J.-P. (Dir.), Barrange, F., Côté, G., Schaillée, N., Shardonofsky, S. (2005). « Projet pilote de réalisation d’une évaluation environnementale stratégique territoriale par les Atikamekw. Rapport final. Tome 1 – Rapport méthodologique ». Rapport du GEIGER au Conseil de la Nation Atikamekw, Montréal, juin. p.280

Waaub, J.-P. (Dir.), Barrange, F., Schaillée, N. (2005). « Projet pilote de réalisation d’une évaluation environnementale stratégique territoriale par les Atikamekw. Rapport final. Tome 2 – Rapports techniques 1 et 2 ». Rapport du GEIGER au Conseil de la Nation Atikamekw, Montréal, juin. p.98

Wotto, M., Waaub, J.-P. (2003). “Process of limited societal participation in the strategic environmental assessment of transportation planning scenarios in Montreal in a GDSS context: methodological proposal”. *RAGEE*, 5, 92-101.

Wotto, M., Waaub, J.-P. (2006). «L’aide à la décision de groupe dans un processus d’évaluation environnementale stratégique (ÉES) – Recherche de consensus pour des scénarios de transport durable à Montréal». Chap. 12, in Graillot, D., Waaub, J-P, Aide à la décision pour l’aménagement du territoire: méthodes et outils. Série Aménagement du territoire (Traité IGAT), Hermès, Lavoisier, London, Royaume-Uni, 345-366.

A Framework for a Context-Aware Multi-Party Emergency Coordination System

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Abstract: Human society has been faced with many natural and man-made disasters that caused the loss of many lives and severe economic damages. Although many disasters are not avoidable, we need to find ways to prevent or reduce the negative impact. An emergency response system can be used as part of the emergency management. In this paper, we propose a framework for an emergency response system which is an extension of but significantly different from traditional group support systems or distributed group support systems. The framework considers the environmental, organizational, and activity-based issues of emergency response for responders and decision makers. These issues are addressed by incorporating context-aware, multi-agency relationship management, and multiparty coordination components into the framework for a context-aware multiparty coordination system.

Keywords: context-aware, multiparty coordination, emergency response

1 Introduction

Our human society often has to face many natural and manmade disasters which causes severe damage and the loss of many lives. A recent and devastating example is the March 2011 triple disaster of earthquake, tsunami, and nuclear power plant meltdown in Japan. As reported by Japan's Disaster Countermeasures Office on April 27, 2011, 14,508 people were confirmed dead and 11,452 were still missing. 76,000 homes collapsed or washed out, with damage occurring to another 244,000 homes, displacing over 350,000 citizens. The cost estimated by the Japanese Government was as high as 25 trillion yen (approx. $300 billion USD) in damage (Mimura, 2011). The meltdown of the Fukushima nuclear reactor caused a severe radiation leak into a large area of atmosphere, subterranean water and sea. Although the Japanese government made a great effort in rescue operations, its slow reaction to the Fukushima nuclear disaster was widely criticized by the international community and the International Atomic Energy Agency (IAEA, 2011). How should human society cope with such disasters more effectively?

There is increased interest in emergency management both in practice and academic research. In general, Emergency Management (EM) is defined as "the process of developing and implementing policies that are concerned with mitigation, preparedness, response, and recovery" (Petak, 1985). Because of the significant impact on public interests, governments are taking more proactive roles on national security, disaster prevention, and rescue efforts. In academia, more research is under way on the general understanding of emergency management.

The main challenge to studying emergencies is to understand that emergency contexts are very different from traditional business contexts. A typical emergency situation has characteristics such as, "great uncertainty; sudden and unexpected events; the risk of possible mass casualty; high amounts of time pressure and urgency; severe resource shortages; large-scale impact and damage; and the disruption of infrastructure support necessary for coordination like electricity, telecommunications, and transportation. This is complicated by factors such as infrastructure interdependencies; multi-authority and massive personal involvement; conflict of interest; and the high demand for timely information (Chen et al., 2008)." Many of these contextual conditions are different from traditional business crises that organizations deal with which makes emergency management much more difficult to plan for, places different stresses on decision makers, and requires different tools to aid in the response.

As IS academics we have expanded our research into the multi-disciplinary field of EM. Much IS research in the EM field pertains to the development of different types of EM information systems, lessons learned from real-world cases, and general frameworks for emergency response.

A few frameworks have been proposed recently to aid in the understanding of emergency management information concepts and systems. For example, Turoff et al. (2004) provided design recommendations for a dynamic emergency response management information system (DERMIS). With the DERMIS proposal, specific system and design requirements based on nine premises are identified. Abrahmansson et al. (2010) proposed a system-oriented framework for analysing and evaluating emergency response, which can also be used as additional guidelines for emergency response information system design. Yuan and Detlor (2005) identified the major task requirements and associated key issues for intelligent mobile crisis response systems.

This paper attempts to enhance the current understanding of emergency response systems by proposing a framework for context-aware multi-agency coordination systems. The proposed framework consists of three key components: i) context-awareness components to deal with environmental issues; ii) multi-agency components to deal with organizational issues; and iii) coordination components to deal with operational issues.

2 Key Differences between Group Decision Support Systems and Context-Aware Multi-Party Coordination Systems

Context-aware multi-party coordination systems (CAMPCS) for emergency response are quite different from traditional group decision support systems (GDSS) or Distributed Group Support Systems (DGSS). GDSS was originally defined as a system that combines communication, computer, and decision technologies to support problem formulation and solution in group meetings. A GDSS aims to improve the process of group decision making by removing common communication barriers, providing techniques for structuring decision analysis, and systematically directing the pattern, timing, or content of discussion (DeSanctis and Gallupe, 1987). The concept of distributed group support systems (DGSS) resulted from the combination of GDSS and computer mediated communication systems (CMCS) to facilitate group decision support from participants in different locations (Turoff et. al. 1993). The proposed CAMPCS however, is significantly different from traditional GDSS and DGSS in terms of the objectives, users, decision contexts, and working environment (see Table 1).

Table 1. Summary of the differences between GDSS/DGSS and CAMPCS.

	GDSS/DGSS	**CAMPCS**
Objective	Support group decision making	Support multiparty coordination
Users	Predetermined group	Large scale multiparty participation
Decision Context	Well defined	Uncertain, dynamic, and urgent
Working environment	In an office setting	Mobile environment

2.1 Objective: Group Decision Support vs. Multiparty Coordination

The main objective of GDSS is to improve the process and the outcome of group decision making. GDSS helps group members resolve conflicts and reach mutual agreement. The implementation of the decision, is usually not the focus. The main objective of CAMPCS is to support multiparty coordination. Coordination is defined as managing dependencies between activities (Malone and Crowston, 1994). Since activities must, in some sense, be performed by "actors," the definition implies that all instances of coordination include actors performing activities that are interdependent. Although multiparty coordination may also involve group decision making and negotiation, it emphasizes the management of the tasks of activities performed by the joint effort of multi-parties, such as communication, resource allocation, scheduling, job dispatching, etc. In other words, GDSS is decision oriented and CAMPCS is action oriented.

2.2 Users: Predefined Group vs. Ad-hoc Multiple Party Participation

The users of a GDSS may be a group within an organization or from different organizations. The roles and the relationships of the group members are usually well defined. For emergency response, the participants may be from different authorities, professions, and regions. For instance, earthquake rescue may involve firefighters, police, medical teams, and volunteers locally or internationally. They come together on an ad-hoc basis and identifying their roles and relationships becomes one of the major tasks.

2.3 Decision Context: Given vs. Dynamic

The decision context for GDSS is often given and well defined. The focus of the group decision makers is on how to reach a better decision. The decision context for CAMPCS is dynamic with great uncertainty and urgency. In a disaster scenario, things change rapidly and decisions must be made immediately. Collecting context information and taking quick corresponding action is critical for saving human life and reducing property damages. Context-awareness becomes an important component of CAMPCS.

2.4 Working environment: Fixed Office Setting vs. Anytime anywhere on the move

The working environment for GDSS is mainly in a meeting room equipped by computers connected through fixed-line communication networks. For DGSS there may be several geographically different locations but the individual locations still generally rely on fixed-line communication networks and are not mobile. The working environment for CAMPCS in emergency response can be for anyone at anytime anywhere.

Emergency responders have to work on a disaster frontline. Emergency command centers may be temporally established on the frontline of the disaster scene even without a camp. With the possible and frequently severe damage of communication infrastructure during a disaster, mobile communication is usually the method used to communicate amongst responders and decision makers. Mobile communication is relatively easy to install and mobile devices are most likely used by rescuers.

As pointed out by Shim et al. (2002), decision support systems technology and applications have evolved significantly. Mobile tools, mobile e-services, and wireless Internet protocols will mark the next major set of developments in DSS. Collaborative support and active decision support could be one of the new application fields.

3 Emergency Coordination System Framework

The proposed framework addresses three main issues that are frequently discussed in emergency response literature. These issues are identified as environmental issues, activity-based issues, and multi-agency issues influencing emergency response coordination. Fig. 1 identifies the three main issues and how they interact. These issues are distinct but interdependent and influence the overall emergency response process.

Environmental issues related to the situation of a disaster will influence the agencies that need to respond to a disaster along with what and how tasks will be performed to address the disaster. Similarly, activity-based issues surrounding the tasks to be performed will be dependent on the operating environment of responders as well as the agencies available to provide the tasks as agencies frequently have different roles performing different tasks. Finally, different agencies will need to work together in order to address complex environmental conditions and provide all the resources necessary to complete required response tasks.

Disasters often develop rapidly with great uncertainty making it essential to collect situational information in order to take quick and appropriate action. Context-aware computing is a response component to be used to manage this environment awareness issue by providing better aggregated, filtered, and processed information to decision makers.

In addition to understanding the environment, emergency response often requires the temporary participation of multiple parties with different professions, from different regions, and belonging to different authorities. It is important to make sure they can work together and appropriately handle their work relationships. The multi-party component of the framework is therefore used to deal with multi-agency organizational issues.

Lastly, emergency response needs to organize multiple interrelated tasks in order to respond to a variety of events. Task execution may require resource sharing and activity coordination. The coordination component of the framework addresses the activity-based issues.

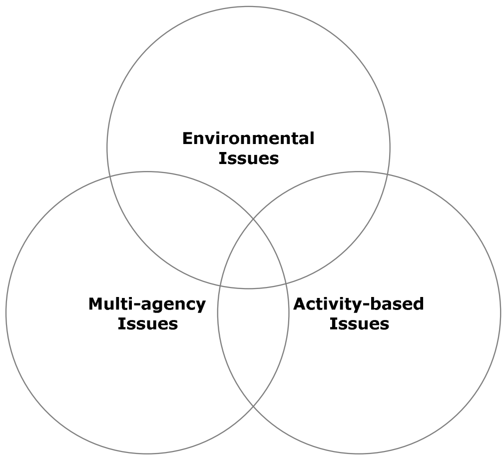

Fig. 1. Emergency response coordination framework outlining the three major types of issues in emergency response and how they overlap with one another.

The remainder of this section breaks down the environmental, organizational, and activity-based issues further and then describes how each component can help address the issues presented.

3.1 Context-Awareness and Environmental Issues

As pointed by Turoff (2003), “Almost everything in a crisis is an exception to the norm (Premise 4 - exceptions as norms)… Learning and understanding what actually happened before, during, and after the crisis is extremely important for the improvement of the response process (Premise 3 – crisis memory).” Understanding the emergency environment is critical to planning an adequate emergency response. Environmental understanding directly influences how people respond to situations. A lack of understanding of the environment can negatively impact the effectiveness of the response. However, understanding the environment is a difficult task because of rapid changes and great uncertainty in the situation.

Environmental conditions may be referred to as context. Context has several different definitions in literature. A general definition of context for an information system provided by Dey et al. (2001) is stated as "any information used to characterize the situation of entities (i.e., whether a person, place, or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves. Context is typically the location, identity, and state of people, groups, computational and physical objects."

In an emergency response setting, context is much more complex as it can be applied to a much broader range of people, places, and things with great uncertainty and difficulty of assess. For example, context information for an emergent event can include the nature of an event (i.e., earthquake, tsunami, explosion, etc.), its location, its magnitude or severity of impact, when it occurred, its immediate impact, the potential affected population, the potential affected area, the speed of onset, the duration of effect, and potential triggered secondary events. The Japan earthquake and tsunami of 2011 had context information of ocean earthquake, at 38°N and 142.9°E off the North East coast of Japan, measuring M9.0, at 2:46PM JST, had an immediate effect of shaking and damaging infrastructure and causing injury and death to citizens of Japan, and lasted for 0.2 to 1.0 seconds at its peak, with the potential for triggering further emergencies from aftershocks, infrastructure failure, fires, and a tsunami (Mimura et al., 2011). Decision makers, responders, and citizens were able to use all or part of this context information to plan their responses.

Decision makers, responders, and citizens may also have context information associated with them. Search and rescue personnel context may include where they are, what their role is, what tasks they are performing, what equipment or resources they require, what resources or equipment they are using, when they started their activity, when their status will change, who they are working with, and more. Higher level contexts may include knowledge of where rescuers are in relation to other rescuers, resources, equipment, or security which could provide support if needed, and how long it will take to receive additional support. Information on proximity to victim locations, or search areas to find victims may also be important to rescuers. For victims, context information may include where they are, their health and physiological status, their mobility status, how long they've needed assistance for, or even where they are relative to a physical threat, a safe place, or a search and rescue responder. For decision makers, context information may include what organizations are available to assist, what roles organizations will perform, how to communicate with organizations, what resources are on hand, what resources are required, where are resources deployed, and how resources will get to where they are needed,

During the response effort to the 9/11 terrorist attacks in New York, a geographic information system (GIS) was used to track the search and rescue operation and organize the cleanup effort. Using this tool, decision makers were able to gather relative location based information to coordinate rescuer search for survivors, allow heavy machinery to clean up debris, and develop routes of traffic in and around debris. Other equipment was used to identify unstable search areas in the rubble and map those unsafe areas for rescuer awareness (Thomas et al., 2002).

In context-aware computing, context-awareness is defined as the set of environmental states and settings that determines an application's behavior (active context) or characterizes the conditions in which an application event occurs (passive context) (Chen and Kotz, 2000).

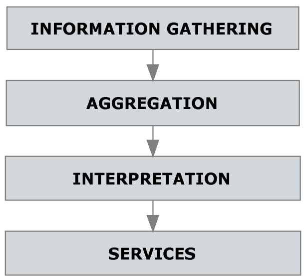

Fig. 2. A generic context-aware framework. Context information is gathered from user input or automatically from sensors. Information is combined with other obtained context information. A higher level of context information may be interpreted from the available context information. Context-aware functions may be executed as system services based on observed or interpreted context information.

Fig. 2 highlights the general components of context-aware systems. Information gathering is the collection of contextual data from various monitoring systems and call centers. There is a great effort to add monitoring systems to aid in gathering emergency contextual data. Examples include earthquake monitoring systems, sea-level monitoring systems, satellite observation systems, and weather monitoring and forecasting systems. Public reporting to emergency call-centers is also a major source of environmental data. The reported data may be in several different formats such as voice, images, sounds, text messages, and video. The next function is the aggregation of the information from different sources and organizing and integrating it into a structured data management system. The information can then be used for modeling and interpretation by experts or expert systems. The interpreted results may be used directly by decision makers to plan a response to an emergency. However, with context-aware computing the interpreted results may trigger services or actions such as notification of key personnel, an automated response such as alarms or engagement of backup systems, or the results may be used to respond to information requests.

Many emergency response agencies have monitoring, expert, and decision support systems that often operate independently but an effective emergency management system needs to have the capability to connect, integrate, understand, and share the information related to an emergency.

Research into context-aware computing has already addressed several of these requirements. Context-awareness uses sensors or other information sources to measure environmental conditions and identify many low-level contexts (location, temperature, orientation, time, etc.) while context-aware applications combine environmental and low-level contexts using artificial intelligence to develop higher level complex contexts (Chen and Kotz, 2000). Context-aware computing utilizes both active and passive context-aware applications where active context-aware applications automatically adapt application behavior when new context is discovered; and passive context-aware applications adapt the presentation of information.

Using context-aware technology can aid in the collection and aggregation of sensory environmental data in several dimensions to provide passive context information to emergency responders. Use of this data can also be combined with real experts or expert systems to better identify the nature and scope of a disaster to interpret more appropriate responses. The context information can also be used to trigger an appropriate action for an active-context application such as responder notification on the changes in the operating environment or availability of resources. Changes in context can also be used in a decision analysis framework for public notifications of disasters (Xu et al., 2009). Many modern ambulance dispatch centers already utilize global positioning system (GPS) tracking on their ambulances along with ambulance status in order to select which ambulance is closest to respond to an emergency.

The contexts for responders may also be influenced by greater contexts. For example, the response to the nuclear disaster in Fukushima, Japan was not limited in scope to the local proximity of the nuclear power plant. Leaking radiation spread widely into the air and sea influenced by the wind, rain and river. Radiation affects the food chain and the human body through exposure to direct radiation and contaminated goods which add additional high-level context information to the response effort.
All of these pieces of contextual data are collected through sensory information, eye witnesses or first responders on scene. It is important to integrate the pieces into a whole picture. A geographic information system (GIS) may serve the purpose of disaster information integration (Radke et al 2000). A crisis memory can be used to log the chain of events during a crisis along the dimension of time (Turoff et al. 2004). As the response continues contextual information is continually monitored, updated, accumulated and analyzed to further refine and redirect decision making processes, resource requirements, and action plans. As pointed by Turoff et al. (2004) during a crisis, those who are dealing with the emergency are flooded with information. The emergency support system should carefully filter information that is directed towards actors. A layered crisis communication architecture (CCA) was proposed to validate, filter, interpret, access, and exchange relevant crisis information (Hale, 1997). As pointed by Turoff (2003), "[e]stablishing and supporting confidence in a decision by supplying the best possible up-to-date information is critical to those whose actions may risk lives and resources (Premise 7 – information validity and timeliness)."

3.2 Multiple Agencies and Organizational Issues

Disasters or crisis usually happen suddenly. The emergency response often requires multiparty participation from different professions, regions, and authorities. Some parties may have previous working relationships but many of them may not. To establish and manage the working relationship is a prerequisite for effective coordination in emergency response. As pointed by Turoff (2003), "the critical problem of the moment is the nature of the crisis, a primary factor requiring people, authority, and resources to be brought together at a specific period of time for a specific purpose (Premise 5 – Scope and nature of crisis)."

Unlike the well-established contract-based multiparty relationship in traditional business relationships for routine operation such as supply-chain management (SCM), emergency response is often a dynamic response that may lead to the formation of ad hoc relationships with responders from different departments, agencies, regions, cultures, or even countries.

The establishment of command center for emergency response is the first priority. Depending on the scope of the disaster, the command center could be local, regional, or national. Government chief officers are often directly in charge of the command center in order to have authority to mobilize the resources for emergency response. Without the establishment of appropriate authority, the rescue effort cannot be well organized. For example, in the case of hurricane Katrina, when the storm badly destroyed the coast from Alabama to Texas, many citizens and responders kept asking: “Where is the federal government?” The Federal Emergency Management Agency (FEMA) was supposed to take the leadership role of the federal response for such a large scale disaster but it let individuals and communities act on their own for the first 72 hours (Fischer et al., 2006).

The parties involved in emergency response depend on the nature and scope of the disaster. Typical individuals responding to an emergency are police, fire, and emergency medical service (EMS) personnel. Responders can also be from several different groups including government ministries, non-government organisations (NGOs), and humanitarian agencies. Lastly, responders may be from other divisions or specialized units within the typical responder agencies, such as firefighters from several fire departments, or tactical response teams and bomb squad units from police.

All of the various responders have their own responsibilities to consider based on their training, area of expertise, knowledge, tasks, and organizational contexts. These differences can also include legislated requirements on information sharing policy, processes to follow, and communication hierarchies which influence or mandate how these responders operate. For example, an emergency call to a police dispatch would entail questions the responding officers would need to know about safety such as if there is a weapon on scene, while an emergency medical service (EMS) dispatch would be more concerned about a victim’s medical situation and how to access the victim. The same emergency can generate multiple requests for assistance from different agencies using different contextual data.

In addition to different emergency requirements, the relationships between organizations may vary greatly depending on the history of interacting with one another. Police, fire, and EMS regularly respond to many of the same emergencies giving them an extensive history of working together. Organizations with established relationships have the familiarity with each others' policies and procedures making interdependency more routine. Organizations drawn together for the first time may need to establish coordination relationships to overcome an obstacle or achieve a common goal. It is especially true when rescuers are from different regions or countries and from many volunteer organizations. For instance, FEMA and the Red Cross agreed that FEMA should be the primary agency for mass care in the NRF (National Response Framework) because the primary agency should be able to direct federal agencies’ resources to meet mass care needs, which the Red Cross cannot do. NVOAD (National Voluntary Organizations Active in Disasters), an umbrella organization of 49 voluntary agencies, is supposed to have a broad role of facilitating voluntary organization and government coordination, but limited staff resources constrained its ability to effectively fulfill its role in disaster response situations. At the time of Katrina, NVOAD had only one employee to make daily conference calls with its members which made for ineffective information sharing (US GAO, 2008).

With multiple organizations also come conflicts of interests regarding the goals or objectives of the activities being performed and their overall output. Failure to resolve conflicts of interest amongst parties can negatively affect decision making capabilities. For example, political conflict stemming from mistrust between the Japanese government and Tokyo Electric Power Company (Tepco) was said to be the cause of slow information flow between the two parties and negatively affected the pace of Japan's response to an impending nuclear disaster (Onishi and Fackler, 2011).

The nature of coordination also depends on how agencies and individuals are able to connect with one another and share information or resources. As pointed by Turoff (2003), "[c]rises involve the necessity for many hundreds of individuals from different organizations to be able to freely exchange information, delegate authority, and conduct oversight, without the side effect of information overload (Premise 8 – free exchange of information)." As an example, while SOUTHCOM (U.S. Southern Command) developed an organizational structure designed to facilitate interagency collaboration, the scale of the Haiti earthquake disaster challenged the command’s ability to support the relief effort. SOUTHCOM’s support to the disaster relief efforts in Haiti revealed weaknesses in this structure that initially hindered its efforts to conduct a large scale military operation (US GAO, 2010).

Interoperability is the term used to describe the interaction between multiple agencies. Interoperability is the process of maximizing opportunities for the exchange and re-use of information, whether internally or externally, through the management of systems, procedures and the culture of an organization (Miller, 2000). Technical or hard interoperability, the most commonly discussed form of interoperability, relies on technological factors such as hardware, communication protocols, storage, etc. for the exchange of information. Soft interoperability relies on factors such as semantic, human/political, inter-community, legal, and international operability.

Organizations that have more interdependency and are more familiar with one another may have procedures and established relationships in place to connect with the other organization making them more interoperable. For example, Red Cross may have relationships with various levels of government to manage mass casualty situations.
Unfamiliar organizations, in addition to making contact, will need to quickly establish connections with key personnel in order to share information and resources. These new connections are likely to be subject to a lack of trust and other behavioural issues impacting the relationship that established communication channels should have already resolved.

When multiple agencies are responding to an emergency, problems with authority and dynamically changing roles may also occur. As pointed by Turoff (2003), "[i]t is impossible to predict who will undertake what specific role in a crisis situation. The actions and privileges of the role need to be well defined in the software of the system and people must be trained for the possibility of assuming multiple or changing roles (Premise 6 – role transferability)." During the response to Hurricane Katrina, local civilian authorities sought access to military resources to help with the response, but they did not wish to cede overall control of the response effort to the military. The military roles became one of facilitating transportation of people and resources, providing support to responders, and general repair to destroyed infrastructure (Fischer et al., 2006).

The identified multi-agency issues above illustrate that navigation of the inter-organizational issues related to each of the agencies contributes greatly to the overall response. Information systems can be used to overcome or assist in addressing many of these organizational issues. Current information systems within agencies are mainly used to maintain a list of key contact information for other agencies which dispatchers may interact with or need to notify. However, with the soft interoperability issues that have been mentioned, there is an opportunity to improve the interactions between agencies with context-aware communication systems.

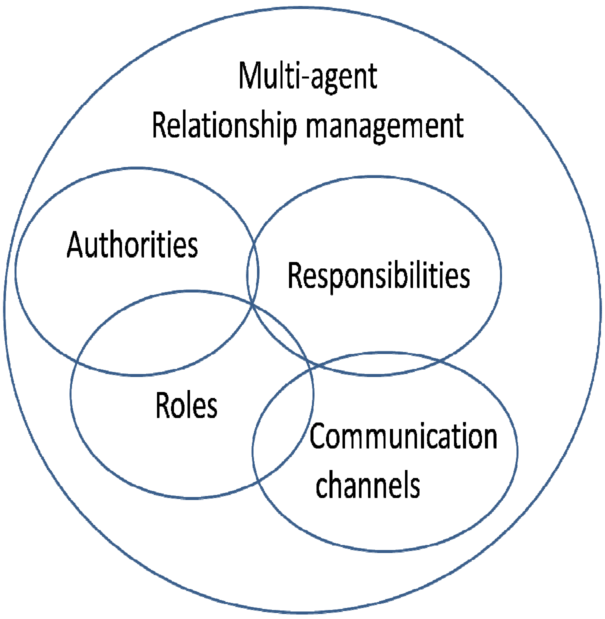

Fig. 3. Multi-agency relationship management.

Fig. 3 summarizes a system controlling the relationships between several agencies. This system clarifies the roles, responsibilities, authorities, and information exchange privileges amongst agencies. The roles describe what role an agency plays in the emergency response while responsibilities describes the tasks the agency is responsible for executing. The system also identifies established authority relationships such as the command and reporting structure for the emergency. Lastly, the system establishes information exchange channels and privileges dictating what information should be exchanged with whom through which channel or contacts. This system is dynamically maintained in order to reflect the changes in the emergency situation and responding agencies. This system helps address multi-agency relationship management issues which helps add control and order to potentially chaotic multi-agency environments.

3.3 Operation Coordination and Activity-Based Issues

Coordination is the last of the key components to discuss. Coordination (consisting of goals, activities, actors, and interdependencies) can be defined as the management of interdependencies between activities to achieve a goal (Malone and Crowston, 1994). Coordination has also been described as the fundamental task of the firm in order to maximize the efficiency gains from specialization (Grant, 1996). With this second perspective, transferring knowledge is not as efficient as integrating knowledge, thus making coordination a priority. In a multi-agency emergency response setting, coordination is the process of getting multiple parties sharing multiple resources to complete multiple tasks. Coordination can be actor-actor based, actor-activity based, or activity-activity based depending on the type of coordination process, with non-human resources intrinsic to all the forms of coordination (Shen and Shaw, 2004). Chen et al (2008) provided a coordination framework for emergency response management. Coordination goals, issues, and supporting mechanisms were analyzed along the dimensions of task flow, resource, information, decision and responder in the life cycle of pre-incident, during incident, and recovery phases.

When a crisis does occur, emergency management personnel must maintain effective communication and coordination in order to manage an effective crisis response and minimize damage or loss of life (Seeger, 2006). "Effective response to catastrophic disasters will require that first responders—law enforcement personnel, firefighters, and others first on the scene—have reliable communication systems, including supporting infrastructure, facilities, and staff. Such communication systems would enable first responders to communicate through voice, video, and other information seamlessly among themselves, various organizations, and different levels of government (US GAO, 2009)." Coordination in emergency response is necessary to share important contextual information about environment conditions, command and control structure, resource availability, process workflows, and task arrangements. This contributes to the decision making process. Coordination is then used to assign tasks, allocate resources, and execute the plan. During a disaster, infrastructure including the roads, electric power supply, and communication networks are often significantly damaged or overloaded due to reduced capacity or high demand. Re-establishing communication networks will be the first priority to facilitate coordination. Usually wireless communication is the first form of communication to be established but an emergency response system should not be designed only based on the use of the most advanced communication infrastructure. For instance in the case of Marmara earthquake in Turkey in August 1999, standard communications were not functioning on the first day after the earthquake, and only sporadically and in very limited areas in days two and three. Electrical power was out and telephone communications were down. The only means of getting information was through short-wave radio provided by Turkish Amateur Radio Club (TRAC) to relay information among different disaster sites, the Governors' Offices and the Prime Minister's Disaster Operations Center in Ankara. Police and military units also used two-way radio for internal communication with limited relay for urgent message to other organizations. Satellite telephones were brought in by search-and-rescue teams for limited users. Only on day 4, the telephone communication was reinstated for major areas (Comfort, 2000).

As pointed by Turoff (2003), "The crux of the coordination problem for large crisis response groups is that the exact actions and responsibilities of the individuals cannot be predetermined (Premise 9 -coordination)." Challenges with coordination begin with different responders having their own specialties and their own methods of conducting business. Agencies cannot necessarily perform all of the activities, nor possess all the knowledge required during an emergency. As such, they must coordinate tasks and information with others in order to effectively manage an emergency. The ability to share information, request information, and coordinate activities relies on the ability of responder agencies to work within their own organizational contexts and interface with other agencies. The importance of coordination is difficult to assess as its true value can only be described when it fails.

In many circumstances collaboration is minimised at an accident scene due to uncertainty, asymmetry, and lack of incentives (Berlin and Carlström, 2011). Coordination is also a challenge due to hard or technical interoperability issues. Emergency management and communication systems currently in place in most responder organizations are mainly targeted for individual agencies. More often than not, each agency has its own equipment, has its own standards, and has its own protocols and communication systems which limit interoperability with other agencies. As such, agencies only support those responders which the dispatch center is responsible for managing thus making coordination amongst multiple agencies more difficult.

Coordination is generally facilitated through aggregation and accumulation of public incident reports providing contextual background information, expert systems to assign priority levels to emergencies, notification systems for tiered responses between multiple agencies, identification of available responder resources, location tracking of responder assets, and any historical information on previous events at the location. The emergency management systems also provide connections to local and national databases to provide additional background information if required, as well as a directory of important agency contact phone numbers. The information and functionality provided by these systems enables dispatchers to coordinate the allocation of responders from one agency to an individual scene or several scenes throughout the entire jurisdiction of responsibility. While effective for single agencies, there is opportunity to extend these systems to support multiple agencies.

There is increasing interest in Emergency logistics and humanitarian logistics in operations research (Simpson and Hancock, 2009). Emergency logistics is defined as “the support function that ensures the timely delivery of emergency resources and rescue services into the affected regions” (DRC, 2008) while humanitarian logistics is aimed to aid people in their survival during and after a disaster. The focus of disaster relief operation is “to design the transportation of first aid material, food, equipment, and rescue personnel from supply points to a large number of destination nodes geographically scattered over the disaster region and the evacuation and transfer of people affected by the disaster to healthcare centers safely and very rapidly” (Kovács and Spens, 2007). Many theoretical models and optimization algorithms have been investigated. However, to put them into a real emergency operation is still a big challenge (Kovács and Spens, 2009).

During a rescue operation, there is usually a serious resource shortage which may affect the tasks being carried out and requires setting priorities and searching for alternative solutions. Thus resource allocation requires coordination between multiple parties at different levels. For instance, after the Haiti earthquake an enormous amount of resources were sent to the nation from the international community. Unfortunately, many of the resources remained at the airport as the logistical infrastructure was not yet established to offload the resources, warehouse and secure the resources, and transport the resources to where they were needed. Rescue personnel improvised to carry what they could by personal automobiles, or by using secondary gateways from nearby Dominican Republic to get personnel and resources to where they needed to be in Haiti (Robbins, 2010).

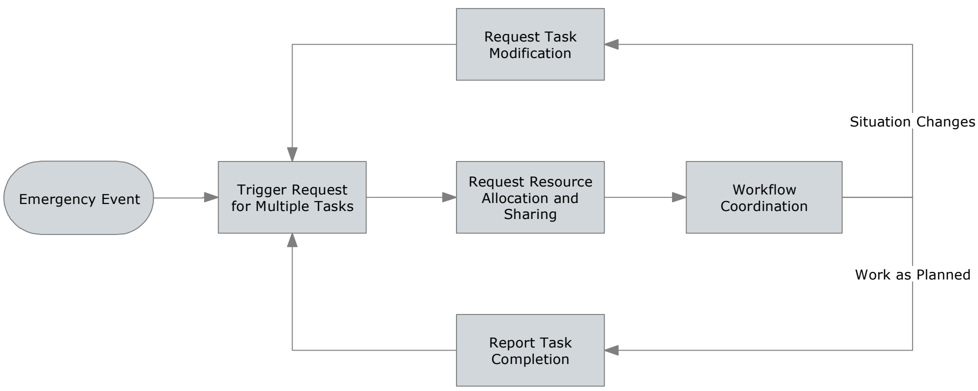

Fig. 4. Emergency response process flow is triggered by an emergency event (*left*) leading to the establishment of tasks to respond to the event (*center left*). Once tasks are identified then resources can be requested and allocated (*center*) and coordination for the execution of tasks is attempted (*right*). Depending on the situation at the time of execution, tasks may either be modified (*top*) or completed (*bottom*) which influences the future tasks to be completed for the overall emergency response.

Fig. 4 outlines a process flow diagram covering a task-based perspective on emergency response coordination. First and foremost is an emergency event that occurs. This emergency event provides the awareness trigger to begin collecting and disseminating contextual information to responders regardless of the source. A context-aware coordination system can measure, accumulate, and filter contextual data before notifying key personnel of an emergency and sharing relevant information with key responder personnel. Responders to the scene can then gather additional context information and begin to identify the tasks that need to be performed in order to respond to the emergency. The determination of the tasks leads to the determination of the required resources and agencies to successfully respond to the scene. Resources may include equipment, personnel, or other miscellaneous requirements from within single or multiple agencies. This is another opportunity for context-aware systems to provide resource availability data to key personnel. This resource availability information does not need to be restricted to a single agency, but can incorporate information from other agencies across organizational boundaries with agencies willing to build connections pre-disaster or during the disaster. An assessment of required resources can also be used to identify key contacts and share contextual information with new agencies that may be sought to assist in the response effort. Once resources have been requested, a plan for response is formulated based on the tasks to be completed, the resources available, and the interdependencies amongst multiple responder agencies. The tasks may be performed through workflow coordination activities. Context-aware computing can aid in the connection of agencies, sharing of resources, and sharing of incident information such as the command and control structure and responder roles such that situational awareness is shared amongst agencies and interdependencies are known. During the task execution unexpected situations may occur. This may trigger requests for modification of existing tasks, or requests for new tasks. Completed tasks need to be reported back to commanders for monitoring purposes and to free up resources. This response process flow is repeated until all identified tasks are completed, the emergency is over, or the response is abandoned. This coordination process involves information gathering, decision making, as well as the execution of processes which is different from previous studies focusing on decision making only.

4 Conclusion

The design of better emergency coordination systems is an opportunity for information systems and communication technology to positively influence group decision making and improve the effectiveness of crisis response coordination. A context-aware multi-party coordination system is the type of tool that can enable more efficient multi-agency coordination and facilitate resource acquisition and assignment to improve an emergency response for the benefit of society.

An emergency coordination response system should take context-aware computing components, multi-agency components, and task-based coordination components into account to address the major issues of environmental, organizational, and activity-based factors affecting an emergency response. By integrating these components into one system it is possible to design a comprehensive supporting information system.

Turoff et al. (2004) presented nine design premises in their DERMIS proposal. They were: i) system training and simulation; ii) information focus; iii) crisis memory; iv) exceptions as norms; v) scope and nature of crisis; vi) role transferability; vii) information validity and timeliness; viii) free exchange of information; and ix) coordination. Throughout this paper we have tried to show how these premises are addressed in our system. The system we propose has the potential to realise all these premises in a systematic and concrete manner. The system needs to be used on a daily basis as part of responders' daily operations so that its use was standard. Second, it needs to utilize filtering amongst different levels of communication to provide only the most relevant information to responders and decision makers. Next, it needs to provide history logs like current emergency management systems employ so that dispatchers and responders can review previous events or communication. Next, the system will sense, monitor, collect, and share information on the context of the emergency response pertaining to the environment, organizations involved, and activities planned or underway. The system will interact with multiple agencies and assign personnel to roles which would have tasks associated with them. The system will quickly collect contextual data in a timely fashion from reputable sources. It will share appropriate non-sensitive information with other responding agencies as required, and it will aid in the coordination of actions and resources by the responding agencies.

This paper currently presents only the framework without architecting a solution. Future research direction will include providing a validation of the proposed framework, architecting a system based on the framework, and developing a prototype system for further evaluating the effectiveness of the proposed CAMPCS.

References

Abrahamsson, M., Hassel, H., Tehler, H. (2010). Towards a System-Oriented Framework for Analysing and Evaluating Emergency Response. *J. Contingencies and Crisis Management, 18* (1), 14-25.

Berlin, J., Carlström, E. (2011). Why is collaboration minimised at the accident scene? A critical study of a hidden phenomenon. *Disaster Prevention and Management*, *20*(2), 159-171.

Chen, G., Kotz, D. (2000). A Survey of Context-Aware Mobile Computing Research. *Dartmouth Computer Science Technical Report TR2000-381*, 1-16.

Chen, R., Sharman, R., Rao, H., Upadhyaya, S. (2008). Coordination in Emergency Response Management. *Communications of the ACM, 51* (5), 66-73.

Comfort, L. (2000). *Information Technology and Efficiency in Disaster Response: The Marmara, Turkey Earthquake, 17 August 1999*. (Quick Response Report #130). Retrieved from Quick Response Grant Program Main Page via Natural Hazards Center: http://www.colorado.edu/hazards/research/qr/

Danish Refugee Council (DRC) (2008). Emergency Logistics and Transport Management, *Programme Handbook*, Chapter 8i, 1-9. Retrieved December 7, 2011 from http://www.drc.dk/fileadmin/uploads/pdf/IA_PDF/relief_work/chapter_8i%20-%20Emergency%20Logistics%20and%20Transport%20Management.pdf

DeSanctis, G., Gallupe, R. B. (1987). A Foundation for the Study of Group Decision Support Systems. *Management Science, 33* (5), 589-609.

Dey, A., Abowd, G, Salber, D. (2001). A Conceptual Framework and a Toolkit for Supporting the Rapid Prototyping of Context-Aware Applications. *Human-Computer Interaction*, *16*, 97-166

Fischer, H., Gregoire, K., Scala, J., Letukas, L., Mellon, J., Romine, S., Turner, D. (2006). *The Emergency Management Response to Hurricane Katrina: As Told by the First Responders--A Case Study of What Went Wrong and Recommendations for the Future*. (Quick Response Report #189). Retrieved from Quick Response Grant Program Main Page via Natural Hazards Center: http://www.colorado.edu/hazards/research/qr/

Grant, R. (1996). Toward a Knowledge-based Theory of the Firm. *Strategic Management Journal, 17*, 109-122.

Hale, J. (2009). A Layered Communication Architecture for the Support of Crisis Response. *Journal of Management Information Systems, 14*(1), 235-255.

International Atomic Energy Agency(IAEA) (2011). *Final Report of the International Mission on Remediation of Large Contaminated Areas Off-site the Fukushima Dai-ichi NPP*. Retrieved November 28, 2011 from http://www.iaea.org/newscenter/focus/fukushima/final_report151111.pdf.

Kovács, G., Spens, K. (2007). Humanitarian Logistics in Disaster Relief Operations. International *Journal of Physical Distribution & Logistics Management*, *37*(2), 99-114.

Kovács, G., Spens, K. (2009). Identifying Challenges in Humanitarian Logistics. International *Journal of Physical Distribution & Logistics Management*, *39*(6), 506-528.

Malone, T., Crowston, K. (1994). The Interdisciplinary Study of Coordination. *ACM Computing Surveys, 26* (1), 87-119.

Malone, T., Crowston, K. (1990). What is Coordination Theory and How Can It Help Design Cooperative Work Systems? *ACM Proceedings of the Thrid Conference on Computer Supported Cooperative Work*, 357-370.

Miller, P. (2000). Interoperability. What is it and Why should I want it? *Ariadne , 24*.

Mimura, N., Yasuhara, K., Kawagoe, S., Yokoki, H., Kazama, S. (2011). Damage from the Great East Japan Earthquake and Tsunami - A quick report. *Mitigation and Adaptation Strategies for Global Change, 16*, 803-818.

Onishi, N., Fackler, M. (2011, June 12). In Nuclear Crisis, Crippling Mistrust. *New York Times Asia Pacific*. Retrieved December 11, 2011 from http://joomla.sns-online.ch/cms/images/stories/unterlagen/20110613_mistrust-during-nuclear-crisis.pdf

Petak, W. (1985). Emergency Management: A Challenge for Public Administration. *Public Administration Review, 45*, 3-7.

Radke, J., Cova, T., Sheridan, M., Troy, A., Mu, L., Johnson, R. (2000). Challenges for GIS in Emergency Preparedness and Response. *An ESRI White Paper*. Retrieved November 30, 2011 from http://www.esri.com/library/whitepapers/pdfs/challenges.pdf

Robbins, L. (2010, January 15). Haiti Relief Effort Faces 'Major Challenge'. *The New York Times*. Retrieved July 13, 2011 from http://www.nytimes.com/2010/01/15/world/americas/15relief.html

Salmon, P., Stanton, N., Jenkins, D., Walker, G. (2011). Coordination during multi-agency response: issues and solutions. *Disaster Prevention and Management, 20*(2), 140-158.

Seeger, M. (2006). Best Practices in Crisis Communication: An Expert Panel Process. *Journal of Applied Communications Research, 34* (3), 232-244.

Shen, S., Shaw, M. (2004). Managing Coordination in Emergency Response Systems with Information Technologies. *Proceedings of the Tenth Americas Conference on Information Systems*, 2110-2120.

Shim, J., Warkentin, M., Courtney, J. F., Power, D. J., Sharda, R., Carlsson, C. (2002). Past, present, and future of decision support technology. *Decision Support Systems, 33* (2), 111-126.

Simpson, N., Hancock, P. (2009). Fifty years of operational research and emergency response. *Journal of the Operational Research Society*, *60*, S126-S139.

Snowden, D., Boone, M. (2007, November). A Leader's Framework for Decision Making. *Harvard Business Review*, 69-76.

Thomas, S., Cutter, S., Hodgson, M., Gutekunst, M., and Jones, S. (2002). *Use of Spatial Data and Geographic Technologies in Response to the September 11 Terrorist Attack*. (Quick Response Report #153). Retrieved from Quick Response Grant Program Main Page via Natural Hazards Center: http://www.colorado.edu/hazards/research/qr/

Turoff, M., Chumer, M., Van de Walle, B., Yao, X. (2004). The Design of a Dynamic Emergency Response Management Information Systems (DERMIS). *J. Information Technology Theory and Applications, 5* (4), 1-36.

U.S. Government Accountability Office (US GAO). (2008, February). *National Disaster Response: FEMA Should Take Action to Improve Capacity and Coordination between Government and Voluntary Sectors.* (Publication No. GAO-08-369). Retrieved from Federal Digital System Main Page via GPO Access database: http://www.gpo.gov/fdsys/

U.S. Government Accountability Office (US GAO). (2009, June). *Emergency Communications: Vulnerabilities Remain and Limited Collaboration and Monitoring Hamper Federal Efforts.* (Publication No. GAO -09-604). Retrieved from Federal Digital System Main Page via GPO Access database: http://www.gpo.gov/fdsys/

U.S. Government Accountability Office (US GAO). (2010, July). *Defense Management: U.S. Southern Command Demonstrates Interagency Collaboration, but Its Haiti Disaster Response Revealed Challenges Conducting a Large Military Operation.* (Publication No. GAO-10-801). Retrieved from Federal Digital System Main Page via GPO Access database: http://www.gpo.gov/fdsys/

Xu, Z., Yuan, Y., Ji, S. (2009). A decision analysis framework for emergency notification: the case of the Sichuan earthquake. *Int. J. Emergency Management , 6* (2), 227-243.

Yuan, Y., Detlor, B. (2005). Intelligent Mobile Crisis Response Systems. *Communications of the ACM, 48* (2), 95-98.

Fuzzy group aggregation approaches

A multiperson multicriteria decision-making method for a group environment with hierarchical structure

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Abstract: This paper introduces a methodology for multicriteria decision-making in a group environment with hierarchical structure, where a group of experts participates as consultants and only one person has authority to make the final decision (that is, there is only one decision-maker). The methodology being proposed is based on preference modeling by means of fuzzy preference relations. It offers computational resources to aid the decision-maker in dealing with discordant opinions, with hesitant judgments and with the need of differentiating the importance of each opinion in the construction of a model of the collective preferences. The applicability of the methodology is demonstrated through the solution of a decision-making problem related to the estimation of rental values for residential properties, considering some known rental values as a guideline.

Keywords: Group decision; Multicriteria decision; Fuzzy Preference Relation.

1 Introduction

Multicriteria decision-making problems are formalized by defining a set of alternatives (or possible solutions) $X=\{x_1, x_2, ..., x_n\}$ for the problem and a set of criteria $C=\{c_1, c_2, ..., c_q\}$ for their evaluation, comparison, prioritization and/or for the selection of the best possible solutions. An approach to dealing with this kind of problems consists in constructing a $<X, R>$ model, where R is a vector of fuzzy preference relations (Pedrycz et al., 2010). A fuzzy preference relation (or fuzzy nonstrict preference relation) is a fuzzy set with bi-dimensional membership function $R_p(x_k, x_l): X \times X \rightarrow [0,1]$, $p=1,2,\ldots,q$ (or binary fuzzy relation (BFR)) (Orlovsky, 1978). In essence, the membership function of a fuzzy preference relation indicates in the unit interval the degree to which the alternative x_k is at least as good as x_l, when the criterion c_p, is considered by a particular expert or by a group of experts. $R_p(x_k, x_l)$ can also represent the degree of truth of the statement "x_k is at least as good as x_l".

In this work, a methodology is proposed for processing and analyzing multicriteria decision-making problems, in a group environment with a hierarchical structure. Such kind of environment is characterized by the presence of only one person with authority to make the final decision, the decision-maker (DM), and a group of experts who participate as consultants (Parreiras and Ekel, 2011). This methodology is based on the construction and analysis of $<X, R>$ models. The experts participate in the decision-making process by expressing their preferences over the alternatives by means of fuzzy preference relations. The collective preferences are constructed by aggregating the fuzzy preference relations constructed by each expert. When the individual preferences are aggregated, the DM interferes in the decision process by assigning weights to the experts in accordance with their experience, knowledge, etc. When the multicriteria analysis of the $<X, R>$ model is carried out, the DM interferes by selecting an aggregation operator which is coherent with his decision attitude.

The methodology being proposed involves the use of an index of consensus, which reflects the level of general agreement in the group of experts; an index of discordance, which allows to identify the most discordant opinions in the group; an index of comparability which allows to identify the unreliable judgments; a computational component which calculates weights to be assigned to the preferences of each expert. In (Parreiras and Ekel, 2011), a similar methodology is proposed to support a DM in dealing with the opinions of several experts discordant experts. The methodology which is proposed here enhances that one in the following aspects:

• a more accurate way of calculating the discordances between the preferences provided by the different experts is utilized in the methodology being proposed here. It considers that the fuzzy preference relation portrays three types of judgments (Fodor and Roubens, 1994): the indifference; the strict preference and the incomparability. Here, only the indifference and the strict preference judgments are considered in the computation of the concordance index;

• here, guidelines to be followed by the experts to express their judgments of preferences and incomparability are included in the methodology. Those guidelines allow the experts to express not only their preferences, but also their hesitations;

• the methodology being proposed makes use of the results in (Peneva and Popov, 2003) to guarantee the construction of consistent collective preferences (by consistent we mean satisfying the weak transitivity condition).

The text is organized as follows: Section 2 presents a review of the theory on preference modeling based on BFRs, which serves as a theoretic background for our proposal. Section 3 describes the method that is utilized for multicriteria analysis of the <*X*, *R*> model, which is based on the Orlovsky choice procedure (Orlovsky, 1978). Section 4 presents three indexes to support the DM in the task of constructing the fuzzy preference relations that are representative of the collective preferences: the consensus index, the discordance index and the comparability index. In Section 5, we describe the full methodology for processing and analyzing multicriteria decision-making problems in a group environment with hierarchical structure. Section 6 contains an example of application related to the estimation of rental values for residential properties, considering some known rental values as guidelines (Gomes et al., 2009). Finally, in Section 7, we draw our conclusions.

2 Strict Preference, Indifference and Incomparability Judgments

In the comparison between two possible solutions, three main types of judgments can be distinguished, namely indifference, strict preference, and incomparability (Fodor and Roubens, 1994). These judgments can be modeled by means of three specific BFRs, with membership functions quantifying in the interval [0,1] the intensity of the observed judgment. They are: the I_p, the fuzzy strict preference relation P_p and the fuzzy incomparability relation J_p.

A relevant property of <*X*, *R*> models is that it allows defining a fuzzy indifference relation I_p, a fuzzy strict preference relation P_p and a fuzzy incomparability relation J_p exclusively in terms of the fuzzy preference relation R_p (by definition, $R_p = P_p \cup I_p$) as follows (Fodor and Roubens, 1994):

$$I_p = R_p \cap R_p^{-1} \ , \tag{1}$$

$$P_p = R_p \cap R_p^{d} \ , \tag{2}$$

$$J_p = \overline{R}_p \cap R_p^{d} \ , \tag{3}$$

where R_p^{-1} is the inverse relation of R_p, that is $R_p^{-1}(x_k, x_l) = R_p(x_l, x_k)$; R_p^d is the dual relation of R_p, being defined as $R_p^d(x_k, x_l) = 1 - R_p(x_l, x_k)$; $\overline{R}_p$ is the complementary relation of R_p, that is $\overline{R_p(x_k, x_l)} = 1 - R_p(x_k, x_l)$. Therefore, once we have at hand R_p, the estimation of I_p, P_p, and J_p is realized on the basis of (1), (2), and (3), respectively. However, as it has been discussed, for instance in (De Baets and Fodor, 1997), it is not simple to select a t-norm to implement (1)-(3), if we want to preserve certain desirable properties of a fuzzy preference structure. More specifically, as a consequence of a result demonstrated in (Alsina, 1985), it is not possible to select the same t-norm to perform the intersection in (1)-(3). Among the admissible t-norms to be utilized in this context (Fodor and Roubens, 1994), we selected the min operator to implement the intersection in (1) and in (3) and the Lukasiewicz t-norm to implement the intersection in (2), as given by the following expressions:

$$I_p(x_k, x_l) = \min\{R_p(x_k, x_l), R_p(x_l, x_k)\} \ , \tag{4}$$

$$P_p(x_k, x_l) = \max\{R_p(x_k, x_l) - R_p(x_l, x_k), 0\} \ , \quad (5)$$

$$J_p(x_k, x_l) = \min\{1 - R_p(x_k, x_l), 1 - R_p(x_l, x_k)\} \ . \quad (6)$$

The use of (4), (5) and (6) is advocated here based on the following arguments:

• (5) is in conformity with the Orlovsky choice procedure (Orlovsky, 1978), which has been successfully utilized to solve multicriteria decision-making problems (Pedrycz et al., 2010);

• (5) and (6) determine a clear relationship between the values of $R_p(x_k, x_l)$ and $R_p(x_l, x_k)$. If (5) and (6) are utilized for defining the fuzzy indifference relation and the fuzzy strict preference relation, respectively, then the difference between $R_p(x_k, x_l)$ and $R_p(x_l, x_k)$ reflects the level of strict preference between the alternatives x_k and x_l. Besides, the minimum value between $R_p(x_k, x_l)$ and $R_p(x_l, x_k)$ reflects the level of indifference between the alternatives x_k and x_l.

When we consider the use of a fuzzy preference relation to represent the preferences of an expert, R_p may be directly or indirectly defined. In the indirect way of constructing a fuzzy preference relation, an expert can make his judgments by using different preference formats. Then, transformation functions are utilized to construct the fuzzy preference relations, which forms the <*X*, *R*> model. More information about the indirect construction of <*X*, *R*> models can be found, for instance, in (Herrera-Viedma et al., 2002) or (Pedrycz et al. ,2010). In the direct way, an expert must select the values in the unit interval that reflect the level of credibility or just the strength of his nonstrict preference for one possible solution over the other. The encoding scheme considered here is reflected by a nonreciprocal fuzzy preference relation (NRFPR), which verifies the following conditions (Pedrycz et al., 2011):

• if $R_p(x_k, x_l) = 1$ and $R_p(x_l, x_k) = 1$, then x_k is indifferent to x_l;

• if $R_p(x_k, x_l) = 1$ and $R_p(x_l, x_k) = 0$, then x_k is strictly preferred to x_l;

• if $R_p(x_k, x_l) = 0$ and $R_p(x_l, x_k) = 1$, then x_l is strictly preferred to x_k;

• if $R_p(x_k, x_l) = 0$ and $R_p(x_l, x_k) = 0$, then x_k and x_l are not comparable;

• the entries of the main diagonal are filled with 1, due to the reflexivity of $R_p(x_k, x_l)$.

Intermediate judgments among the situations described above are also allowed. They can be interpreted as follows:

• if $0 < R_p(x_k, x_l) < 1$ and $R_p(x_l, x_k) = 1$, then x_l is weakly preferred to x_k;

• if $R_p(x_k, x_l) = 1$ and $0 < R_p(x_l, x_k) < 1$, then x_k is weakly preferred to x_l;

• if $0 < R_p(x_k, x_l) < 1$ and $R_p(x_l, x_k) = 0$, then x_k is weakly preferred to x_l and, at the same time, x_k and x_l are to a degree considered incomparable;

• if $R_p(x_k, x_l) = 0$ and $0 < R_p(x_l, x_k) < 1$, then x_l is weakly preferred to x_k and, at the same time, x_k and x_l are to a degree considered incomparable.

With reference to the consistency of the NRFPR, it is necessary to indicate that the minimum requirement that should be satisfied by preference judgments is given by the weak transitivity condition (Herrera-Viedma et al., 2004), which can be stated as:

$$\text{if } R_p(x_k, x_j) > R_p(x_j, x_k) \text{ and } R_p(x_j, x_l) > R_p(x_l, x_j), \text{ then } R_p(x_k, x_l) > R_p(x_l, x_k), \text{ for all } x_k, x_j, x_l \in X \ . \quad (7)$$

Weak transitivity is also a sufficient condition to guarantee that the Orlovsky choice procedure produces results with rational properties. A consistency condition which is relevant to the methodology that we propose here, is the $\max-\Delta$ transitivity, which is defined as follows (Peneva and Popov, 2003):

$$R_p(x_k, x_j) \geq \max\{0, R_p(x_k, x_l) + R_p(x_l, x_j) - 1\}, \forall x_k, x_l, x_j \in X \ . \quad (8)$$

In Section 5, we explain the importance of condition (8) for the use of the methodology being proposed.

3 Multicriteria Decision-Making Method

According to the Orlovsky choice procedure, as $P_p(x_l, x_k)$, for k=1,2,…,n and $k \neq l$, describes the set of all solutions x_k that are strictly dominated by x_l, its compliment $\overline{P_p(x_l, x_k)}$, for k=1,2,…,n and $k \neq l$, corresponds to the set of solutions that are not dominated by other solutions from X. Therefore, in order to meet the fuzzy set of nondominated solutions, it suffices to obtain the intersection of all $\overline{P_p(x_l, x_k)}$, which is given by

$$ND_p(x_k) = \inf_{X_l \in X}\{1 - P_p(x_l, x_k)\} = 1 - \sup_{X_l \in X} P_p(x_l, x_k) \ . \tag{9}$$

A natural choice for a monocriteria problem based on this model should be the alternatives providing (Orlovsky, 1978):

$$X^{ND}_{R_p} = \left\{ x^{ND}_k \in X \mid R^{ND}_p(x^{ND}_k) = \sup_{x_k \in X} ND_p(x_k) \right\} \ . \tag{10}$$

A ranking of the possible solutions can be obtained by executing the following procedure: (5), (9) and (10) are applied to R_p. The nondominated solutions given by (10) are ranked first. Therefore, they must be excluded from a subsequent analysis, where (5), (9) and (10) are applied to the corresponding submatrix of R_p. These steps are executed as many times as it is necessary to obtain a complete ranking of the possible solutions.

The Orlovsky choice procedure may be used to solve choice or ranking problems not only with a single criterion, but also with multiple criteria (Pedrycz et al., 2010). In this paper, the multicriteria analysis is carried out by aggregating the rankings of the alternatives, which are produced with the use of the Orlovsky choice procedure, in a coherent way with the ranking determined by the weak transitivity property of each collective fuzzy preference relation (Kulshreshtha and Shekar, 2000). The aggregation of the rankings can be implemented by means of different operators. Here, four aggregation functions are considered to deal with values of ordinal nature. Each function reproduces one among the following possible decision attitudes of the DM, which are also considered in (Yager, 1995):

- pessimistic attitude: the possible solutions are evaluated according to their worst characteristics (or the worst possible consequences of their implementation). The DM prefers the solutions that have the best worts characteristics (or consequences);
- optimistic attitude: the possible solutions are evaluated according to their best characteristics (or the best possible consequences of their implementation). The DM prefers the solutions that have the maximum best characteristics (or consequences);
- Hurwicz approach: the decision attitude of the DM is reproduced by means of a linear combination of the optimistic attitude and the pessimistic attitude, with a pessimism-optimism index whose value must be defined in advance by the DM;
- normative approach: the possible solutions are evaluated according to their mean evaluation. The DM prefers the solutions that have the best mean evaluation.

Let us consider the following approach to decision making:

- **Step 1:** for each alternative, calculate

$$G(x_k) = F(O_1(x_k), O_2(x_k), ..., O_q(x_k)) \ . \tag{11}$$

where F is some aggregation function and $O_p(x_k)$ is a permutation function, which returns a value which indicates the position of alternative x_k in the ranking obtained by processing the fuzzy preference relation R_p. $O_p(x_k) = u$ means that x_k is in the uth position in the ranking. When there is more than one alternative occupying the same position, for instance, z alternatives in the uth position, then the $O_p(x_k)$ returns a value for these alternatives, which is calculated as follows:

$$O_p(x_k)=(u + (u+1) + (u+2) + \dots + (u+z-1))/z \ . \tag{12}$$

- **Step 2:** Select the alternative $x_k \in X$, such that its valuation $G(x_k)$ is minimal. In this approach, the four possible attitudes of a DM are implemented by defining function F as follows:

• pessimistic attitude:

$$F(O_1(x_k), O_2(x_k), ..., O_q(x_k)) = \max_{1 \le p \le q} O_p(x_k) \ ; \quad \textbf{(13)}$$

• optimistic attitude:

$$F(O_1(x_k), O_2(x_k), ..., O_q(x_k)) = \min_{1 \le p \le q} O_p(x_k) \ ; \quad \textbf{(14)}$$

• Hurwicz attitude:

$$F(O_1(x_k), O_2(x_k), ..., O_q(x_k)) = \alpha \max_{1 \le p \le q} O_p(x_k) + (1-\alpha) \min_{1 \le p \le q} O_p(x_k) \ , \quad \textbf{(15)}$$

where $\alpha \in [0,1]$ represents an "pessimism-optimism" index whose magnitude is defined on advance by a DM;

• normative attitude:

$$F(O_1(x_k), O_2(x_k), ..., O_q(x_k)) = \sum_{p=1}^{q} \frac{O_p(x_k)}{q} \ . \quad \textbf{(16)}$$

4 Indexes of Discordance, Consensus and Comparability

When a group of experts $E_p = \{e_{p,1}, e_{p,2}, ..., e_{p,v_p}\}$, p=1,2,...,q (the sub-index p in E_p specifies the group of experts working on the p-th criterion) participates in a decision-making process based on <X, R> models, one manner of estimating the level of discordance between the preferences of the yth expert and the zth expert is by executing the following procedure: first, the fuzzy preference relation constructed by each expert is processed in order to obtain a fuzzy indifference relation and a fuzzy strict preference relation for each expert. Then, the discordances between their preferences are calculated with the use of the following index of discordance

$$IDisc(e_{p,y}, e_{p,z}) = \frac{2}{n(n-1)} \sum_{k=1}^{n} \sum_{l=k+1}^{n} D_{p,y,z}(x_k, x_l) \ , \quad \textbf{(17)}$$

where n is the number of possible solutions and the term $D_{p,y,z}$ is given by

$$D_{p,y,z}(x_k, x_l) = \frac{1}{2}\left(| I_{p,y}(x_k, x_l) - I_{p,z}(x_k, x_l) | + \frac{1}{2}\left(| P_{p,y}(x_k, x_l) - P_{p,z}(x_k, x_l) | + | P_{p,y}(x_l, x_k) - P_{p,z}(x_l, x_k) | \right)\right) \ . \quad \textbf{(18)}$$

In the expression (18), it is worth noting that, because of the asymmetry of the fuzzy strict preference relation (Fodor and Roubens, 1994), the difference between $P_{p,y}(x_k, x_l)$ and $P_{p,z}(x_k, x_l)$ and the difference between $P_{p,y}(x_l, x_k)$ and $P_{p,z}(x_l, x_k)$ must be considered. At the same time, because of the symmetry of the fuzzy indifference relation I_p (Fodor and Roubens, 1994), it is sufficient to consider the absolute value of the difference between $I_{p,y}(x_k, x_l)$ and $I_{p,z}(x_k, x_l)$. Furthermore, it should be indicated that, in a different way that in our previous work (Parreiras and Ekel, 2011), J_p is not considered here in the evaluation of the degree of discordance. We believe that it is more rational to exclude the contribution of $J_{p,y}$ from (18), since the fuzzy incomparability relation reflects the credibility degree of the judgments provided by each expert (and not the strength of his preferences). Finally, expression (17) is an arithmetic average of the $D_{y,z}$, for y=1,2,…,n and z=1,2,…,n, which can be simplified by considering only the entries of matrix $D_{y,z}$ which are located above the main diagonal (taking advantage of the symmetry of $D_{y,z}$ and of the fact that the entries on the main diagonal of $D_{y,z}$ are equal to zero).

The mean level of concordance for the group, which can be taken as a measure of consensus degree, can be calculated as follows:

$$ICons = 1 - \frac{2}{v(v-1)} \sum_{y=1}^{v} \sum_{z=y+1}^{v} IDisc(e_{p,y}, e_{p,z}) \ . \quad (19)$$

When the experts are allowed to make paired judgments with a non-null level of incomparability, an index of comparability can be utilized by the moderator to supervise the credibility of the available information. Each expert can assign a low credibility degree to a paired comparison whenever he cannot define with conviction the preference degree for one alternative over another. The lack of conviction may be associated with missing information or to the occurrence of contradictory information about one alternative or both alternatives belonging to the pair.

The complement of a fuzzy incomparability relation J_p can be taken as an index of comparability (which can be understood as an index of credibility), associated with the fuzzy preference relation $R_{p,y}$ provided by the *y*th expert. The complement of the incomparability relation (which is given by (6)) results in the following expression:

$$\overline{J_{p,y}(x_k, x_l)} = 1 - J_{p,y}(x_k, x_l) = \max\{R_{p,y}(x_k, x_l), R_{p,y}(x_l, x_k)\} \ . \quad (20)$$

The global index of comparability is given by the intersection of all comparability relations obtained by means of the min operator:

$$IComp(x_k, x_l) = \min\{\overline{J_{p,1}(x_k, x_l)}, \overline{J_{p,2}(x_k, x_l)}, ..., \overline{J_{p,v}(x_k, x_l)}\} \ . \quad (21)$$

As it is described in the next section, with the use of (21), it is possible to identify all pairs $(x_k, x_l) \in X \times X$ that need to be reconsidered in the discussion process with the intention of helping the experts to dissolve their doubts and decrease the level of incomparability of their judgments.

5 Methodology for the Construction and Analysis of a <*X*, *R*> Model

Among the existing approaches for multiperson multicriteria decision-making, the one named Aggregation of Individual Preferences per Criterion (AIC) allows the process to be divided into several sessions, being each one devoted to the analysis of a criterion (Pedrycz et al. 2010), (Parreiras et al., 2012). In the methodology that we are proposing, some principles of AIC are utilized to coordinate the work of the groups of experts. Here, as in AIC, given the *p*th criterion, each expert $e_{p,y} \in E_p$ must construct a fuzzy preference relation $R_{p,y}$, $y \in \{1,2,...,v\}$. Then, they are aggregated into collective preferences per criterion $R_{p,C}$, $p \in \{1,2,...,q\}$. In this methodology, the aggregation is carried out with the use of the weighted arithmetic mean. Having a collective fuzzy preference relation per criterion at hand, the multicriteria decision-making method based on the Orlovsky choice procedure, which is described in Section 4, is applied for the analysis of the <*X*, *R*> model.

An important aspect that needs to be addressed here refers to the fact that the weak-transitivity is a requisite to be satisfied by the collective preferences, since it is a necessary consistency condition to guarantee the rationality of the decisions based on applying the Orlovsky choice procedure (Sengupta, 1998). As it is demonstrated in (Peneva and Popov, 2003), when the weighted arithmetic mean is utilized to aggregate the individual preferences, one possible way to guarantee the weak transitivity of the collective preferences is to assure that the individual preferences satisfy the $\max-\Delta$ transitivity, which is given by (8), and have the moderately comparative property, which means that they must satisfy the following condition (Peneva and Popov, 2003):

$$R_{p,y}(x_k, x_l) + R_{p,y}(x_l, x_k) \geq 1, \forall (x_k, x_l) \in X \times X \ . \quad (22)$$

Taking all those into consideration, this methodology can be described as having the following phases:

Phase 1: each expert e_y belonging to E_p must construct a fuzzy preference relation $R_{p,y}$ which reflects his own preferences. The following guidelines, which are proposed here, can be followed by the experts to perform the direct assessment of a fuzzy preference relation R_p:

Process of Preference Elicitation

Step 1. For each pair of alternatives (x_k,x_l), the expert must indicate the strength of his strict preferences $\alpha \in [0,1]$, as well as the direction of his strict preferences (i.e., whether x_k is preferred to x_l or if x_l is preferred to x_k).
Step 2. If the strict preference is not at the maximum degree, he can specify the degree of incomparability of this judgment β in the range $\beta \in [0, \frac{1-\alpha}{2}]$. It is worth mentioning that the maximum value of this interval is determined by considering that each pair of judgments must present moderate comparability (Peneva and Popov, 2003), in order to guarantee that the collective preferences satisfy the $\max - \Delta$ transitivity.
Step 3. If x_k is preferred to x_l, the corresponding entries of the fuzzy preference relation are constructed as follows:

$$R_{p,y}(x_k, x_l) = 1 - \beta \qquad \textbf{(23)}$$

and

$$R_{p,y}(x_l, x_k) = 1 - \beta - \alpha \ . \qquad \textbf{(24)}$$

If x_k is preferred to x_l, then $R_{p,y}(x_k, x_l) = 1 - \beta - \alpha$ and $R_{p,y}(x_l, x_k) = 1 - \beta$.

Step 4. Those steps from Step 1 to Step 2 must be repeated for every pair of alternatives. When we have at hand a completely filled matrix $R_{p,y}$, it is necessary to verify whether the fuzzy preference relation constructed by the yth expert satisfies $\max - \Delta$ transitivity. If it does not satisfy this condition, then this expert must review and repair his judgments until this condition is satisfied.

Example: Given alternatives (x_1,x_2), in Step 2, the expert e_1 says that, when a criterion f_1 is considered, x_1 is strictly preferred to x_2 at a degree $\alpha = 0.7$. In Step 2, he says that $\beta = 0.15$. Hence, in Step 3, by applying (7) and (8), we obtain $R_1(x_1, x_2) = 0.85$ and $R_1(x_2, x_1) = 0.15$. It is possible to confirm that $R_1(x_1, x_2)$ and $R_1(x_2, x_1)$ satisfy condition (21). Besides, by applying (5) to $R_1(x_1, x_2)$ and $R_1(x_2, x_1)$, we obtain $P_1(x_1, x_2) = 0.7$ and $P_1(x_2, x_1) = 0$. Finally, (6) gives us $J_1(x_1, x_2) = J_1(x_2, x_1) = 0.15$ and (4) provides $I_1(x_1, x_2) = I_1(x_2, x_1) = 0.15$, as it was expected.

Phase 2: the index of discordance; the index of consensus, and the index of comparability are calculated by means of (17), (19) and (21), respectively. If an expert assigns a degree of incomparability such that $\beta > (1-\alpha)/2$, the fuzzy preference relation constructed by him may not be included in the analysis of the problem, in order to guarantee that the aggregated preferences satisfy weak transitivity.
Phase 3: whenever it is necessary, the DM can assign a weight $\lambda_{p,y}$, y=1,2,…,v to each expert to differentiate their respective importance in the group;
Phase 4: in as similar way as in (Hsu and Chen, 1996), the weights to be associated to the preferences of each expert penalize those opinions that disagree with the opinions given by the experts that are associated with higher weights $\lambda_{p,y}$, $y \in \{1,2,...,v\}$. The weights are calculated as follows:

$$w_{p,y} = \frac{1}{(v-1)} \sum_{z=1, z \neq y}^{v} \lambda_{p,z} (1 - IDisc(e_{p,y}, e_{p,z})), \qquad \textbf{(25)}$$

where *IDisc* is calculated by means of (17).
Phase 5: The operation allowing one to generate collective information is performed over the fuzzy preference relations per criterion as follows (Parreiras and Ekel, 2011):

$$R_{p,C} = \sum_{y=1}^{v} \frac{w_{p,y}}{W_p} R_{p,y} \ , \qquad \textbf{(26)}$$

where $W_p = \sum_{y=1}^{v} w_{p,y}$.

Phase 6: After the construction of a <*X*, *R*> model for the group (which means that those phases from Phase 1 to Phase 5 must be executed *q* times in order to obtain $R_C = \{R_{1,C}, R_{2,C}, ..., R_{q,C}\}$), a method for multicriteria analysis of <*X*, *R*> models is applied to solve the problem and derive a ranking of the alternatives.

6 Example of Application

The multiperson multicriteria decision-making problem considered here is a version of the study presented in (Gomes et al., 2009), which aims at determining a reference value for the rent of residential properties, considering some known rental values as a guideline. In this way, several experts are asked to help a DM to rank four properties $X = \{x_1, x_2, x_3, x_4\}$. The value for the rent of x_1 and x_2 are already known. A DM needs to estimate adequate values for the rent of x_3 and x_4, by considering the values for the rent of x_1 and x_2.

The four properties have the same constructed area, number of rooms, number of garage spaces and location (they are located at the same street), level of security. However, they may differ if we consider the following qualitative criteria: c_1) state of conservation; c_2) quality of construction; c_3) attractiveness of the leisure area. Three engineers E_1={$e_{1,1}$, $e_{1,2}$, $e_{1,3}$} are invited to evaluate the quality of construction; three architects E_2={$e_{2,1}$, $e_{2,2}$, $e_{2,3}$} are invited to evaluate the state of conservation; three rental agents E_3={$e_{3,1}$, $e_{3,2}$, $e_{3,3}$} are invited to evaluate the attractiveness of the leisure area.

In the execution of Step 1 of AIC, the following fuzzy preference relations are obtained:

• criterion c_1:

$$R_{1,1} = \begin{bmatrix} 1 & 1 & 1 & 0.7 \\ 0 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 \\ 0.7 & 1 & 1 & 1 \end{bmatrix}, \ R_{1,2} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 0.8 & 1 & 1 & 1 \\ 0.8 & 1 & 1 & 1 \\ 1 & 0.65 & 0.2 & 1 \end{bmatrix}, \ R_{1,3} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 0.5 & 1 & 1 & 0.5 \\ 0.5 & 1 & 1 & 0.5 \\ 1 & 1 & 1 & 1 \end{bmatrix}. \quad \textbf{(27)}$$

• criterion c_2:

$$R_{2,1} = \begin{bmatrix} 1 & 0.5 & 0 & 1 \\ 1 & 1 & 0.5 & 1 \\ 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \ R_{2,2} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 1 \end{bmatrix}, \ R_{2,3} = \begin{bmatrix} 1 & 0.5 & 1 & 0.5 \\ 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 0 \\ 1 & 1 & 1 & 1 \end{bmatrix}. \quad \textbf{(28)}$$

• criterion c_3:

$$R_{3,1} = \begin{bmatrix} 1 & 0.5 & 0.5 & 0.5 \\ 1 & 1 & 1 & 1 \\ 1 & 0.8 & 1 & 0.8 \\ 1 & 1 & 1 & 1 \end{bmatrix}, \ R_{3,2} = \begin{bmatrix} 1 & 0.8 & 0.8 & 0.4 \\ 1 & 1 & 0.8 & 0.4 \\ 1 & 0.9 & 1 & 0.4 \\ 1 & 1 & 1 & 1 \end{bmatrix}, \ R_{3,3} = \begin{bmatrix} 1 & 0.9 & 0.9 & 0.4 \\ 1 & 1 & 1 & 0.5 \\ 1 & 0.9 & 1 & 0.5 \\ 1 & 0.9 & 1 & 1 \end{bmatrix}. \quad \textbf{(29)}$$

In Phase 2, the DM can verify that all the preferences of all experts are with an acceptable degree of incomparability. Table 1 shows the index of consensus calculated for each criterion in Phase 2. It is worth noting that the degree of consensus is high only for c_3.

In Phase 3, the DM assigned weights to the experts, as it is shown in Table 2.

Table 3 shows the weights to be assigned to each fuzzy preference relation, which are calculated in Phase 4 by means of (25).

In Phase 5, the fuzzy preference relations which are representative of the collective preferences are as follows (Parreiras and Ekel, 2011):

$$R_{1,C}=\begin{bmatrix}1 & 1 & 1 & 0.85\\ 0.35 & 1 & 1 & 0.42\\ 0.35 & 0.94 & 1 & 0.42\\ 0.79 & 0.94 & 0.94 & 1\end{bmatrix},\ R_{2,C}=\begin{bmatrix}1 & 0.65 & 0.76 & 0.77\\ 1 & 1 & 0.88 & 1\\ 0.24 & 0.24 & 1 & 0.54\\ 0.45 & 0.45 & 0.76 & 1\end{bmatrix},$$
$$R_{3,C}=\begin{bmatrix}1 & 0.69 & 0.69 & 0.85\\ 1 & 1 & 0.94 & 0.69\\ 1 & 0.86 & 1 & 0.60\\ 1 & 0.97 & 1 & 1\end{bmatrix}. \quad (30)$$

Table 1. Index of Consensus for each criterion (Phase 2).

	c_1	c_2	c_3
ICons	0.67	0.57	0.83

Table 2. Weights $\lambda_{p,y}$ assigned by the DM to each expert (Phase 3).

	$e_{p,1}$	$e_{p,2}$	$e_{p,3}$
p=1	0.17	0.33	0.50
p=2	0.17	0.33	0.50
p=3	0.17	0.33	0.50

Table 3. Normalized weights of each fuzzy preference relation (Phase 4).

	$e_{p,1}$	$e_{p,2}$	$e_{p,3}$
p=1	0.48	0.32	0.20
p=2	0.24	0.30	0.46
p=3	0.43	0.29	0.28

In Phase 6, $R_{1,C}, R_{2,C}, R_{3,C}$ are processed separately, by applying the multicriteria decision-making method which is described in Section 4. Table 4 shows the rankings that are obtained for each criterion separately, as well as the results of applying expressions (13)-(16). According to the data shown in Table 4, the results of the multicriteria analysis are as follows:

- pessimistic attitude: $(x_2 \approx x_4) \succ (x_1 \approx x_3)$;
- optimistic attitude: $(x_1 \approx x_2 \approx x_4) \succ x_3$;
- Hurwicz attitude (with $\alpha = 0.5$): $(x_2 \approx x_4) \succ x_1 \succ x_3$;
- Normative attitude: $x_2 \succ x_4 \succ x_1 \succ x_3$.

These results allow the DM to affirm that, among the elements belonging to X, x_2 is one of the most attractive rental properties and x_3 is one of the least attractive rental properties, when criteria c_1, c_2 and c_3 are considered. In this way, the rental value of x_2 may be the highest one; whereas the rental value of x_3 may be the lowest one; the rental value of x_4 may be calculated as a linear combination of the rental values of x_1 and x_2. The rental value of x_3 may be lower than the rental value of x_4.

Table 4. Normalized weights of each fuzzy preference relation (Phase 4).

	$O_1(x_k)$	$O_2(x_k)$	$O_3(x_k)$	$\max\limits_{1\le p\le q} O_p(x_k)$	$\min\limits_{1\le p\le q} O_p(x_k)$	$0.5\max\limits_{p=1,\dots,q} O_p(x_k)+0.5\min\limits_{p=1,\dots,q} O_p(x_k)$	$\sum\limits_{p=1}^{q}\frac{O_p(x_k)}{q}$
x_1	1	2	4	4	1	2.5	1.75
x_2	3	1	2	3	1	2	1.50
x_3	4	4	3	4	3	3.5	2.75
x_4	2	3	1	3	1	2	1.50

7 Conclusions

In real-world situations, it is usual to invite different experts or different groups of experts to analyze the problem from the perspective of each criterion. In this paper, we proposed a methodology for multiperson multicriteria decision-making in a group environment with hierarchical structure. This methodology offers to the DM an index of consensus, which reflects the level of general agreement in the group of experts; an index of discordance, which allows to identify the most discordant opinions in the group; an index of comparability which allows to identify the unreliable judgments; a computational component which calculates weights to be assigned to the preferences of each expert. The methodology also presents guidelines to be followed by the experts to express their judgments of preferences and incomparability.
The DM must interfere in the decision process in two ways: by assigning an importance weight to each expert, which must be coherent with the degree of knowledge and experience of each expert; by selecting an approach to reflect his decision attitude. In the Section 6, an application example shows that it is also possible to derive recommendations for the decision problem, by considering different decision attitudes simultaneously.

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References

Alsina, C. (1985), On a family of connectives for fuzzy sets. *Fuzzy Sets and Systems*, 16, 231-235.

De Baets P., Fodor J.C. (1997), Twenty years of fuzzy preference structures. *Rivista di Matematica per le Scienze Economiche e Sociali*, 20, 45-66.

Fodor, J.C., Roubens, M. (1994), Valued preference structures. *European Journal of Operational Research*, 79, 277-286.

Gomes, L.F.A.M., Rangel, L.A.D. (2009), An application of the TODIM method to the multicriteria rental evaluation of residential properties. European Journal of Operational Research, 193, 204-211.

Herrera-Viedma E., Herrera F., Chiclana F. (2002), A consensus model for multiperson decision making with different preference structures. *IEEE Transactions on Systems, Man and Cybernetics – Part A: Systems and Humans*, 32, 394-402

Herrera-Viedma, E., Herrera, F., Chiclana, F., Luque, M. (2004), Some issues on consistency of fuzzy preference relations. *European Journal of Operational Research*, 154, 98-109.

Hsu, H.M., Chen, C.T. (1996), Aggregation of fuzzy opinions under group decision making. *Fuzzy Sets and Systems*, 79, 279-285.

Kulshreshtha, P., Shekar, B. (2000), Interrelations among fuzzy preference-based choice functions and significance of rationality conditions: A taxonomic and intuitive perspective, *Fuzzy Sets and Systems*, 109, 425-429.

Orlovsky, S.A. (1978), Decision-making with a fuzzy preference relation. *Fuzzy Sets and Systems*, 1, 155-167.

Parreiras, R.O., Ekel, P. Ya., Morais, D.C. (2012), Fuzzy Set Based Consensus Schemes for Multicriteria Group Decision making Applied to Strategic Planning. *Group Decision and Negotiation*, 21, 153-183.

Parreiras, R., Ekel, P., (2011) Procedures for group multicriteria decision making using fuzzy preference relation modeling (in Portuguese). In: Proceedings of the Red Iberoamericana de Evaluación y Decisión Multicriterio, Recife, (in press).

Pedrycz, W., Ekel, P., Parreiras, R. (2011), *Fuzzy Multicriteria Decision-Making: Models, Methods, and Applications*. Wiley, Chichester.

Peneva, V.,Popchev, I. (2003), Properties of The Aggregation Operators Related with Fuzzy Relations. *Fuzzy Sets and Systems*, 139, 615– 633.

Sengupta, K. (1998), Fuzzy preference and Orlovsky choice procedure. *Fuzzy Sets and Systems*, 93, 231-234.

Yager, R.R. (1995), An approach to ordinal decision making. *International Journal of Approximate Reasoning*, 12, 237-261.

Synergetic use of consensus methods coupled with fuzzy set based multiperson multicriteria decision-making methods

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Abstract: In this paper, we propose two manners of making a synergetic use of Consensus Methods (namely, Nominal Group Technique and Delphi Technique), combined with fuzzy set based multiperson multicriteria decision-making methods, to support group processes. In our proposal, different indexes, namely the discordance index, the consensus index, and the comparability index can be utilized by a moderator to regulate the interactions among the experts in an efficient way. Besides, our proposal allows some functions which are usually delegated to a human moderator to be executed by means of computational components. The applicability of our proposal is demonstrated through decisions situations associated with strategic planning in the organizations.

Keywords: Nominal Group Technique, Delphi Technique, Consensus methods, Multiperson multicriteria decision-making methods, Fuzzy preference relation.

1 Introduction

Usually, the decision-making processes in organizations involve multiple experts, who are invited to work cooperatively and contribute with their own knowledge, skills and intuition to construct a collective decision. A difficulty inherent to those processes is associated with the confrontation between experts who vary substantially in perceptions and reasoning, and have access to different information sources. Such type of situations can be handled more efficiently with the use of Consensus Methods (Wortman, 2001). In the literature, it is increasingly recognized that the application of Consensus Methods combined with the multiperson multicriteria decision-making methods (MPMCDM) can support group decision-making processes (Pedrycz et al., 2010), (Lu et al., 2007). In particular, consensus methods can aid the experts to deal with certain aspects inherent to complex decisions, such as (Armacost et al., 1999): the decision problem structuring, which involves criteria and solutions creation; preference elicitation subjected to lack of information and in presence of uncertainties; prioritization of items (for instance, innovative ideas or possible solutions for a complex decision situation).

Among the methods being utilized to support the consensus development (Bourrée et al., 2008), two of them have received great attention from researchers and practitioners: the Nominal Group Technique (NGT) and the Delphi Technique (DT). In this paper, we show how NGT and DT, combined with fuzzy set based MPMCDMs can be utilized to support group decision-making processes. We can find in the literature previous efforts where DT or NGT are associated with multicriteria decision-making methods. For instances, one can refer to (Ishikawa et al., 1993), (A1-Shemmeri et al., 1997), (Armacost et al., 1999); (Chang et al., 2011). Among the advantages of the approach being proposed, we can name:

• the input of information is considered more flexible, since different preference formats (fuzzy estimates, fuzzy preference relations, ordering of the alternatives, utility functions, multiplicative preference relations) can be offered to the experts to express their judgments;

• in this approach, different types of aggregation operators are available to combine the individual preferences into collective preferences;

• in this approach, different types of operators can be applied to aggregate the preferences associated with the different criteria and thereby construct the global preferences;

• it offers different types of indexes which supports a moderator in regulating the group processes;

• it offers instruments for portraying uncertain and doubtful preference judgments in the context of individual, as well as of group decision-making.

The text is organized as follows: Section 2 presents a review of the theory on methods of multiperson multicriteria analysis based on fuzzy preference relations (that is, methods based on the construction and analysis of <*X*, *R*> models in a group environment (Pedrycz et al., 2010), which serves as a theoretic background for our proposal. In Section 3, an approach for applying NGT combined with fuzzy set based MPMCDM is introduced. Section 4 presents an approach in which DT is combined with fuzzy set MPMCDM. Finally, in Section 5, we draw our conclusions.

2 Fuzzy models and methods for group decision making

Assume that a group of experts must evaluate, compare, and/or prioritize a finite and discrete set of items $X=\{x_1, x_2, \ldots, x_n\}$ (which may be innovative ideas, strategic plans, disease treatments, feasible solutions for complex problems, etc.), under the consideration of different criteria $F_1, F_2, \ldots, F_q$. In a fuzzy environment, this situation usually can be structured as a decision-making problem (Pedrycz et al., 2010) modeled as a pair $<X, R>$, where $R=\{R_1, R_2, \ldots, R_q\}$ is a set of fuzzy nonstrict preference relations (Orlovsky, 1978).

A fuzzy nonstrict preference relation R_p is a fuzzy set with bi-dimensional membership function (a binary fuzzy relation) $R_p(x_k, x_l): X \times X \to [0,1]$. Such relation associates with each ordered pair of elements (x_k,x_l) a number $R_p(x_k,x_l)$ coming from the unit interval that reflects a degree to which x_k weakly dominates (or is at least as good as) x_l, when the criterion F_p is considered. Next, we describe how fuzzy preference relations can be constructed and how a ranking of the elements belonging to a set X can be obtained through the analysis of $<X, R>$ models.

2.1 On the construction of fuzzy nonstrict preference relations

When we consider the use of a fuzzy nonstrict preference relation to represent the preferences of experts, the entries of each pairwise comparison matrix R_p may be directly or indirectly defined by each expert. In the direct way, an expert must select the values in the unit interval that reflect the level of credibility or just the strength of his nonstrict preference for one possible solution over the other. The encoding scheme considered here is reflected by a nonreciprocal fuzzy preference relation (NRFPR), which verifies the conditions summarized in Table 1 (Pedrycz et al., 2011). When both $R_p(x_k, x_l)$ and $R_p(x_l, x_k)$ are not equal to 1 and $R_p(x_k, x_l) > R_p(x_l, x_k)$, it is said that x_k is weakly preferred to x_l and to a degree incomparable to x_l. Similarly, when both $R_p(x_k, x_l)$ and $R_p(x_l, x_k)$ are not equal to 1 and $R_p(x_k, x_l) < R_p(x_l, x_k)$, it is said that x_l is weakly preferred to x_k and to a degree incomparable to x_k.

Table 1. Encoding scheme reflected by a nonreciprocal fuzzy preference relation.

$R_p(x_k, x_l)$	$R_p(x_l, x_k)$	
0	0	x_k and x_l are incomparable
0	1	x_l is strictly preferred to x_k
1	0	x_k is strictly preferred to x_l
1	1	x_k and x_l are indifferent

In an indirect way of constructing a NRFPR, transformation functions are utilized to build the fuzzy preference relations coherently with the preferences of an expert, which can be expressed in different preference formats (Herrera-Viedma et al., 2002), (Pedrycz et al.,2010).

With reference to the consistency of the NRFPR, it is necessary to indicate that the minimum requirement that should be satisfied by preference judgments are given by the weak transitivity condition (Herrera-Viedma et al., 2004), which can be stated as: if $R_p(x_k, x_j) > R_p(x_j, x_k)$ and $R_p(x_j, x_l) > R_p(x_l, x_j)$, then $R_p(x_k, x_l) > R_p(x_l, x_k)$, for all $x_k, x_j, x_l \in X$. It implies that if someone says that x_k is preferred to x_j and that x_j is preferred to x_l, then x_k is preferred to x_l, without considering the strength of the preferences.

2.2 On the processing of fuzzy nonstrict preference relations

As it was indicated above, in the comparison between two possible solutions, three main types of judgments can be distinguished, namely indifference, strict preference, and incomparability. These judgments can be modeled by means of three specific binary fuzzy relations (BFR), in such a way that the membership function of each BFR quantifies in the interval [0,1], the intensity of the observed judgment. They are: the fuzzy indifference relation I_p, the fuzzy strict preference relation P_p and the fuzzy incomparability relation J_p. As it is discussed in (Fodor and Roubens, 1994) or in (Llamazares, 2003), given a fuzzy preference relation R_p, those three relations can be obtained as given by the following expressions:

$$I_p(x_k, x_l) = \min\{R_p(x_k, x_l), R_p(x_l, x_k)\} \ , \quad \textbf{(1)}$$

$$P_p(x_k, x_l) = \max\{R_p(x_k, x_l) - R_p(x_l, x_k), 0\} \ , \quad \textbf{(2)}$$

$$J_p(x_k, x_l) = \min\{1 - R_p(x_k, x_l), 1 - R_p(x_l, x_k)\} \ . \quad \textbf{(3)}$$

2.3 On indexes of discordance, consensus and comparability

Let us consider that a group of experts $E=\{e_1,e_2,\ldots,e_v\}$ participates in a decision-making process based on constructing and processing the $<X, R>$ models. In this situation, it is possible to estimate the level of discordance between the preferences of the yth expert and the zth expert in the range [0, 1], with the use of the following two formulas:

$$D_{y,z}(x_k, x_l) = \frac{1}{2}\left(|I_{p,y}(x_k, x_l) - I_{p,z}(x_k, x_l)| + \frac{1}{2}\Big(|P_{p,y}(x_k, x_l) - P_{p,z}(x_k, x_l)| + |P_{p,y}(x_l, x_k) - P_{p,z}(x_l, x_k)| \Big) \right) \ , \quad \textbf{(4)}$$

$$IDisc(e_y, e_z) = \frac{2}{n(n-1)} \sum_{k=1}^{n} \sum_{l=k+1}^{n} D_{y,z}(x_k, x_l) \ . \quad \textbf{(5)}$$

In the expression (4), the fuzzy incomparability relation is not counted because it does not reflect the strength of preferences of an expert (it reflects the credibility degree of the judgments provided by each expert). Expression (5) takes advantage of the symmetry of $D_{y,z}$ and does not count the contribution of those entries of $D_{y,z}$ which located above the diagonal.

The degree of consensus within the group, being defined in the range [0, 1], can be calculated as follows:

$$ICons = 1 - \frac{2}{v(v-1)} \sum_{y=1}^{v} \sum_{z=y+1}^{v} IDisc(e_y, e_z) \ . \quad \textbf{(6)}$$

If the experts are allowed to make judgments with hesitation (that is, a non-null level of incomparability), it is useful to provide the moderator with an index which reflects the credibility of the judgments provided by each expert. An index of comparability, which can be taken as an index of credibility, can be defined as the complement of a fuzzy incomparability relation J_p, which results in the following expression:

$$\overline{J_{p,y}(x_k, x_l)} = 1 - J_{p,y}(x_k, x_l) = \max\{R_{p,y}(x_k, x_l), R_{p,y}(x_l, x_k)\} \ . \quad \textbf{(7)}$$

A global index of comparability, under a pessimistic approach which emphasizes the existence of judgments expressed with large hesitation, can be defined as follows:

$$IComp(x_k, x_l) = \min\{\overline{J_{p,1}(x_k, x_l)}, \overline{J_{p,2}(x_k, x_l)}, \ldots, \overline{J_{p,v}(x_k, x_l)}\} \ . \quad \textbf{(8)}$$

2.4 On the multicriteria analysis based on <*X*, *R*> models

Literature presents several procedures which can be utilized to solve decision-making problems based on the analysis of <*X*, *R*> models (Pedrycz et al., 2010). Among them, we consider in this work a technique based on applying the Orlovsky choice procedure (Orlovsky, 1978), which carries out the choice of alternatives based on the concept of fuzzy non-dominated solutions.
According to the Orlovsky choice procedure, as $P_p(x_l, x_k)$, for k=1,2,…,n and $k \neq l$, describes the set of all solutions x_k that are strictly dominated by x_l, its compliment $\overline{P_p(x_l, x_k)}$, for k=1,2,…,n and $k \neq l$, corresponds to the set of solutions that are not dominated by other solutions from X. Therefore, in order to meet the fuzzy set of non-dominated solutions, it suffices to obtain the intersection of all $\overline{P_p(x_l, x_k)}$, which is given by

$$ND_p(x_k) = \inf_{X_l \in X} \{1 - P_p(x_l, x_k)\} = 1 - \sup_{X_l \in X} P_p(x_l, x_k) \ . \qquad \textbf{(9)}$$

A natural choice for a monocriteria problem based on this model should be the alternatives providing (Orlovsky, 1978):

$$X_{R_p}^{ND} = \left\{ x_k^{ND} \in X \mid R_p^{ND}(x_k^{ND}) = \sup_{x_k \in X} ND_p(x_k) \right\} \ . \qquad \textbf{(10)}$$

A ranking of the possible solutions can be obtained by executing the following procedure: (2), (9) and (10) must be applied to R_p. The non-dominated solutions given by (10) are ranked first. Therefore ,they must be excluded from a subsequent analysis, where (2), (9) and (10) are applied to the corresponding submatrix of R_p. These steps are executed as many times as it is necessary to obtain a complete ranking of the possible solutions.

The Orlovsky choice procedure may be used to solve choice or ranking problems not only with a single criterion, but also with multiple criteria (Pedrycz et al., 2010). Having at hand the fuzzy preference relation for each criterion, one possible procedure for including all of them in the analysis of decision-making problems consists in obtaining a global relation through the intersection of those relations as follows:

$$G = R_1 \cap R_2 \cap ... \cap R_q \ . \qquad \textbf{(11)}$$

The use of intersection to aggregate all criteria is suitable, when it is a necessary condition that a good solution x_k must simultaneously satisfy F_1 and F_2 and ... and F_q. Among the *t*-norm operators, the use of the min operator, as proposed in (Orlovsky, 1981), allows one to construct the global fuzzy nonstrict preference relation

$$G(x_k, x_l) = \min\{R_1(x_k, x_l), R_2(x_k, x_l), ..., R_q(x_k, x_l)\}, \qquad \textbf{(12)}$$

under a completely non-compensatory approach for multicriteria decision-making, in the sense that the high satisfaction of some criteria does not relieve the remaining ones from the requirement of being satisfied (there is no compensation among the criteria). Such approach is also considered pessimistic, since it gives emphasis to the worst evaluations of each possible solution.
On the other hand, the use of the union operation is also admissible, when it is necessary to verify at which level the organization satisfies at least one criterion, which can be associated with F_1 or F_2 or … or F_q. The use of max operator to implement the union operation allows one to construct a multidimensional performance indicator

$$G(x_k, x_l) = \max\{R_1(x_k, x_l), R_2(x_k, x_l), ..., R_q(x_k, x_l)\}, \qquad \textbf{(13)}$$

under an extremely compensatory approach, in the sense that the high level of satisfaction of any criterion is sufficient.
Finally, it can be useful to apply OWA (Grabisch et al., 1998), which can produce results that is more compensatory than min or that is less compensatory than max, under a proper adjustment of its weights. An OWA operator of dimension q corresponds to a mapping function $[0,1]^q \to [0,1]$. Here it is utilized to aggregate a set of q normalized values $\mu_{ND_1}(X_0^1), ..., \mu_{ND_m}(X_0^m)$, in such a way that

$$G(x_k, x_l) = \sum_{p=1}^{q} w_p b_p \, , \tag{14}$$

where b_p is the pth largest value among $R_1(x_k,x_l)$, $R_2(x_k,x_l)$,…, $R_q(x_k,x_l)$ and the weights w_1, w_2,…, w_q satisfy the conditions w_1+ w_2+…+ w_q=1 and $0 \le w_p \le 1$, p=1,2,…,q. The major attractive aspect of using OWA is associated with the fact that it allows to indirectly specify the weights by using linguistic quantifiers. Here, OWA is utilized with the linguistic quantifier “majority” to indicate at which level the organization satisfies most of the goals (Yager 1995).

2.5 On the construction of <*X*, *R*> models in a group environment

In this work, an approach for multiperson multicriteria decision-making which is named Aggregation of Individual Preferences per Criterion (AIC) (Pedrycz et al. 2010) serves as a background for the development of two methodologies for applying NGT and DT, being each of them combined with a fuzzy set based MPMCDM.

The AIC guidelines can be summarized as follows (Parreiras et al., 2012):

• **Step 1**: given a pth criterion, the experts provide their preferences by assessing directly or indirectly the fuzzy preference relation.

• **Step 2**: the fuzzy preference relations constructed by each expert are aggregated into collective preferences per criterion. Step 1 and Step 2 must be repeated q times for the consideration of all criteria.

• **Step 3**: After the construction of a <*X*, *R*> model for the group (which means that Step 1 and Step 2 were repeated q times), a method for multicriteria analysis of <*X*, *R*> models is applied to solve the problem and derive a ranking of the alternatives.

In AIC, the operation allowing one to generate collective information is performed over the fuzzy preference relations per criterion (before the aggregation across all criteria is performed). Hence, given the p^{th} criterion, the operation of aggregation makes use of a function that maps the fuzzy nonstrict preference relations $R_{p,1}, R_{p,2}, ..., R_{p,v}$, to another fuzzy nonstrict preference relation $R_{p,C}$. When the weighted arithmetic mean (WAM) is utilized, we have:

$$R_{p,C}(x_k, x_l) = \sum_{y=1}^{v} w_y R_{p,y}(x_k, x_l) \, , \tag{15}$$

where $x_k, x_l \in X$, $0 \le w_y \le 1$, y=1,2,…,v, and $\sum_{y=1}^{v} w_y = 1$.

Other aggregation operators can be utilized to construct the collective preferences. In addition to WAM, the most commonly utilized are (Pedrycz et al., 20120):

• weighted geometric mean:

$$R_{p,C}(x_k, x_l) = \prod_{y=1}^{v} R_{p,y}(x_k, x_l)^{w_y} \, , \tag{16}$$

where $x_k, x_l \in X$, $0 \le w_y \le 1$, y=1,2,…,v, and $\sum_{y=1}^{v} w_y = 1$;

• min:

$$R_{p,C}(x_k, x_l) = \min\{R_{p,1}(x_k, x_l), R_{p,2}(x_k, x_l), ..., R_{p,v}(x_k, x_l)\} \, , \tag{17}$$

and

• OWA:

$$R_{p,C}(x_k, x_l) = \sum_{y=1}^{v} w_y a_y \, , \tag{18}$$

where a_y is the yth largest value among $R_{p,1}(x_k,x_l)$, $R_{p,2}(x_k,x_l)$,…, $R_{p,v}(x_k,x_l)$ and the weights w_1, w_2,…, w_v satisfy the conditions w_1+ w_2+…+ w_v=1 and $0 \le w_y \le 1$, y=1,2,…,v.

As it is discussed in (Pedrycz et al. 2010), an important factor that should be considered in the choice of an operator corresponds to the set of requirements imposed by the group, taking into account the expectations of each expert. For instance, if the group agrees that the content of the opinion is more important than its author, it may be more helpful to utilize the operator of minimum or else the operator OWA. Conversely, if certain experts need to be privileged rather than certain opinions, then it is interesting to utilize WAM or WGM. It also should be taken into account that whereas OWA may have or not a compensatory behavior, depending on the fuzzy linguistic quantifier selected, WAM and WGM always have a compensatory character. The minimum operator, on the other side, always has a non-compensatory behavior. Particularly, its use is helpful when the group agrees that the collective decision should be pessimistic in the sense that, an alternative which was badly evaluated by any expert should be badly evaluated by the group in a non-compensatory way. Finally, another helpful property of OWA lies in the fact that it can be utilized for considering only part of the opinions, by the proper setting of the linguistic operator. When the opinions of experts are very discordant, if we aggregate all of them by means of an averaging operator, the result may be an intermediate one, which does not satisfy any expert in the group. On the other hand, if we consider, for instance, "most" opinions rather than "all" opinions, this undesired outcome can be avoided.

3 Nominal Group Technique

NGT has been mainly utilized for structuring the process of idea generation and prioritization by a group of experts (Delbecq et al., 1975). Feedback mechanisms are implemented for information and clarification of the ideas presented by the other experts. A collective opinion is typically reached by a voting mechanism. NGT requires the execution of the following main steps:

• **Step 1**: the question statement is enunciated in the panel and the experts are called to generate as many ideas as possible in writing individually and silently;

• **Step 2**: generated ideas are written by the moderator on a board and become the property of the group. Each time an expert is invited to communicate to the moderator a response he had written on the paper. There are as many rounds as necessary to collect all different responses;

• **Step 3**: the ideas are discussed and clarified to make sure all experts assign the same meaning to the items written on the board;

• **Step 4**: experts rank the generated ideas;

• **Step 5**: the moderator compiles the results.

In the context of group decision-making, NGT can be utilized to aid the experts in defining a set of criteria adequate to evaluate the possible solutions belonging to X. In such cases, the question statement enunciated in Step 1 can be "how can one evaluate the level at which each feasible solution satisfies (or helps to achieve) the objectives behind the current decision situation?" and the output of the process is the ranking of criteria, which is a relevant information for performing a multicriteria analysis.

Besides, it is necessary to indicate that, in certain applications, such as in strategic planning or in the development of treatments for diseases, the experts are usually invited to create the possible solutions for the decision-making problem. In these situations, the question statement enunciated in Step 1 can be "how can is it possible to achieve the objectives that we desire to achieve in this decision situation?" and the output of the process is a list of possible solutions for a decision situation.

In the modified version of NGT being proposed, Step 1, Step 2 and Step 3 should be executed as in the version of NGT described above. A Step 6 (which is presented below) is included in the process and Step 4 and Step 5 are modified as follows:

• **Step 4**: each expert compares the generated ideas by directly assessing a NRFPR. When an expert can not compare two items, he can assign a non-null value of incomparability to his judgment. The experts are forbidden to construct NRFPRs that does not satisfy weak transitivity.

• **Step 5**: *IComp* is computed and if *IComp* is not completely filled with zeros, the process moves back to Step 3. Step 3 and Step 4 are repeated as many times as necessary, until *IComp* becomes completely filled with zeros. In this case, the process moves to Step 6;

• **Step 6**: the moderator compile the results. In order to derive a ranking of the generated ideas according to their respective relevance by executing the decision-making method based on the Orlovsky choice procedure to an aggregated or collective fuzzy preference relation. Obviousy, to assure the validity of the ranking, before applying a decision-making method, the moderator must make sure that the collective fuzzy preference relation satisfies weak transitivity.

Example: Let us consider that a board of directors $E=\{e_1,e_2,\ldots,e_5\}$ of an organization are participating in a process based on NGT. In Step 2, each of them proposes a strategic course of action to be executed in the following five years. In Step 3, as the group considers the proposal of e_3 as being identical to the proposal of e_1, the set of items to be considered by the group in Step 4 is $X=\{x_1,x_2,\ldots,x_4\}$.

When Step 4 is executed, the following fuzzy preference relations are constructed by the directors:

$$R_{1,1}=\begin{bmatrix}1&1&1&1\\0&1&1&0\\0&1&1&0\\1&0.6&0.7&1\end{bmatrix},\ R_{1,2}=\begin{bmatrix}1&0&0&1\\1&1&1&1\\1&1&1&1\\1&0&0&1\end{bmatrix},\ R_{1,3}=\begin{bmatrix}1&1&1&1\\0&1&1&0\\0&1&1&0\\1&0.7&0.7&1\end{bmatrix},\ R_{1,4}=\begin{bmatrix}1&1&1&1\\0&1&1&0\\0&1&1&0\\0&1&1&1\end{bmatrix},\ R_{1,5}=\begin{bmatrix}1&1&1&1\\0&1&1&0\\0&1&1&0\\1&1&0.6&1\end{bmatrix}. \quad \mathbf{(19)}$$

In Step 5, expression (3) provides the following fuzzy incomparability relations:

$$J_{1,1}=\begin{bmatrix}0&0&0&0\\0&0&0&0.4\\0&0&0&0.3\\0&0.4&0.3&0\end{bmatrix},\ J_{1,2}=\begin{bmatrix}0&0&0&0\\0&0&0&0\\0&0&0&0\\0&0&0&0\end{bmatrix},\ J_{1,3}=\begin{bmatrix}0&0&0&0\\0&0&0&0.3\\0&0&0&0.3\\0&0.3&0.3&0\end{bmatrix},\ J_{1,4}=\begin{bmatrix}0&0&0&0\\0&0&0&0\\0&0&0&0\\0&0&0&0\end{bmatrix},\ J_{1,5}=\begin{bmatrix}0&0&0&0\\0&0&0&0\\0&0&0&0.4\\0&0&0.4&0\end{bmatrix}. \quad \mathbf{(20)}$$

The global index of comparability is as follows:

$$IComp=\begin{bmatrix}0&0&0&0\\0&0&0&0.7\\0&0&0&0.6\\0&0.7&0.6&0\end{bmatrix}. \quad \mathbf{(21)}$$

In Step 5, as *IComp* is non-null for the pairs of alternatives (x_2,x_4) and (x_3, x_4), the moderator decides to invite the experts to repeat Step 3 and Step 4. By analyzing the fuzzy incomparability relations in (20), the moderator notes that possibly e_2, e_4 or e_5 are able to help e_1 and e_3 to improve their judgments, by clarifying to them the differences between alternatives x_2 and x_4. Besides, e_2 and e_4 can be invited to aid e_1, e_3 and e_5 in judging alternatives (x_3, x_4). In this way, the moderator can conduct the process associated with Step 3 in a more objective way.

Let us consider that, with the execution of Step 3 and Step 4 for the second time, e_1, e_3 and e_5 arrived at the new judgments reflected by the following NRFPRs:

$$R_{1,1}=\begin{bmatrix}1&1&1&1\\0&1&1&1\\0&1&1&1\\1&0.5&0.5&1\end{bmatrix},\ R_{1,3}=\begin{bmatrix}1&1&1&1\\0&1&1&0.8\\0&1&1&0.8\\1&1&1&1\end{bmatrix},\ R_{1,5}=\begin{bmatrix}1&1&1&1\\0&1&1&0\\0&1&1&0.8\\1&1&1&1\end{bmatrix}. \quad \mathbf{(22)}$$

In Step 5, it is possible to verify that the fuzzy incomparability relations associated with (22) are null for all pairwise comparisons. Thus, the process moves to Step 6. The aggregation of the individual preferences by means of average mean operator results in

$$R_{1,1} = \begin{bmatrix} 1 & 0.8 & 0.8 & 1 \\ 0.2 & 1 & 1 & 0.4 \\ 0.2 & 1 & 1 & 0.48 \\ 0.8 & 0.8 & 0.8 & 1 \end{bmatrix} . \quad \textbf{(23)}$$

The compilation of the results provides the following ranking of strategic courses of action:

$$x_1 \succ x_4 \succ (x_2 \approx x_3) \ . \quad \textbf{(24)}$$

It is necessary to indicate that an output of a NGT process can aid a group to arrive at conclusions such as: if the list of generated ideas is large and should be reduced, the group can select the ideas to be eliminated by identifying the ones with the lowest priority degrees; if it is possible to give an opportunity to the experts to improve their ideas, it is possible to identify the least attractive ideas. For instance, the results reflected by (24) suggests that x_2 or x_3 can be eliminated; or that x_2 or x_3 should be improved; or that the group may consider whether x_2 or x_3 can be combined into a unique new idea because they possibly have some properties in common.

4 Delphi technique

The DT is a structured group process, whose objective is usually to synthesize knowledge based on the input of multiple experts acting as anonymous respondents in a group dynamic (Linstone and Turoff, 1975). In the beginning of a Delphi panel, usually a questionnaire is designed and sent by a moderator to the experts. The individual answers are returned to the moderator. Based upon the answers, a new questionnaire is sent for the experts, who have at least one opportunity to examine the group response and reevaluate their original answers. A collective opinion/knowledge, obtained by aggregating individual opinions, is taken as the process output. Consensus is not enforced (indeed, discordances are acceptable), but is a signal to cease information polling. Taking all those into account, DT can be described in a generalized manner as follows (here we omit those Steps that are associated with organizing the panel, that is, the selection and invitation of experts, the preparation of questionnaires, etc.):
• **Step 1**: a questionnaire with a list of items is distributed to the experts;
• **Step 2**: the experts evaluate each item of the list;
• **Step 3**: disagreements are identified by a moderator, who seeds a new questionnaire to the experts, aiming to bring out the underlying reasons for the differences between the evaluations provided by each expert. Steps 2 and 3 can be repeated as many times as it is necessary to construct a general agreement in the group (unanimous preferences are desirable but are considered a utopia);
• **Step 4**: a final evaluation occurs when all previously gathered information can be aggregated in a collective evaluation in a reasonable manner.

In the modified version of DT being proposed, Step 1 and Step 4 should be executed as in the version of DT described above. Step 2 and Step 3 are modified as follows:

• **Step 2**: the experts evaluate the items of the list and construct a fuzzy preference relation (in a direct way or in an indirect way). In the current Step, when an expert cannot evaluate or compare two items, he can assign a degree of incomparability to his judgment. An incomparability judgment should be taken by the moderator as a judgment with hesitation. Hesitation may be caused by missing information or conflicting information about the items being analyzed (Fodor and Roubens, 1994). The experts must construct NRFPRs that satisfy weak-transitivity.
• **Step 3**: disagreements are identified by a moderator by means of the index of discordance. A new questionnaire is seed to the experts, aiming to bring out the underlying reasons for the differences between the evaluations provided by each expert and for the judgments with non-null levels of

incomparability. Steps 2 and 3 can be repeated as many times as it is necessary to reduce the hesitation judgments in the group and to construct a general agreement in the group.

Example: A board of directors $E=\{e_1,e_2,\dots,e_5\}$ participating in a process based on DT have to prioritize three strategic courses of actions $X=\{x_1,x_2,x_3\}$. The panel is to be divided in four sessions. Each session is devoted to the consideration of a perspective among the four perspectives suggested by the Balanced Scorecard Methodology (Kaplan and Norton, 1996): F_1) financial perspective, F_2) the customer satisfaction, F_3) internal business process perspective, F_4) learning and growth perspective. Let us consider the session associated to F_2 (customer satisfaction).

In Step 1, the experts receive a questionnaire in which they are invited to evaluate the four courses of action. When Step 2 is executed, the following fuzzy preference relations are constructed by the directors (all of them satisfy weak transitivity):

$$R_{2,1}=\begin{bmatrix}1&1&1&1\\0&1&1&1\\0&0&1&1\\0&0&0&1\end{bmatrix},\ R_{2,2}=\begin{bmatrix}1&1&1&1\\1&1&1&1\\0&0&1&0.5\\0&0&0&1\end{bmatrix},\ R_{2,3}=\begin{bmatrix}1&1&1&1\\0&1&1&1\\0&0&1&1\\0&0&0&1\end{bmatrix},\ R_{2,4}=\begin{bmatrix}1&1&1&1\\0.5&1&1&1\\0.5&0.5&1&1\\0&0&0&1\end{bmatrix},$$
$$R_{2,5}=\begin{bmatrix}1&1&1&0.5\\1&1&1&1\\0&0&1&1\\0&0&0&1\end{bmatrix}. \quad \textbf{(25)}$$

In Step 3, the moderator, being aided by a computational system can obtain the incomparability fuzzy relations for each director as follows:

$$J_{2,1}=\begin{bmatrix}0&0&0&0\\0&0&0&0\\0&0&0&0\\0&0&0&0\end{bmatrix},\ J_{2,2}=\begin{bmatrix}0&0&0&0\\0&0&0&0\\0&0&0&0.5\\0&0&0.5&0\end{bmatrix},\ J_{2,3}=\begin{bmatrix}0&0&0&0\\0&0&0&0\\0&0&0&0\\0&0&0&0\end{bmatrix},\ J_{2,4}=\begin{bmatrix}0&0&0&0\\0&0&0&0\\0&0&0&0\\0&0&0&0\end{bmatrix},$$
$$J_{2,5}=\begin{bmatrix}0&0&0&0.5\\0&0&0&0\\0&0&0&0\\0.5&0&0&0\end{bmatrix}. \quad \textbf{(26)}$$

As it can be seen, e_2 could not compare x_3 and x_4 and e_5 could not compare x_1 and x_4. As the other experts compared all solutions, possibly they can provide useful information to e_2 and e_5.
Besides, the discordances among the obtained answers can be calculated with the use of (4) and (5). Table 2 shows the discordance degrees between the directors' opinions. As it can be seen, the most discordant preferences are provided by e_4. The consensus level calculated with the use of (6) is *ICons*=0.871, which may be considered satisfactory to cease the process. However, considering that it may be worth to terminate the process only after all preferences are associated with a null level of incomparability, the moderator asked the group to execute Step 2 and Step 3 again.
When Step 2 is executed for the second time, e_2 and e_5 modify their fuzzy preference relations as indicated below:

$$R_{2,2}=\begin{bmatrix}1&1&1&1\\1&1&1&1\\0&0&1&1\\0&0&0.5&1\end{bmatrix},\ R_{2,5}=\begin{bmatrix}1&1&1&1\\1&1&1&1\\0&0&1&1\\0.5&0&0&1\end{bmatrix}. \quad \textbf{(27)}$$

In Step 3, the following fuzzy incomparability relations are obtained for e_2 and e_5:

$$J_{2,2} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix},\ J_{2,5} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}. \tag{28}$$

Table 3 shows the discordance degrees between the directors' opinions. It is worth noting that the discordances in the group have increased a little. For a second time, the most discordant preferences are provided by e_4. As all experts arrive at preferences with a null level of incomparability and the current consensus degree *ICons*=0.838 remains satisfactory (although it is lower than the consensus degree observed in the first round), the moderator decides to conduct the process to Step 4.
Under a pessimistic approach, by applying (17) to the final version of the fuzzy preference relations provided by each director, the most exigent judgments in the group prevail as follows:

$$R_{2,C} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}. \tag{29}$$

Here, we omit the description of the execution of DT for the consideration of the criteria F_1, F_3 and F_4 and assume that, in these cases, the following fuzzy preference relations are constructed to reflect the collective preferences:

$$R_{1,C} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 1 & 0.5 & 0.3 \\ 1 & 1 & 1 & 0.6 \\ 1 & 1 & 1 & 1 \end{bmatrix},\ R_{3,C} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 0.6 & 0.5 & 1 & 1 \\ 0.4 & 0.4 & 0 & 1 \end{bmatrix},\ R_{4,C} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 0 \\ 0.5 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 \end{bmatrix}. \tag{30}$$

The application of (14), with the linguistic term "majority" produces a global fuzzy preference relation which is given by (31). In this case, G_C is reflecting the preferences intrinsic to the majority of the judgments observed across the different criteria:

$$G_C = \begin{bmatrix} 1 & 0.9 & 0.9 & 0.9 \\ 0.4 & 1 & 0.95 & 0.55 \\ 0.49 & 0.65 & 1 & 0.7 \\ 0.6 & 0.6 & 0.4 & 1 \end{bmatrix}. \tag{31}$$

Finally, by applying the multicriteria decision-making method based on the Orlovsky choice procedure, which is described in Section 2, the following ranking of the alternatives is obtained:

$$x_1 \succ x_2 \succ x_3 \succ x_4\ . \tag{32}$$

Table 2. Discordance degrees for the first questionnaire.

	e_1	e_2	e_3	e_4	e_5	*Mean discordance per expert*
e_1	0	0.146	0.125	0.188	0.146	0.151
e_2	0.146	0	0.020	0.208	0.042	0.104
e_3	0.125	0.020	0	0.187	0.021	0.088
e_4	0.188	0.208	0.187	0	0.208	0.198
e_5	0.146	0.042	0.021	0.208	0	0.104

Table 3. Discordance degrees for the second questionnaire.

	e_1	e_2	e_3	e_4	e_5	*Mean discordance per expert*
e_1	0	0.187	0.125	0.188	0.188	0.172
e_2	0.188	0	0.062	0.250	0.125	0.156
e_3	0.125	0.062	0	0.187	0.062	0.109
e_4	0.188	0.250	0.187	0	0.250	0.219
e_5	0.188	0.125	0.062	0.25	0	0.156

5 Conclusions

This paper introduced ways of making a synergetic use of the Nominal Group Technique and of the Delphi Technique, coupled with fuzzy set based multiperson multicriteria decision-making methods. In our proposal, those functions of the consensus methods which are usually delegated to a human moderator can be implemented computationally. Besides, different indexes are offered to help a moderator to regulate the group process. A concordance index is utilized to identify the most discordant expert, who can be invited to review his opinion or to explain his judgment to the other experts. A consensus index can help a moderator to identify an adequate moment to cease the group process. A comparability index allows the moderator to identify the subgroups of experts that have faced difficulties in making their judgments. By promoting an efficient information flow in the group, we expect to improve the process of pooling relevant information and thereby improve the quality of the collective decisions.

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References

A1-Shemmeri, T., A1-Kloub, B., Pearman, A. (1997), Computer aided decision support system for water strategic planning in Jordan. *European Journal of Operational Research*, 102, 455-472.

Armacost, R.L., Hosseini, J.C., Pet-Edwards, J. (1999), Using the Analytic Hierarchy Process as a Two-phase Integrated Decision Approach for Large Nominal Groups. *Group Decision and Negotiation*, 8, 535–555

Bourrée, F, Michel, P., Salmi, L.R. (2008), Consensus methods: review of original methods and their main alternatives used in public health. *Revuew d´Epidémiologie et de Santé Publique*, 56, e13-e21.

Chang, P.L., Hsu, C.W., Chang, P.C. (2011), Fuzzy Delphi method for evaluating hydrogen production Technologies. *International Journal of Hydrogen Energy*, 36, 14172-14179.

Delbecq, A. L., Van de Ven, A. H., and Gustafson, D. H. Group techniques for program planning: A Guide to Nominal Group and Delphi Processes. Scott, Foresman, 1975.

Fodor, J.C., Roubens, M. (1994), Valued preference structures. *European Journal of Operational Research*, 79, 277-286.

Grabisch, M., Orlovski, S.A., Yager, R.R., Fuzzy aggregation of numerical preferences in Fuzzy Sets, in Decision Analysis, Operations Research and Statistics, The Handbook of Fuzzy Sets Series, Vol. 4, Kluwer, Boston, 1998, pp. 31-68

Herrera-Viedma E., Herrera F., Chiclana F. (2002), A consensus model for multiperson decision making with different preference structures. *IEEE Transactions on Systems, Man and Cybernetics – Part A: Systems and Humans*, 32, 394-402

Herrera-Viedma, E., Herrera, F., Chiclana, F., Luque, M. (2004), Some issues on consistency of fuzzy preference relations. *European Journal of Operational Research*, 154, 98-109.

Kaplan R.S., Norton D. (1996), *The Balanced Scorecard: Translating Strategy into Action*. Harvard Business School, Boston.

B. Llamazares (2003), Chatacterization of fuzzy preference structures through Lukasiewicz triplets. *Fuzzy Sets and Systems*, 136, 217-235.

Linstone, H.A., Turoff, M. (1975), *The Delphi Method: Techniques and Applications.* Addison-Wesley, London.

Lu, J., Zhang, G., Ruan, D., Wu, F. (2007), *Multi-objective Group Decision Making: Methods, Software and Applications with Fuzzy Set Techniques*. Imperial College Press, London.

Ishikawa, A., Amagasa, M., Shiga, T., Tomizawa, G., Tatsuta, R., Mieno, H. (1993), The max–min Delphi method and fuzzy Delphi method via fuzzy integration. *Fuzzy Sets and Systems*, 55, 241–253.

Ma, Z., Shao, C., Ma, S., Ye, Z. (2011), Constructing road safety performance indicators using Fuzzy Delphi Method and Grey Delhi Method. *Expert Systems and Applications*, 38, 1509-1514,

Orlovsky, S.A. (1978), Decision-making with a fuzzy preference relation. *Fuzzy Sets and Systems*, 1, 155-167.

Orlovsky, S.A. (1981), *Problems of Decision Making with Fuzzy Information* (in Russian). Nauka, Moscow.

Parreiras, R.O., Ekel, P. Ya., Morais, D.C. (2012), Fuzzy Set Based Consensus Schemes for Multicriteria Group Decision making Applied to Strategic Planning. *Group Decision and Negotiation*, 21, 153-183.

Pedrycz, W., Ekel, P., Parreiras, R. (2011), *Fuzzy Multicriteria Decision-Making: Models, Methods, and Applications*. Wiley, Chichester.

Wortman, P.M. (2011), Consensus Panels: Methodology. *International Encyclopedia of the Social & Behavioral Sciences*, 4, 2609-2613

Yager, R.R. (1995), Multicriteria decision making using fuzzy quantifiers. In: *Proceedings of the IEEE Conference on Computational Intelligence for Financial Engineering 1995*, pp. 42-47. IEEE Press, New York.

Problem structuring

A systematic planning for improvements in a program of urban food harvest, using the new configuration of Soft Systems Methodology.

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Abstract: The problem addressed by this article is to combat malnutrition and reducing food waste through the collection and distribution of food that even in perfect conditions of use will be discarded by low commercial value. The objective of this paper is to present an improvement to the process of urban harvest food. To achieve this goal was an action research carried out by using a configuration of Soft Systems Methodology. This methodology has proved to be able to structure the process of gathering information in a scenario with multiple involved, enabling the systematic planning of actions. This procedure was used in a real case, a single unit of a mixed organization that develops, together with similar units in 350 cities met in Brazil, one of the largest programs of sampling and urban distribution of perishable foods, in our country. To this end, collects food donors, sorts them and then distributes in social institutions. Our expectation is that the results of the application will contribute to the dissemination of the model, helping to reduce hunger, a complex social problem.

Keywords: Problem structuring, Soft Systems Methodology, Urban food harvest.

1 Introduction

The possibility of contributing to improvement of a complex social and real program of urban collection and distribution of food is the main motivation for this work. This improvement focused in minimizes food and nutrition insecurity as well as the food waste.

In order to achieve this goal, the structuring the current context and the implementation of a systematic planning were the main objectives.

However, it is expected other contributions such as validation in the Ion Georgiou's (2006) proposal about SSM Methodology on a truly situation and the spread of urban food harvest in order to generate the visibility of humanitarian projects.

The work is presented in sections, the conceptualization of the current situation through problem structuring methodology in operational research is detailed; then the whole stages of Soft Systems Methodology (SSM) is applied; finally the results of this applications are presented as well as the relevant conclusions.

2 Conceptualization

Human decisions occur in the presence of conflicting criteria often difficult to reconcile. So, to help the decision-making processes emerged decision support methodologies, a branch of operations research that is characterized by various analytical methods and principles that will help the participants in a given situation to select the best paths considered decisions especially in complex environments.

2.1 Problem Structuring Methods

The application of Operations Research traditional methods requires that the real problems are modeled mathematically, indicating a goal, constraints and decision variables. The problem is determinate the decision variables to optimize the goal and satisfying the constraints.

On numerous occasions, this is not the case, since the situations are complex issues to address, either because the interests of stakeholders may conflict which does not allow agreements to achieve the goal, the information gathered may be incomplete, may influence not only aspects of numerical analysis, but also ethical, psychological, social, etc., requiring a multidisciplinary approach. To address these situations have arisen in the last 40 years, the problem structuring methods (PSM).

They are characterized by: Incorporate conceptual models that consider subjective aspects; Promote the active participation of all involved; and, encourage their creativity. It can be defined as a systemic intervention (Midgley, 2000).

The three problem structuring methods (PSM), commonly known are: SCA Strategic Choice Approach (John Friend *apud* Rosenhead, 1989), SODA Strategic Options Development and Analysis (Fran Ackerman & Colin Eden, *apud* Rosenhead, 1989) and SSM Soft Systems Methodology (Peter Checkland *apud* Rosenhead, 1989).

2.2 Soft System Methodology

Soft Systems Methodology (SSM) was developed by Peter Checkland in Lancaster University by the 70 years (Rosenhead, 1998).

Soft Systems Methodology (SSM) was developed by Peter Checkland in Lancaster University by the 70 years. Friend realized that hard OR methods were inadequate for complex problems. It took the methodology of traditional systems engineering (hard), and analyzed its transformation to be able to deal with "humanity" of humans, highlighting the importance of creativity, irrationality, and values. (Rosenhead, 1998)

SSM is a learning system that articulates a process of questions that leads to action. It is a process for management. It assumes that different individuals and groups are autonomous, making different ratings, leading to different actions with which the administrator has to deal with, and reacting facing an ever-changing flow of events and ideas.

The SSM features are:

• Applies to management problems.

• Individuals: assumed to be different, make different assessments, leading to different actions. Perceptions and assessments partially overlap.

• System: the concept of a whole which has properties as an emerging entity. In a dynamically interconnected world, explore how the idea of system can be mobilized to help explain the complex reality.

• Works with the complexity of human activity systems, characterized by being listed in a logical one with a purpose. These references are given in terms of a "private interpretation" of each exhibitor, opening multiple possible descriptions. Each one will be based on explicit assumptions about the world, "world view" (the set of images in our heads, put there from the beginning) taken as given. SSM considers the need to describe any human activity system in relation to a particular image of the world. Likewise every action in the real world can be described by different systems of human activity.

• Process information (questions). SSM learns by comparing pure models of purposeful activity with perceptions of what is happening in a real world problem situation.

SSM provides a class of highly explicit comparisons, based on models of systems used in an organized process, which is itself a learning process.

SSM in essence seeks to:

• Describe everything possible about the problem situation on its history, the commitment of assistance, potential problems, the existing culture, power and politics. Expresses this in the form of rich picture;

• Developing systemic models of human activity in order that explicitly incorporate viewpoints or perspectives relevant to the situation;

• Expressed in terms of logically these root definitions and conceptual models of activity;

• Use the templates as a way of questioning and analyzing the situation to structure a debate between the parties on the changes desirable and feasible;

• Search the agreements between the different perspectives or world views about the changes that could make the situation;

It works best if most of the activity was in fact made by the participants of the situation with the OR practitioner acting as a facilitator. It is they who have the detailed knowledge and, finally, must be committed to act.

The purpose of the comparison, in the latter stages of the method, is to achieve the ability to make useful actions in the problem situation in question, the actions defined in the comparison phase (versus the perception of the real world model).

Briefly, SSM involves the following steps:

Steps 1 and 2: Discovering the situation, through three analyses:

Analysis 1: Takes intervention in the situation as his subject and identifies the occupants of the functions: customers, who makes the intervention takes place; solving the problem: who leads the study and owners of the problem, who can stop the activity.

Analysis 2: Observe the problematic situation as a social system. What roles are significant, which are expected standards of conduct. It is to give primary care systems as "culture."

Analysis 3: It examines the political situation: how to get, use or preserve relations of power.

Step 3: Formulating roots definitions (RD)

Write the names of the relevant systems, which allow useful activities. RD must be built by considering the elements CATWOE (clients, actors, transformation process, world view, owner and environmental constraints)

Step 4: Building conceptual models

It consists in joining the verbs that describe activities that must be in the RD and structure them according to logical dependencies. They are activities carried out by the Transformation of the RD. The final model is a system, i.e. an entity that can adapt and survive through processes of communication and control in a changing environment. To do this it must be necessary to add a monitoring and control subsystem, which examines the operations and control the actions to change and / or improved them. It tests effectiveness, efficiency and effectiveness. The construction of the model focuses on RD. What it is seen is a coherent and defensible model, rather than "right." It is obtained a number of models of activity systems, some related hierarchically, each built according to a vision of the world declared in the W of the CATWOE.

Step 5: Comparing the models and reality.

It offers four ways: a) recording the difference b) greater detail, c) operate the system on paper, d) build the model. This step provides the structure and content of a debate organized on how to improve a situation considered problematic.

Step 6: Setting changes

It makes a debate on the possible exchange that for participants, bring potential improvements. These movements have to consider two aspects: being systematically desirable and culturally feasible.

Step 7: Taking actions

When it is identified some transformations accepted as desirable and the cycle is completed with the implementation of these changes, which alter the initial perception, creating a new cycle. It is a management approach with a broad point of view.

The method makes use of systems with significant activities in a combination that is directed not only to facts and logic of a situation, but also the myths and meanings of people associate with the situation and realizes it.

2.3 A new configuration of Soft Systems Methodology

To perform this research was chosen a new configuration of Soft Systems Methodology developed by Ion Georgiou. The author of this one defines "managerial effectiveness" as the ability to answer three questions:

1) How is it possible to extract information from a problematic situation with little knowledge?

2) How can this information be structured in a way that allows a rigorous definition of the problem? And,

3) How this definition can be used to offer a systemic approach to the resolution?

He presents a configuration that allows answering these three questions.

To answer the first question: the production of knowledge, proposes an analysis by three diagrammatic analysis, one focusing on the actors, the two focused on socio-cultural dynamics and three focusing on power dynamics. May be made a rich figure, obtaining as a product a database of organized knowledge. This associated with steps 1 and 2 of the SSM.

To answer the second question: the application of knowledge, he proposes analyses the transformations with the rules of SSM, its contextualization by CATWOE and planned by root definition (Checkland apud Rosenhead, 1989). It is obtained a database of application which is associated with steps 3 and 4 of SSM.

To answer the third question: the planning system, he proposes the control criteria in the planning of individual and integrated systems, using the tools of an individual human activity system and super system respectively, to assess effectiveness, efficiency, effectiveness, ethics and elegance. It is obtained as a product a database of systems and is associated with steps 5, 6 and 7 of SSM.

The proposal is a systemic planning (Midgley, 2000) through a systematic process that allows planning in the short, medium and long term and can serve for modelling dynamic systems.

3 Application of the methodology

In this paper we used the configured version of Soft Systems Methodology Georgiou (2008).

This methodology is intended to achieve three key objectives for the decision maker, to produce knowledge about the context of a problematic situation, to call this application of phase one, use this knowledge to the problem definition, phase two, and plan to systematically action, phase three.

This procedure was used in a real case study in a single unit of a mixed organization that develops, together with similar units in 350 cities met in Brazil, one of the largest programs of sampling and urban distribution of unprocessed foods, in our country. To this end, collects food donors (3,253 partner companies), sorts them and then distributes in social institutions (entities assisted 5399), 18,623,474 kg of food distributed benefiting 1,518,060 people just in the first half of 2011 (SESC, 2011). Thus fosters the social commitment of donors and educational commitment of social institutions.

To understand the operation of the program, was interviewed the coordinator of this unit, initially.

To achieve the first goal, the production of knowledge, Analysis I, Analysis II and Analysis III are used, which can be generated from the production of a rich picture.

In the first interview, was made use of the rich figure to illustrate the current situation, i.e., the authors of this article, the role of facilitators of the process, questioned the program coordinator of a food crop to explain through speaking and writing, which the daily operation, the logistics of a food crop of the relationship, the process of conquest of donors, and the selection of institutions to be met.

This first meeting may take place the first two analyses. In Analysis I, it was identified the actors, that is, everyone involved in the situation, individuals and entities. In the Analysis II, it was identified the socio-cultural dynamics of the problematic context.

After the interpretation of the interview, and compiling the data, the facilitators required a new meeting, where initially took to validate the Analysis I and II, to verify that all the actors and socio-cultural dynamics were listed correctly in this new intervention of the problem, included some missing elements, few, which shows that the figure was rich and informative and helpful understanding of the context.

In this second interview, proceeded to the list of power relations, it was observed that the separation in a new interview helped the process, because the actors defined and listed the issue of power of each relationship was more punctual, making the process clearer fast and the final stage, a fact that helps to save the time of the interview, because as it is a multi-phase approach is of great value does not exhaust him so that he intends to continue the process until the end of all the proposed methodology.

For Phase 2, the application of knowledge, we have three steps.

The Stage I of Phase 2 is to identify the desired transformations, which are what is needed to change the situation that has to a new you want. These transformations were obtained by the knowledge acquired in Phase 1, and validated with the interviewee.

To identify these transformations using the four rules it is spoken by Checkland (1989), they are: consider only one input and one output, the entry must be present in the output but changed; an intangible or abstract input must result in an output intangible or abstract, a concrete or tangible input must result in a tangible or concrete output.

Stage II, Phase 2 aims to contextualize the transformations, for that makes use of the mnemonic CATWOE, where for each desired transformation, it makes the description of the Customers, who benefits and who loses from this transformation, Actors, who will that this transformation happen, Transformation, the transformation itself; Weltanschauung, which justifies this transformation; Owner (s), who can stop this transformation; Environmental restriction (s), which restrictions are immediately connected to this restriction.

In Stage III, Phase 2, the transformations will be made from the root definitions, which are the basis for continuing with the Phase 3.

As a way of describing the elements of CATWOE for a full understanding, this should be stated in the form of a logical statement, as well known as structured setting root.

Phase 3 will conclude the work in the end we will have a systematic planning of actions to improve the situation existing in the general program of urban food crop studied.

In this last phase the main concern is planning for the future, involves the use of knowledge acquired in two phases to make a better future. If this improvement is small or short-term view is more likely to be fully planned and executed later than normal in the medium and long term.

The procedure for carrying out this phase is: For each transformation must be listed the activities necessary to accomplish it, then it should bind the activities conceptually, then it is stipulated criteria of control. This is called a conceptual model or system of human activity.

While there, the relationship between the transformations, it can establish a connection between them, thus creating a larger system (the super system) and to provide control criteria for this larger system. This super system is the plan of action.

4 Results

The results of application described are shown in this section.

Rich picture, targeted by the program coordinator of urban food harvest studied is displayed (Fig. 1).

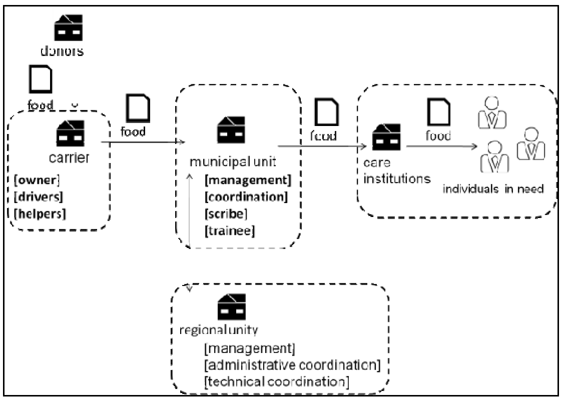

Fig. 1. Rich picture.

The data generated by the analysis I, can be seen:

Table 1. Analysis I, identification of the actors involved in the problematic situation.

People	Institutions
Coordinator / Nutritionist (helper nutritionist and trainee)	Harvest Program
Drivers and driver helpers	Donors (supermarkets, street markets, restaurants, industries, bakeries, grocery stores, coffee shops, rural cooperatives)
People with nutritional needs	Recipient institutions (social institutions caring for children, elderly, drug addicts, pregnant women, adults)
	Regional unit
	Local unit
	Federal government

Analysis II, identification of the dynamics of the socio-cultural context of the problematic situation:
• Model urban harvest;
• Hierarchical structure of power;
• Centralized Organization;
• Activities dependent on the schedules of donors and recipients;
• Legal responsibility on the quality of food;
• Positive image for the realization of social activity;
• Promotion of nutrition education;
• Prioritization of beneficiaries of the majority needed.
The data obtained from Analysis III, can be checked below:

Table 2. Analysis III, identification of power dynamics in the context of the problem situation.

Who?	What power?
Coordinator / Nutritionist	Dependent on the structure SESC
(helper nutritionist and trainee)	Execution of the contract of carriage
	Definition of the daily activities of drivers
	Promoter relationship with donors
	Promoter of the related institutions
	Responsibility for the registration of charities to deliver
	Power of choice for prioritizing needs
	Training for food handlers
	Responsibility for quality control of food
	Administrative management
	Defender of the importance
Drivers and driver´s helpers	Subordinate to the transportation company
	Dependent on the orientation of the program coordinator
	Compliance with local traffic rules
	Responsible for continuous temperature control of the truck
	Responsible for compliance with quality characteristics for acceptance of food collection
	Direct relationship with donors
	Transfer and handling of food
	Direct relation to delivery for charities
	Inform possible waste or bad uses
Relief	Dependent on the promotion of charities
	Main beneficiaries of the program
Harvest Program	Enables the operation of the process of urban harvest
	Promotes the reduction of hunger in the country
	Reduce hidden hunger through the possibility of missing nutrient intake
	Sets an example to other projects of its kind
Donors	Deliver food to the program
	It valued its social image
	Security transparency of the work
	Participate in the sensitization
Recipient institutions	Receive food program (demand)
	Provide food assistance and care to people in social vulnerability

	Participate in educational activities
Local unit	It provides structure for the operation of the program
	Collect monetary resources
	Report progress and experience local
Regional unit	Report overall progress and experience
	Choose the model to be developed
Federal government	Develop laws of transport and food handling
	Liability laws stipulates the donation
	Encourages programs to combat hunger

In stage 1, Phase 2, the SSM approach, we identified the following transformations.

Table 3. Identification of the transformations.

Undesirable state		Desired state
Routing performed monthly by the nutritionist	T1	Facilitating the routing
Waiting list	T2	Expansion of service
Lack of resources	T3	Expansion of resource gathering
Legal impediment to receive processed foods	T4	Legal incentive for donations
Insufficient third-party vehicles	T5	Reverse bureaucracy to have another vehicle
Lack of community involvement	T6	Mobilization and awareness
Concentration of work to the nutritionist	T7	Increased team to division of labor

They were then filled the 'CATWOE' of each transformation, and found the root definitions:

In the following table, are filled in the CATWOE of each transformation, and the definitions derived from the root definition of each:

Table 4. Characterization of the transformations.

Transformation	CATWOE	Root definition
T1	C Customer (s): Nutritionist, drivers, donors and recipient institutions A Actor (s): A consulting contract T Transformation: ‘Routing performed monthly by the nutritionist’ to ‘Facilitating the routing’ W Weltanschauung: Speed of execution of tasks, better use of truck capacity and time O Owner (s): Harvest Program E Environment: Monetary resources controlled	A consulting contract-operated system that defines and maintains a facilitating routing to meet the nutritionist, drivers, corporate donors and recipient institutions in accordance with the expectations of the harvest program, in order to ensure speed of execution of tasks, better use of capacity truck and schedules in an environment of controlled monetary resources.
T2	C Customer (s): People needing food in the region A Actor (s): Harvest program T Transformation: ‘Waiting list’ to ‘Expansion of service’ W Weltanschauung: Extensive number of people with food deficit O Owner (s): Local unit E Environment: Lack of prioritization of social programs, lack of interest.	A harvest program-operated system that defines and maintains an expansion of service to meet the people needing food in the region in accordance with the expectations of the local unit, in order to ensure extensive number of people with food deficit in an environment of lack of prioritization of social programs, lack of interest.
T3	C Customer (s): Charities, people needing food A Actor (s): Network of donors, nutritionist T Transformation: ‘Lack of resources’ to ‘Expansion of resource gathering’ W Weltanschauung: Network of donors can be increased by increasing the dissemination and collection capacity O Owner (s): Harvest Network E Environment: Low collection capacity, low coverage of the disclosure of the program and	A network of donors and nutritionist operated system that defines and maintains a expansion of resource gathering to meet the charities and people needing food in accordance with the expectations of the harvest network, in order to ensure network of donors can be increased by increasing the dissemination and collection capacity in an environment

	benefits generated	of low collection capacity, low coverage of the disclosure of the program and benefits generated.
T4	C Customer (s): Donors, recipients and harvest program A Actor (s): Popular initiative T Transformation: ‘Legal impediment to receive processed foods’ to ‘Legal incentive for donations’ W Weltanschauung: Extension of tax deductions by donors O Owner (s): Federal government E Environment: Current Legislation rigid, disinterest	A popular initiative operated system that defines and maintains a legal incentive for donations to meet the donors, recipients and harvest program in accordance with the expectations of the federal government, in order to ensure extension of tax deductions by donors in an environment of current legislation rigid, disinterest.
T5	C Customer (s): Harvest program A Actor (s): Local unit T Transformation: ‘Insufficient third-party vehicles’ to ‘Reverse bureaucracy to have another vehicle’ W Weltanschauung: Power to control the transport O Owner (s): Local unit E Environment: Budget control, parking, maintenance	A local unit-operated system that defines and maintains a reverse bureaucracy to have another vehicle to meet the harvest program in accordance with the expectations of the local unit, in order to ensure power to control the transport in an environment of budget control, parking and maintenance.
T6	C Customer (s): Society in general, program A Actor (s): Marketing of the program T Transformation: ‘Lack of community involvement’ to ‘Mobilization and awareness’ W Weltanschauung: Involve more people O Owner (s): Local unit E Environment: Social conscience and humanitarian responsibility	A marketing of the harvest food program operated system that defines and maintains a mobilization and awareness to meet the society in general and the program in accordance with the expectations of the local unit, in order to ensure involve more people in an environment of social conscience and humanitarian responsibility.
T7	C Customer (s): Harvest program A Actor (s): Local unit T Transformation: ‘Concentration of work to the nutritionist’ to ‘Increased team to division of labour’ W Weltanschauung: Division of labour, much work focused on a single person, limited expandability O Owner (s): Local unit E Environment: Budget control, vision	A local unit-operated system that defines and maintains an increased team to division of labour to meet the harvest program in accordance with the expectations of the Local unit, in order to ensure division of labour, much work focused on a single person, limited expandability in an environment of budget control, vision. Following the work for the last stage, the corresponding actions were listed for the execution of each transformation.

Following the work for the last stage, the corresponding actions were listed for the execution of each transformation.

Table 5. Action listed to be developed.

Transformation	Actions
T1	Review records of donors and recipients Provide criteria for prioritizing and scheduling windows To quote software routing Hiring an expert for making routing software program-specific Make use of training software Adopting new software
T2	Catalog institutions on the waiting list Check prioritization criteria Mobilize action to expand the collection of donations

	Run a better distribution of food obtained
T3	List sources of funds to provide increased resources Discover how to get access to responsible Studying processes of bureaucracy needs to stipulate Educate leaders and potential funders about the importance of investment Quote values of resources Distribute proceeds
T4	Studying the current legislation on food donation Find studies already existing and possible proposals on this subject Study feasibility of these proposals Propose a solution Exposing to the bodies responsible
T5	Make an economic comparison between the current system and a system of own fleet See what the bureaucracies involved in the request for new trucks Using a routing software for planning the number of trucks on the basis of collective capacity, capacity of the truck routes and shifts Make the budget Propose purchase
T6	Studying how to reach people See where the availability of agents and prosecutors in the unit out Partnering in action Donors to promote social responsibility as agents (e.g., seal, reusable bags) Promote education and awareness actions
T7	Study the need for staff Doing the work schedule Divide tasks Provide necessary qualification See resources for hiring Hire Train

And finally the product obtained by applying the methodology was the production of seven systemic planning of human activity, each corresponding to a transformation, by way of illustration is in the appendix attached to the design obtained one of the seven transformations, which can be seen all information obtained and that can help the implementation process of transformation, i.e., the root definition, the CATWOE, the list of actions and their control measures and monitoring.

5 Conclusions

The work performed was of great value for testing the methodology in a real application and usefulness to society. Showing it ideal for the development of knowledge gained and systems planning implementation expected. Validating the choice of method to a complementary work, the application being performed with the group involved in urban food crop. Action research provided a real experience, where they could live with the real difficulties of applying the methodology, especially as regards the various steps and stages proposed.

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References

Checkland, P., 1989. Soft systems methodology. *In: Rosenhead J (ed.) Rational analysis for a problematic world problem structuring methods for complexity, uncertainty and conflict. Wiley, Chichester, pp 71–100*.

Eden, C., 1989. Soft systems methodology. *In: Rosenhead J (ed.) Rational analysis for a problematic world problem structuring methods for complexity, uncertainty and conflict. Wiley, Chichester, pp 21–42*.

Friend, J., 1989. Soft systems methodology. *In: Rosenhead J (ed.) Rational analysis for a problematic world problem structuring methods for complexity, uncertainty and conflict. Wiley, Chichester, pp 121–158*.

Georgiou, I., 2006. Managerial Effectiveness from a System Theorical Point of View. *Systemic Practice and Action Research 19:441–459.* doi: 10.1007/s11213-006-9035-3

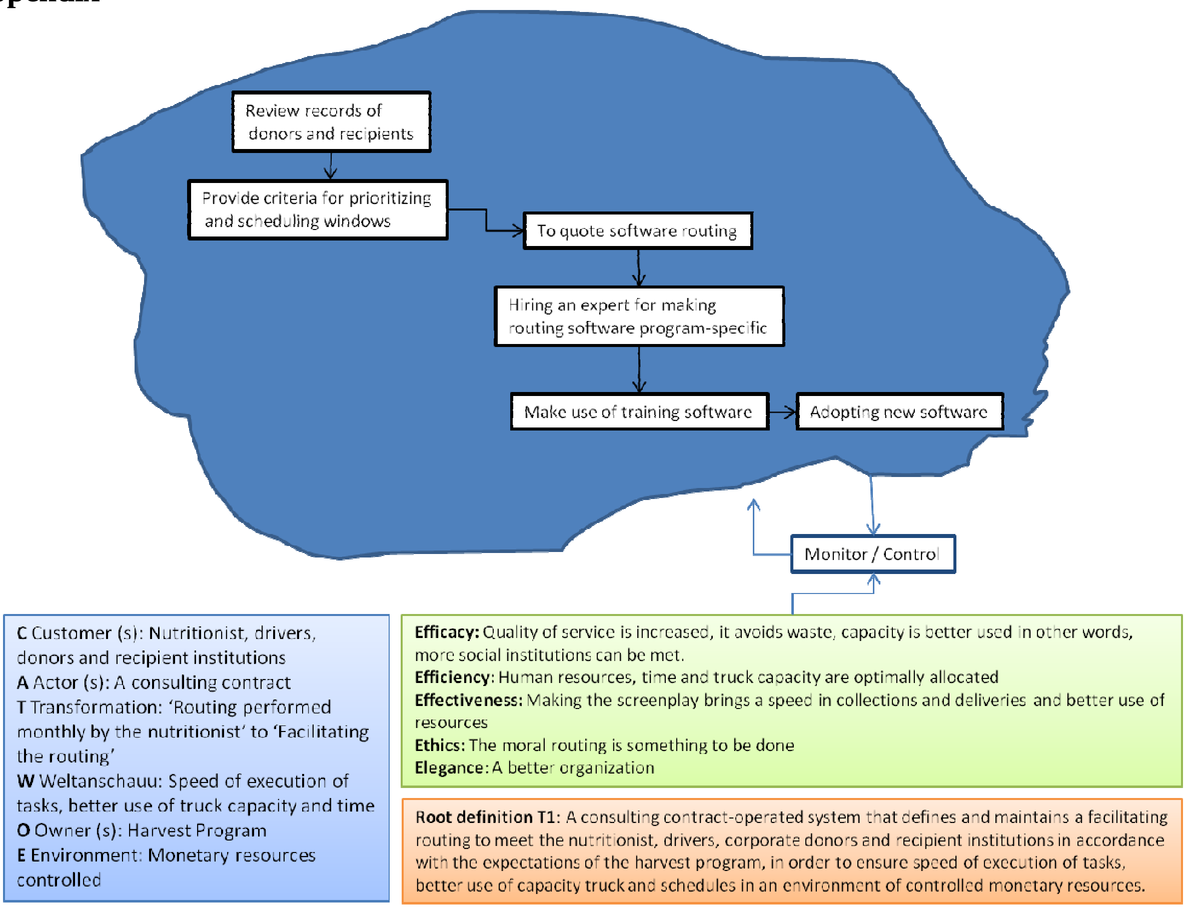
Georgiou, I., 2008 Making decisions in the absence of clear facts. *European Journal of Operational Research 185, 299–321.* doi:10.1016/j.ejor.2006.12.038

Maranhão Filho, E. A., Toward an architecture for a decision support system for soft system methodology. *In progress.*

Midgley, G., 2000. Systemic Intervention Philosophy, Methodology, and Practice. *Kluwer Academic/Plenum Publishers.*

SESC, 2011. Results. http://www.sesc.com.br/mesabrasil/resultados.html (*last accessed on 15 December 2011*)

Appendix



MCDM application in group context

Developing an implementation model to VIP Analysis Software by using Action Research

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Abstract: This paper presents an Action Research intervention in Multicriteria Decision Aiding for a group done in a federal university of Brazil. It intends to contribute to developing an Implementation Model of Decision Support with the VIP Analysis software. Action research enables the assessment of VIP Analysis acceptability at the same time that it makes possible the implementation of a decision aiding process by the researcher.

Keywords: MCDA for groups, VIP Analysis Software, Cognitive Maps, MAUT, Action Research.

1 Introduction

This study is part of a PhD research with the main objective of developing an implementation model to VIP Analysis software (Dias and Climaco, 2000), a Multicriteria Decision Aiding (MCDA) software that allows the evaluation of decision alternatives according to Multi-Attribute Utility Theory (MAUT) advocated by Keeney and Raiffa (1976). This study also uses Cognitive Maps (CM) as a Problem Structuring Method and Action Research (AR) as a research method.

AR was chosen to be used in this work because some authors had indicated it as an appropriated method to study MCDA (Montibeller, 2007; Belton and Stewart, 2002, Eden and Huxham, 1996). The reason for that is the intensive participation of the researcher in the study, the main characteristic of this method (Fellows and Liu, 2005; Thiollent, 1997), and also the possibility to provide changes in the organization, unlike other research methods, and increase understanding of the research object by involving participants in a cycle of learning and reflection.

According to McKay and Marshall (2001) the AR method has a Research Cycle (using Action Research Method) and a Problem-solving Cycle (using in this study Cognitive Maps, Value Functions and VIP Analysis software) which should be restarted until the research questions are satisfactorily resolved and the outcomes of the actions on problems are satisfactory. In this study the researcher intends to make real world interventions in organizations with decision problems with different characteristics and to test the suggested model of implementation to VIP Analysis software The first intervention of this process was done in Top Atlântico, a group of travel agencies from Portugal (Ventura et al., 2010), where it was used an individual cognitive map and quantitative descriptors of impact. This is the report of the second intervention, done in UFAL, a federal university of Brazil, using a group cognitive map in a sharing mode, according to Belton and Pictet (1997), and qualitative descriptors of impact.

In the sharing mode all elements of the decision problem are shared by the Decision Makers (DMs). So it is possible to have consistency in the global procedure and there are good chances to achieve a consensus because there is a point by point negotiation, without loss of the individual information.

2 The Organization and the Decision Problem

The Organization that participated in this study was the Federal University of Alagoas – UFAL, the largest public institution of higher education in the State of Alagoas (Brazil) with over 21000 students.

The Ministry of Education and Culture (MEC) of Brazil presented a proposal to the National Association of Directors of Institutions of higher education to use the National Secondary Education Examination (in Brazil called ENEM), which assesses student performance at the secondary education, to support their selection process. This proposal aimed at unifying the selection of students to graduated courses in fifty-five universities in the Brazilian federal government.

The proposal's main objectives are to democratize access to opportunities for federal universities (candidates who can afford to take admission examinations in federal universities located in different cities have more opportunities to enroll in a federal university than those who do not), to enable academic mobility and to induce the restructuring of school programs.

The federal universities have autonomy and can choose from four possibilities of using the new exam as a selective process:

a) *As a single phase, with the unified system of selection*. Universities that choose this option do not apply any other assessment test to select candidates for their vacancies in undergraduate courses, or would no longer have the Vestibular test (an entrance exam developed by each university to measure the knowledge acquired by the candidates in elementary and secondary education). The influx of new students would be determined solely by passing the ENEM up to the limit of available places.

b) *As the first phase (getting the second by the institution)*. In this case, the universities would still have to develop and implement their own Vestibular test. However, only students previously approved in ENEM could participate in this selection process. As a result, the number of candidates who would do the Vestibular test would be reduced from the current quantity.

c) *Combined with the Vestibular test of the institution*. This option also implies the need for development and implementation of a Vestibular test of the University. However, the number of candidates would be the same as if they do not use the ENEM, because all candidates should do both exams (ENEM and Vestibular test). The candidate's overall score is the result of a weighted average of the final grade obtained in ENEM and the final score obtained in the Vestibular test of the University.

d) *As a single phase for the remaining places after the Vestibular test*. In this case the University develops and implements its Vestibular test as usual, but the remaining places being offered to successful candidates in ENEM, according to the sort order and the number of places available.

The UFAL, through the Standing Committee of the Vestibular - COPEVE (internal organ of the university, responsible for all the processes inherent to their entrance exams) examined this decision problem, in order to analyze MEC´s proposal.

At the same time, COPEVE also intends to evaluate the use of vestibular tests themselves (compiled by the staff of COPEVE) compared with the use of vestibular tests purchased from other specialized institutions.

It is noteworthy that the decision of COPEVE will only be part of the decision of this problem, because the final decision will still be taken by the University Council of UFAL (CONSUNI), where the COPEVE will present its decision.

3 The Alternatives

The alternatives are just the ways of using ENEM by federal universities, according to MEC'S proposal presented in section 2 (with exception of the fourth option because since 2009 UFAL has been adopted the ENEM to fill their vacancies remaining after the vestibular test). Adding to this analysis there is the possibility of a Vestibular test prepared by COPEVE or by a specialized institution, which would prepare the tests according to the guidelines of COPEVE.

The alternatives to this problem are therefore:

A1: Use of ENEM as a single phase;

A2: Use of ENEM as the first phase of selection and Vestibular test of UFAL as a second phase;

A3: Use of ENEM as the first phase of selection and Vestibular test of UFAL as a second phase, but purchasing UFAL tests from a specialized institution, which would prepare the tests according to the recommendations of COPEVE;

A4: Combining ENEM tests and Vestibular tests of UFAL, with tests developed by the University;

A5: Combining ENEM tests and Vestibular tests of UFAL, but purchasing UFAL tests of an institution specialized in the production of Vestibular tests, which would prepare the tests according to the recommendations of COPEVE.

4 The Field Research

4.1 Training the Decision-Makers (DMs) on the subjects under study

One of the roles of the researcher in AR is the training of the DMs on the subjects under study (Mckay and Marshall, 2001). So, during the intervention the DMs received training on Cognitive Maps using Decision Explorer software (Brightman, 2002), MAUT and VIP Analysis software immediately before they needed to use these tools.

4.2 Modeling the Cognitive Map

In group decision processes, one can choose to produce CMs of each of the group and then aggregate them into a single map - or develop a single map that represents the group awareness about the problem at hand. In this case only one map was developed because none of the group's members considered having a complete and detailed description of the problem. It was done after discussion and after getting a group consensus, using the sharing mode (Belton and Pictet, 1997).

The development of a single map for the group is a faster process and very interesting from the aspect of group interaction. However, there is an increased risk of occurrence of groupthink (Janis, 1972; 1982), which may affect the use of the map as a tool for decision support.

Montibeller (1996) explains that when a group is a victim of groupthink, it loses some of the cognitive abilities of its members; it seeks total agreement and complacency. This author points out that in these cases the leaders interfere in the process of thinking of the other members of the group, dominating it in order to achieve cohesion and compliance, a situation that affects the contribution of group members in its creativity and innovation.

Montibeller also states that in these cases there is loss of quality of the group's cognitive map in the following aspects: incomplete survey of objectives / goals / values and also alternatives / actions, failure to assess the risks of a particular choice, failure to reconsider alternative / shares initially dropped, poor information search about the problem; excessive bias in processing the information available.

To mitigate the risk of occurrence of these effects and to ensure a better development of the cognitive map, the researcher called the group's attention to each of these points, especially encouraging them to seek more information about the problem and not just stopping to analyze the information they initially had. So, the group brought new information on similar cases at other universities and about the ENEM tests.

The researcher also tried to minimize the influence of the group's leadership and the pursuit of cohesion, giving each member the opportunity to write their individual opinions in blocks of post-it notes which were later posted on a flip-shart for analysis and discussion of the whole group. Thus, it was possible to ensure a greater level of creativity and innovation of the participants.

The researcher could act this way because the AR method allows him/her to act as a facilitator, supporting the decision process and trying to drive it as well as possible, which might not occur when using another scientific method

To elaborate this cognitive map, the researcher started using some group dynamics to awaken creativity and lateral thinking (de Bono, 1995) of the group. In a brainstorming process (Rodrigues, 2004) the group members were asked what would be important factors to consider when choosing the ideal selection process for the admission of new students in undergraduate courses of UFAL.

The researcher then proceeded to turn the whole tangle of information into words and phrases that would later be the primary elements of assessment (PEA's) for this decision problem by constructing a CM, according to Eden et al (1983), Eden (1988), Bana e Costa (1992) and Montibeller Neto (1996). The resulting CM is presented in Fig.1.

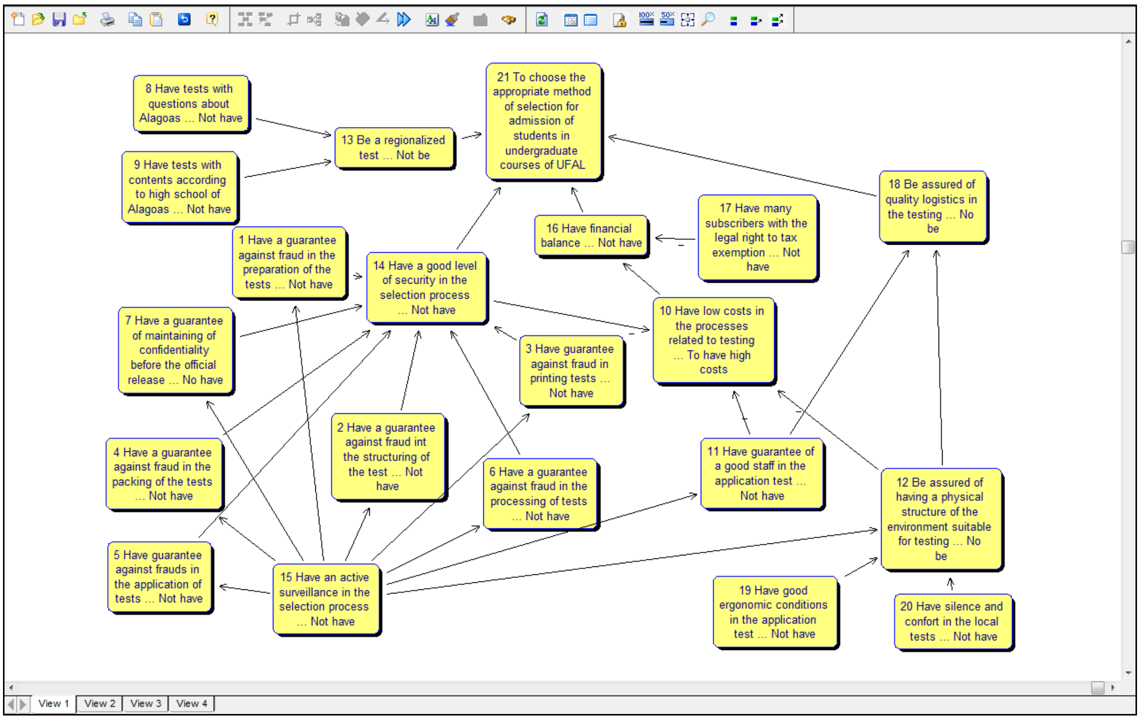

Fig. 1. Cognitive Map – To choose the appropriate method of selection for admission of students in undergraduate courses of UFAL.

4.3 Identification of Clusters

Looking at the CM it is possible to detect concepts with similar meanings, which represent areas of interest to DMs. In this case, there are four strategic objectives which are broken down into groups of concepts. These objectives are clusters in the CM: Safety, Quality Logistics, Regionalization and Financial Balance.

Each cluster became a "candidate" Fundamental Point of View (FPV) and was tested to meet the properties for being a fundamental objective according to Keeney (1992). All the "candidates" were approved.

4.4 Definition of Descriptors of Impact

According to Bana e Costa (1992) and Ensslin et al (2001), after the definition of FPV it is possible to start building a multicriteria model for evaluating alternatives. For this, the first step is to build the criteria that will measure the performance of the alternatives.

The construction of the criteria, however, requires two basic tools: a descriptor of impact and a value function associated with the descriptor. The descriptors will present the possible performance levels for each alternative FPV, while the value functions provide information regarding differences between levels of attractiveness of the descriptor.

Observing the structure of the CM, the FPVs identified are the following:

1) Security - Guarantee against fraud at all stages of the selection process of new students on preparation, review, print, application, processing, correction and disclosure of results of tests.

2) Regionalization - Identification of students with its regional context, addressing topics related to Alagoas, especially the test of Geography and History.

3) Quality Logistics - Ensure selection of a suitable location for the application of tests and qualified and reliable support staff and supervision.

4) Financial Balance - Net financial balance between the costs of preparing and printing tests, and the revenue collected in the process of registration of candidates.
After this identification, the group defined descriptors of impact for each FPV and constructed the Value Functions. The descriptors of impact were defined by assigning attributes to each FPV. Qualitative descriptors were defined through levels of impact in terms of preference by the DMs.

In this type of problem attributes are not easily quantifiable. These attributes reflect the personal opinions of the DMs about the alternatives. As an example, a good security process in the application of Vestibular test can be defined with different points of view by each DM. Nevertheless, they have to discuss and express in significant words what each opinion really means. They discussed these meanings, and finally reached a consensus. The following descriptors were thus defined for each FPV:

FPV Security: reasonable, fair, good, very good and excellent.

FPV Regionalization: no regionalization, low regionalization, medium regionalization, good regionalization, full regionalization.

FPV Quality Logistics: bad quality, regular quality, medium quality, good quality, excellent quality.

FPV Financial Balance: costs far above the revenues, costs exceed revenues, costs slightly exceed revenues, costs and revenues are balanced, and there is some profit.

According to Ensslin et al (2001) a descriptor should be unambiguous and the impact levels should have a clear meaning to the actors in decision making. The researcher asked the DMs to clarify what each level of impact of FPVs meant. It was interesting to note that the real meaning of each level of impact was not clear to them until that moment. It seemed very simple to refer to the levels only in intuitive terms, but now it was necessary to express in words each level of impact. After some discussion, the DMs agreed on the following descriptions:

FPV Security

Table 1 - Overview of the impact of levels of FPV Security

Level	Description
Reasonable	Selection process developed by the institution not certified by UFAL
Regular	Selection process developed by the institution not certified by UFAL, but certified by MEC.
Good	Selection process developed by an institution with proven credibility and suitability for UFAL in partnership with another institution.
Very good	Selection process developed exclusively by institution with credibility and reliability proven by UFAL and without a history of fraud in public tenders.
Excellent	Selection process with complete safety (human and technological) and total guarantee against fraud.

FPV Regionalization

Table 2 - Overview of the impact of levels of FPV Regionalization

Level	Description
None	Tests with unique content for use in all of Brazil.
Little	Test with different content for each of five regions: North, Northeast, Midwest, Southeast and South
Medium	Combination of tests with unique content for use in all of Brazil and tests in context to culture, history and geography of Alagoas, developed by teachers with no experience in local educational institutions
Good	Combination of tests with unique content for use in all of Brazil and tests in context to culture, history and geography of Alagoas, developed by teachers with good experience in local educational institutions.
Complete	Only tests contextualized to the culture, history and geography of Alagoas, prepared by teachers who know the specific context of the state of Alagoas and have experience in local educational institutions.

FPV Quality Logistics

Table 3 - Overview of the impact of levels of FPV Quality Logistics

Level	Description
Bad	Selection of local of tests without a good ergonomic structure and with poorly designed and operated inspection process.
Regular	Selection of local of tests with minimal comfort and ergonomics and a vulnerable inspection process.
Medium	Selection of local of tests with comfort and ergonomics reasonably adequate and inspection process with little vulnerability.
Good	Selection of local of tests with appropriate comfort and ergonomics and well planned and operated process monitoring.
Excellent	Selection of local of tests with exceptional comfort and ergonomics and highly safe and effective process monitoring.

FPV Financial Balance

Table 4 - Overview of the impact of levels of FPV Financial Balance

Level	Description
Costs far in excess of revenues	Costs exceed revenue by more than 50% .
Costs over revenues	Costs exceed revenue by 20% to 50% .
Costs a little higher revenue	Costs exceed revenue by 5% to 20% .
Costs and revenues are balanced	Costs are within a margin between -5% and 5% of revenue
There is some profit	Revenues exceed costs by more than 5%

As each semiannual Vestibular test has different costs and revenues due to the number of candidates, number of exemptions from registration, etc., the DMs chose to define the level of impact of the descriptor "Financial Balance" in a qualitative way, as shown in Table 4.

4.5 Construction of Value Functions

This study does not assume that there exists in the minds of DMs a value function to evaluate alternatives (Fischhoff et al., 1998; Tversky, 1996) and they are configured just as artificial tools built with the aim to reflect the preferences of DMs in a quantitative manner (Roy, 1996).

To construct value functions, the researcher started associating the value 0 to the worst level of attractiveness and value 1 for the highest level of each FPV. These values served as the anchor for the definition of the other levels of attractiveness. Using the Nominal Group Technique – NGT (Delbecq e Van de Vem, 1971) to minimize the risks of the effects of the groupthinking, the researcher guided the DMs to identify a level of quantitative impact for each of the descriptors of each FPV. For example, the following type of question was used: "If a reasonable assurance worth 0 and an excellent safety was worth 1, how many points would give a good security?".

All descriptors of impact were associated with an increasing order of preference, with values to maximize: the higher the scale value, the better. This means that the value of 0 indicates the worst performance and 1 the best performance value. After all the questions the researcher got the following levels of impact which are accompanied by graphs showing the equivalence between actual values and the values with the range of 0 to 1.

• FPV Security (Figure 2)

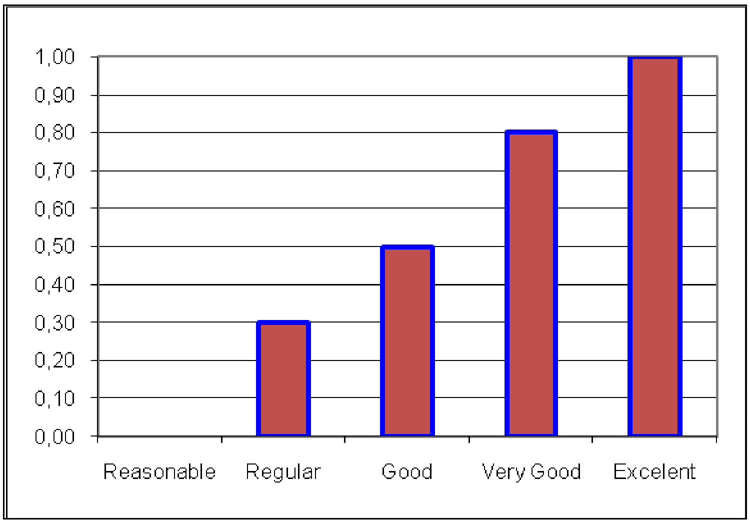

Fig. 2. Value Function of the FPV Security

• FPV Regionalization (Figure 3)

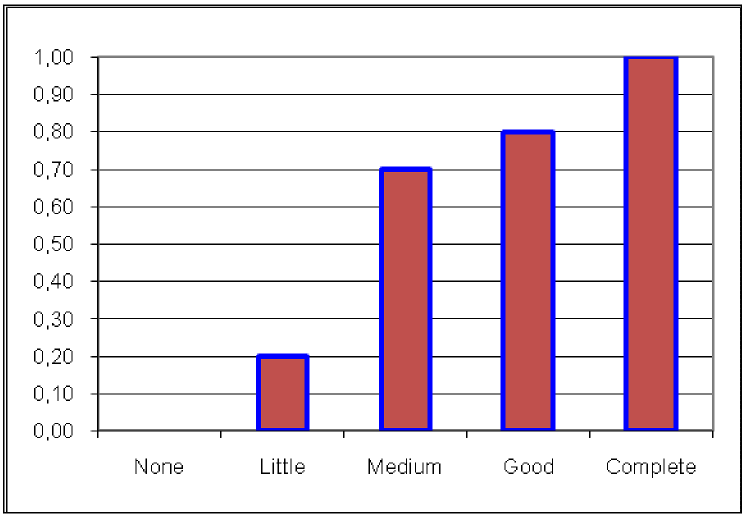

Fig. 3. Value Function of the FPV Regionalization

• FPV Quality Logistics (Figure 4)

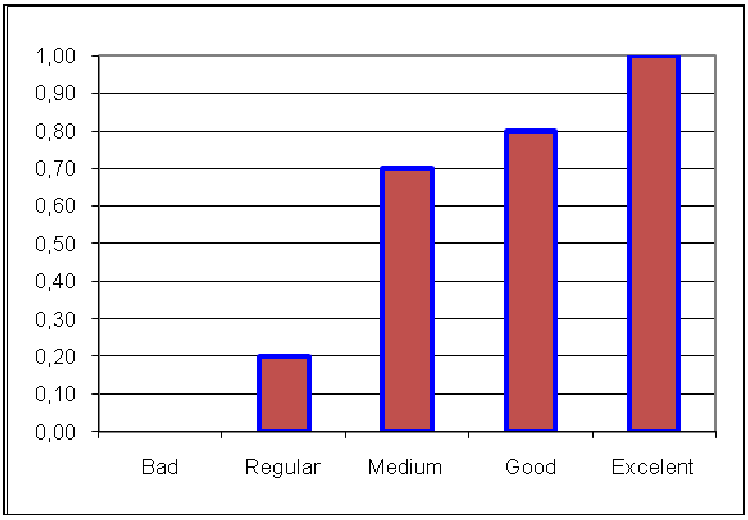

Fig. 4. Value Function of the FPV Quality Logistics

• FPV Financial Balance (Figure 5).

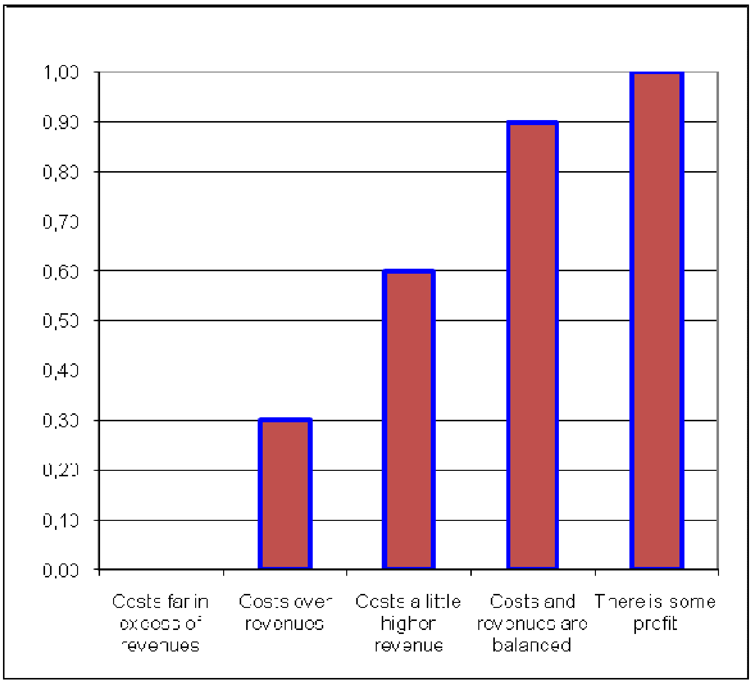

Fig. 5. Value Function of the FPV Financial Balance

4.6 Definition of a ranking for the weights

For this intervention, the well-known additive model for multicriteria aggregation was used. The global value of an alternative is given by a sum of the value it attains on each value function, weighted by the scaling coefficient associated with that value function:

$$V(a_i) = k_1\, V_1(a_i) + k_2\, V_n(a_i) + \ldots + k_n\, V_n(a_i),$$

where n is the number of criteria (n=4 in this case) and k_1 , ... , k_n are the scaling coefficients (weights) that reflect value trade-offs between criteria.

The DMs are often unable or unwilling to provide precise values for the weights, but they may be able to establish certain relations that are interpretable in terms of marginal substitution rates between the criteria (Marmol, 1998; Dias and Clímaco, 2000). So, the researcher explained the DMs that they could set weights for each criterion or just set the ranking of these weights, because the VIP Analysis Software would be able to deal with this type of information, or any other type of linear constraints on the weights.

The researcher also explained that the direct rating techniques should be avoided, because the value of these coefficients does not reflect the intuitive notion that the DMs have about the importance of each criterion and that it would be more appropriate to use the Swings Technique (Edwards and Barron, 1994).

Using the Swings Technique, the researcher presented to DMs the following situation: "Recall the performance levels attached to the values 0 (the minimum) and 1 (the maximum) in each criterion. Suppose an alternative that is 0 on all criteria. If you could change the performance of a criterion from 0 to 1, what criterion would you choose? And if you could not change this option, which would you choose?".

These questions are posed by the researcher to the DMs until all criteria were ordered. Let us note that, for a group, agreeing on a ranking of the weights is easier than agreeing on the precise weight

values by answering trade-off questions of the type "How much would you be willing to lose in criterion x to increase a unit in criterion y?"
Thus, the ranking of the criteria was as follows:

Table 5 - Order of importance of the criteria, according to the DMs.

Safety> Quality Logistics> Financial Balance> Regionalization

4.7 Performance of the Alternatives

Table 6 shows the performance of each alternative on the criteria considered in this problem, according to the consensus of the DMs.

Table 6 – Qualitative performance criteria in each of the alternatives, according to DMs.

ALTERNATIVES	CRITERIA			
	Security	**Regionalization**	**Quality Logistic**	**Financial Balance**
Alternative 1	Regular	No regionalization	Medium	There is profit
Alternative 2	Very good	Good	Good	Costs a little higher than revenues
Alternative 3	Good	Medium	Good	Costs higher than revenues
Alternative 4	Very good	Good	Good	Costs higher than revenues
Alternative 5	Good	Medium	Good	Costs much higher than revenues

4.8 The Use of the VIP Analysis Software

VIP Analysis is a multicriteria decision support software to evaluate a discrete set of alternatives in choice problems (Dias and Climaco, 2000). Using this software the DMs do not need to indicate precise values for the trade-offs between different criteria, because it can accept imprecise/ partial information on the criteria weights k = (k_1, k_2, ... k_n) and also can identify which results are more affected by the imprecision (robust conclusions).

So, the researcher started by entering all data of this decision problem (criteria, alternatives and the respective values of these alternatives with performance on a scale of 0 to 1) into the software (Fig. 6). Based on this information, VIP Analysis presented the results summarized in Fig. 7.

File Edit Criteria Alternatives Results Filter Help

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Data | Bounds | Constraints

Criteria:	Security	Regionalization	Q._Logistic	Financial_Balance
Importance:				
a1	0.3	0	0.7	1
a2	0.8	0.8	0.8	0.6
a3	0.5	0.7	0.8	0.3
a4	0.8	0.8	0.8	0.3
a5	0.5	0.7	0.8	0

Fig. 6. VIP Analysis Software – Data

Summary | Range | Confrontation | Max Regret

Alternative	Value	Min Value	Max Value	Max Regret	Dominated?
a1		0.3	0.667	0.5	YES (Abs)
a2		0.733	0.8	0	
a3		0.5	0.65	0.3	YES (Abs)
a4		0.633	0.8	0.1	YES
a5		0.433	0.65	0.3	YES (Abs)

Fig. 7. VIP Analysis Software – Summary

It was not necessary to give a weight for each criterion. The unique constraint inserted on the software was the order of importance that the DMs gave to the four criteria, defining a subset K of acceptable weights. With this information VIP Analysis uses optimization to compute the maximum value and minimum value that each alternative a_i may achieve given these constraints: $min\{V(a_i): (k_1,\ldots,k_n)\in K\}$ and $max\{V(a_i): (k_1,\ldots,k_n)\in K\}$. In the "Summary" page (Fig. 7), these results appear in the column "Min Value" (Minimum Value) and "Max Value" (Maximum Value).

The alternatives are compared in pairs and the software computes the maximum difference of value between them. The "Confrontation" table in Fig. 8 indicates, in each cell, the maximum difference $max\{V(a_{row})\text{-}V(a_{column}): (k_1,\ldots,k_n)\in K\}$. For instance, it can be read that A1 can win over A3 by a difference of 0.133 (for some vector of weights), but A3 can win over A1 by a difference of 0.2 (for another combination of weights). In the column referring to A2 the negative values indicate that the other alternatives can never win over A2, and the zero value indicates that A4 can at most equal A2. Therefore, A1, A3, A4 and A5 are *dominated* by A2 given K.

Summary | Range | Confrontation | Max Regret

	a1	a2	a3	a4	a5
a1		-0.067	0.133	0.033	0.233
a2	0.5		0.3	0.1	0.3
a3	0.2	-0.15		-0.1	0.1
a4	0.5	0	0.3		0.3
a5	0.2	-0.15	0	-0.15	
Max Regret:	0.5	0	0.3	0.1	0.3

Fig. 8. VIP Analysis Software – Confrontation

The maximum difference of value by which an alternative can lose to another is presented in the line "Max Regret" (maximum regret). The best alternative suggested by this result is the one that has the lowest Max Regret. If Max Regret is equal to zero or even negative, that would mean that the alternative was better than all other for all vectors of weights complying with the given ranking.

The lowest value of each alternative (Min Value) and the highest value of each alternative (Max Value) are presented in a Range Map (Fig. 9). The difference between these values shows how much each alternative's value depends on eliciting further constraints on the weights: uncertainty for A2, for instance, is much less than uncertainty about the value of A1.

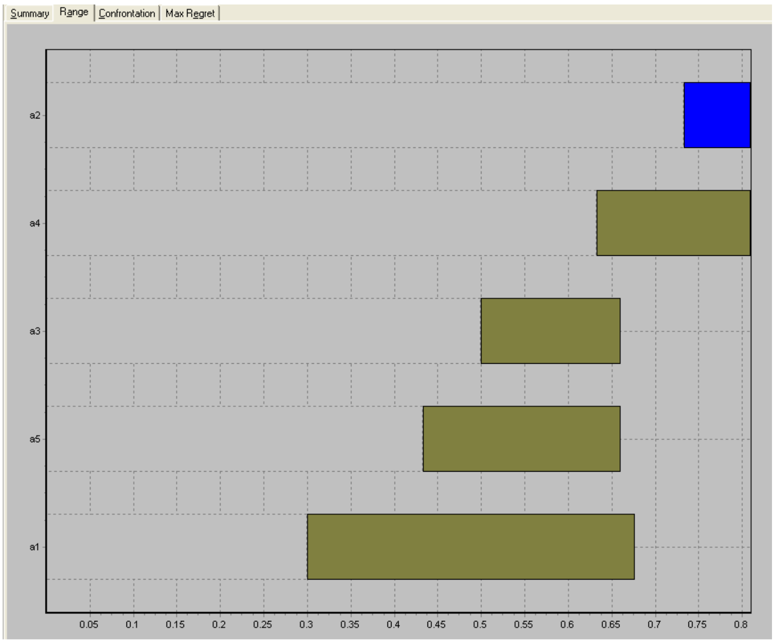

Fig. 9. VIP Analysis Software – Range Map

5 Assessment of the effects of actions on the problems and the effects of the intervention

The evaluation of the effects of the actions, and the intervention were the final stages of the Problem-solving Cycle and the Research Cycle in AR (McKay and Marshall, 2001). The researcher made these evaluations by using an application form in which the DMs could evaluate the process of decision support and the use of VIP Analysis software.

According to the DMs' evaluations, this study brought a new and interesting knowledge about a structured decision making process and the tools can be used in future decision problems.
DMs considered that the process was extremely rich in terms of knowledge transfer and that this knowledge will allow them to better defend the adoption of the alternative indicated by the VIP Analysis software in CONSUNI.

The VIP Analysis software was considered a very good tool, especially because it accepted imprecise information and the DMs did not need to assign weights to their preferences, but only to rank them. However the software was considered difficult to be used, requiring greater interactivity with the users and also an online help.

Recognizing that there is a practical difficulty in evaluating the effectiveness of group process and therefore the quality of their cognitive map, Montibeller (1996) recommends an indirect evaluation of effectiveness through observation of symptoms associated with groupthink or teamthink. Based on this recommendation, the researcher developed an evaluation form of the effectiveness of group and used the technique of observation to assess if in this intervention had any symptom of groupthink or teamthink, according to Neck and Manz (1994). This analysis is presented in Table 8 and its conclusions are indicated in section 7.

Table 8 – Analysis of the symptoms of groupthink in this intervention

Symptoms of groupthink (GT)	Symptoms of teamthink (TT)	What was observed in this intervention
Direct social pressure against a member of the group who opposes values and beliefs shared by the group	Encouragement of divergent views	It was not detected any GT or TT symptom because there were no strong differences among the group members.
Self-censorship of thoughts or concerns whose members deviate from the consensus of the group	Opening to express concerns and ideas	The researcher noticed the GT symptom when that the group did not want to talk about their opinions when the president of COPEVE was not present.
Illusion of invulnerability to failure, in the group.	Concern about limitations / threats	The group did not show feel infallible, since on several occasions it stressed the possibility of divergent opinions.
Shared illusion of unanimity	Recognition of the uniqueness of its members	In most cases the group has unanimous views on the problem analyzed, showing a potential symptom of GT
Self-supervised creation of minds, they disregard information from outside the group	-----------------------------	The group consistently had information arising from cases in other federal universities, not showing this GT symptom.
Collective efforts to rationalize	Discussion of collective doubts	This effort was very intense in the group, mainly because it is a decision problem with qualitative data. The group did not discuss questions of its members.
Stereotyped views of enemy leaders of other organizations, or segments of the organization as weak or incompetent	-----------------------------	This symptom of GT was clearly seen. The group has restrictions on political issues at the federal level involving the problem and they thought these were inappropriate.
Belief, unquestionably, on the group's inherent morality	-----------------------------	This symptom of GT was also clearly seen. The group demonstrated belief that their opinions were indeed the most correct on the point of view of social interests of the community of Alagoas.

The final decision of this problem was taken by CONSUNI: the selection process for admission to undergraduate courses of UFAL should occur in single phase only based on the outcome of ENEM.

According to the COPEVE team, the difference between the partial COPEVE decision (alternative 2 of this problem) and the final decision of CONSUNI (A1) is mainly because COPEVE value the process of regionalization of entry into public universities, while the other members consider that the unified test throughout the country would be an advantage to students from all over the country because it would ensure greater mobility (eg, a candidate can take exam in Alagoas and compete for a place at a university in another state), but it may also run simultaneously to two universities.

The researcher learning is very important in AR method. As a research process, this intervention was very useful because the researcher could see details, especially in the structure of CMs, which had not recognized in a prior intervention with Top Atlântico (Ventura et al., 2010), whose data were entirely quantitative.

Because of the large number of qualitative data of this intervention, , which portrayed personal opinions, and therefore with a strong context of subjectivity, the researcher had to be more investigative, trying to turn this subjectivity in more analytical data (i.e the description of levels of impact presented in section 4.4).

6 Rectifications of the Research Plan

In this intervention the researcher developed two new forms to be used in the next interventions: to describe the levels of impact of qualitative descriptors and to analyse the symptoms of GT and TT of the intervention.

To improve the research plan and compare this intervention with the a future one, the researcher intends to use CMs for each individual component of a group and make the congregation of the CMs later, using aggregation mode, according to Belton and Pictet (1997).

7 Conclusions

According to AR method the researcher not only observed the decision process in this intervention, but had an intensive participation, training DMs on the subjects under study, applying group dynamics, giving opinions, etc.

It was surprising that, according to Table 8, the DMs did present symptoms both of groupthinking and teamthinking. The symptoms of groupthink were more common, but at times the group also showed symptoms of teamthinking: For example, the group did not feel invulnerable to failure, which may have occurred by the fact that this group would not be effectively responsible for the final decision on the problem evaluated, but was only in the process of forming an opinion that would make a vote on the final decision process. The group also took into account information (including divergent information) arising out of cases from other federal universities, which certainly does not reflect a groupthink

So, in this intervention was possible to observe that the use of AR, with the intense participation of the researcher, the use of NGT and some group dynamics to awake the lateral thinking could provide a greater effectiveness to the process of group decision making, minimize the groupthinking and obtaining a satisfactory representation of the perspectives of actors in the group CM. In other words, with this intervention the researcher concluded that is not necessarily a link between groupthink and a poor representation of the CM. This depends on the attitudes of the group leader and how the process is developed by the researcher.

The use of CM as a PSM and MAUT to develop value functions demonstrated to be a good choice to structure decision problems to be evaluated by VIP Analysis software. However it is necessary to analyze the use of a group CM in aggregation mode to define what mode is better to use in this process. This would be the next "round" of the two AR cycles of this study.

References

Bana e Costa, C. (1992), Structruration, construcion et explotation d'une modèle d'aide à la décision, *PhD Thesis of Universidade Técnica de Lisboa*. Lisboa, PT.

Belton V, Pictet J (1997), A framework for group decision using a MCDM model : sharing, aggregating or comparing individual information, *Journal of Decision Systems*, 6, 283-303.

Brightman, J. R. (2002), An introduction to Decision Explorer, *Banxia Software Ltd*, (available online at http://www.banxia.com/dexplore/pdf/DEIntro1.pdf)

De Bono, E. O. (1995). O Pensamento Lateral. Rio de Janeiro, *Record*, 2ª edição.

Delbecq, A. L.; Van de Vem, A.H. (1971). A group process model for problem identification and program planning. *Journal of Applied Behavioral Science*. 7, 466-492.

Dias, L., Climaco, J. (2000), Additive Aggregation with Variable Interdependent Parameters: The VIP Analysis Software. *Journal of Operational Research Society*, 51 , 1070-1082

Eden, C. (1988), Cognitive Mapping. *European Journal of Operational Research*, 36 , 1-13.

Eden, C., Huxham, C. (1996), Action Research for Management Research, *Journal of Management* , 7) , 75-86.

Eden, C., Jones, S., Sims, D. (1983), Messing about problems., *Pergamon.Oxford*, UK.

Edwards, W., Barron, F.H. (1994), SMARTS and SMARTER: improved simple methods for multiattribute utility measurement, *Organizational Behavior and Human Decision Processes* 60, 306-325.

Ensslin, L., Montibeller Neto, G., Noronha, S. (2001), Apoio à Decisão – Metodologias para estruturação de problemas e avaliação multicritério de alternativas, *Editora Insular*, Florianópolis/Santa Catarina – Brasil.

Fischhoff, B., Slovic, P. Lichtenstein, S. (1998), Knowing what you want: measuring labile values. In: Bell, D. E., Raiffa, H., Tversky, A. (Eds.) *Decision Making: Descriptive, Normative and Prescriptive Interactions*, p. 398-421.

Janis, I. (1972), Victims of groupthink. Boston: *Houghton Mifflin*.

Janis, I. (1982), Groupthink. Boston: *Houghton Mifflin*.

Keeney, R.L. (1992), Value-Focused Thinking: A Path to Creative Decisionmakin, *Harvard University Press*, Cambridge, UK.

Keeney, R. Raiffa, H. (1976), Decisions with Multiple Objectives: Preferences and Value Tradeoffs, *Wiley*, New York - USA.

Marmol, A., Puerto, J., Fernandez, F. (1998), The Use of Partial Information on Weights in Multicriteria Decision Problems, *Journal of Multicriteria Decision Analysis*, 7, 322-329.

Mckay, J., Marshall, P. (2001), The Dual Imperatives of Action Research, *Information Technology & People*, 14, 46-59.

Montibeller, G. (2007), Action Researching MCDA Interventions. 49th *British Operational Research Conference (OR 49)*, Edinburg: OR Society.

Montibeller Neto, G. (1996), Mapas Cognitivos: Uma Ferramenta de Apoio à Estruturação de Problemas, *Dissertação de Mestrado da Universidade Federal de Santa Catarina*, Santa Catarina-Brasil.

Neck, C., Manz, C. (1994), From groupthinking to teamthinking: toward the creation of constructive thought pattern in self-managing work teams. *Human Relations*, v. 47, n. 8, pp. 929-951.

Rodrigues, M.V.C. (2004), Ações para a qualidade: GEIQ, gestão integrada para a qualidade: padrão seis sigma, classe mundial. Rio de Janeiro: *Qualitymark*.

Roy, B. (1996), Mulcriteria Methodology for Decision Aiding. *Kluwer Academic Plublishers*, Netherlands,

Tversky, A. (1996), Contrasting rational and psychological principles of choice. In Zeckhauser, R. J., Keeney, R. L., Sebenius, J. K. (Eds.) *Wise Choises*. Boston: Harvard Business Scholl Press, p. 5-21.

Ventura, A., Dias, L., Clímaco J.N. (2010), Using Action research on the process of decision support with VIP Analysis software. in: A. Respício, F. Adam, G. Phillips-Wren, C. Teixeira, J. Telhada (eds), Bridging the Socio-technical Gap in Decision Support Systems - Challenges for the Next Decade, *IOS Press*, Amsterdam, pp. 259-270.

A Probabilistic Strategy for Real Time Iterative Group Decisions

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Abstract: A methodology to deal in real time with the choice problem by a group of decision makers is here explained. The first step of such methodology consists in obtaining vectors of imprecise individual evaluations, possibly given in a Likert scale, and transforming such vectors into vectors of probabilities of being ranked as the best choice. Another important feature of the methodology is the probabilistic composition of such individual vectors of probabilities into global vectors of preferences by different composition approaches. The transformation of the initial evaluations into probabilities is based on treating the observed evaluations as values of random variables.

Keywords: group decision. composition of probabilistic preferences. multicriteria decision making.

1 Introduction

The ability to deal with imprecise subjective information is particularly important when the speed in reaching a group decision and start action is impending. The key issue is then to choose an automatic rule for determining the aggregate ranking, that is, a fast composition rule. This composition mechanism must be able to rank the possible options for those people in charge of making a final choice and must be sensitive to inconsistencies and contradictions in such a way as to provide indications on the need of additional efforts to revise the evaluations before concluding the decision process.

This can be done by ranking the options by two distinct approaches to combine the individual evaluations. The differences between the results of the application of these two composition rules will filter discrepant evaluations of decision makers which may be asked to impart information to be added in a next round of individual evaluations.

The mechanisms of composition here considered are those of the probabilistic composition proposed in Sant'Anna (2002). The main advantage presented by this approach is that it takes into account the imprecision in the evaluations given. After the problem is precisely formulated, a small list of options easy to deal with is offered for the fast consideration of the decision makers. Filling mistakes may occur in the quick answer by such decision makers. The probabilistic approach starts by the transformation of such initial evaluations into probabilities by taking the values prompted by the decision makers in their evaluation sheets, not as definitive numbers but as location parameters of probability distributions. The statistical model is completed by assumptions of independence and form of the distributions.

Each vector of initial individual evaluations is then replaced by a vector of probabilities of each option being that with the highest preference in a replication of the same data generation process. These probabilities of being the best option according to each decision maker are then combined into a unique vector as a joint evaluation of the group.

The two forms of composition are determined by two opposite points of view, a pessimistic point of view that takes as the global score the probability of being preferred by all the individual evaluations and an optimistic point of view that takes as the global score the probability of reaching such extreme position according to at least one of the decision makers.

This work is divided into 5 sections. The next section discusses the main features of the group decision problem envisaged. Section 3 presents a review of the main points of the different composition approaches applied. Section 4 compares the results of the application of the different methods to enlightening cases. Section 5 brings final comments.

2 The Decision Problem

Communications and data-transfer capabilities have improved dramatically in the last years the ability to formulate problems as they are rising and to bring together answers. The speed in setting and combining information allows for iteratively validating those data sets that are shown to be important by the results generated. What is missing is the bridge to automatically relate information to decision (Larson, 2010; Walk, 2011; Sant'Anna et al., 2012).

The members of a group making a decision may disagree about the ranking of a set of options because they disagree about which options are more likely to lead them to their common goal. There is a correct ranking, in the sense that some options are really more likely than others to lead the team of evaluators to such goal. But there is not enough time to discuss the problem to make clear what is the correct reasoning and the individual evaluations are noisy estimates of the correct values. The objective of the composition technique is then to find an aggregate ranking that is as close as possible to the correct ranking, based on such noisy estimates.

Classical multiple criteria decision algorithms usually present judgments as exact numerical values. On the other hand, information about the options is often imprecise or the decision makers can only give approximate, incomplete or not well-defined information. The presence in the decision team of people affected by the results of the decision or more directly involved on some less accessible aspect of the problem may be as important as that of specialists in critical aspects of the decision. This is the case of patients to be submitted to a medical treatment or the parents of a small child in a nursery or the relatives of old people and mental patients assisted by social agents. Such participants may counterbalance the lack of technical information by a deeper knowledge of the real case. If they are really unable to a proper contribution, we may expect that they will throw less distinct answers in the information sheets. We may take this as a general rule and include in the decision model a way to take into account precision and variability.

Another point that justifies the use of a probabilistic approach is that the evaluation frequently involves qualitative attributes. To deal with problems such as imprecision and subjectivity in measurements, Fuzzy Sets theory (Zadeh, 1965) provides a basis simple to operate and easy to understand. Employing fuzzy evaluations may help resolve some difficulties frequently encountered in decision-making when it makes sense to think of each evaluation as a noisy estimate. Replacing crisp numbers by membership intervals, the fuzzy approach mainly allows for reducing the effects of imprecision in human judgment while searching for the optimal decision.

But the application of fuzzy logic (Zadeh, 1978) may yield some loss of information in multiple criteria composition. It applies principles of sufficiency and necessity to combine the information which lead to disregard the contribution of less definite evaluations. On the contrary, the probabilistic composition under the assumption of independence between the stochastic disturbances affecting the evaluations set by the individual evaluators allows for the combination of the observed values in a multiplicative form, in such a way as taking all of them into account.

The derivation of the probabilities from the observations starts like the transformation of crisp numbers into membership intervals in Fuzzy Sets theory. As a general rule, a Likert scale (Likert, 1932) of nine points is used by the evaluators to translate their judgement into values from 9 to 1. These values are taken as the mode of triangular distributions with extremes at 10 and 0.

An alternative approach would consist of, instead of assuming fixed extremes, obtaining the extremes of each evaluator distribution by adding one to the highest and subtracting one from the lowest value chosen by that evaluator. This second approach is easier to extend to other composition methods, but it disregards the information present in the admission of the possibility of extreme evaluations. Both approaches are considered in this work.

Example of a practical context where the probabilistic composition of probabilities of reaching fixed extremes may be iteratively employed to improve comparison is that of Failures Modes and Effects Analysis - FMEA (US Army, 1949). This procedure is based on ranking potential failures according to a risk priority number obtained by classifying them into levels of importance and multiplying the numbers representing such levels. The criteria considered, of severity, frequency and indetectability of the failure, are assumed to be applied independently. The levels of importance are previously defined in such a way that the criteria may present much diverse variability. The procedure may be applied in a project or production context. In the second case a fast decision context is characterized.

In any case, the joint probability of maximizing the three risk levels advantageously replaces the risk priority number. Assuming independence both are computed by direct multiplication but the risk priority number will be higher, for instance, for a failure classified in the levels 2, 2 and 2 than for a failure classified in the levels 5, 1 and 1, while the product of the probabilities of maximizing the levels will be larger in the second case, specially if no failure is classified on high levels according to the two last criteria and the probabilities are computed for distributions with absolute bounds.

Besides, while FMEA takes only a pessimistic point of view by multiplying the three levels of risk, the comparison with the results of the optimistic composition is useful to help dealing with the problem of assuring independent evaluations according to each criterion. A frequent problem in the practice of FMEA is that of the evaluators increasing the level assigned to some risk to match the high classification given according to another criterion. This will raise the product employed in the pessimistic approach. The comparison to the ranking derived from the optimistic approach will automatically call attention to that.

The probability of being preferred in the probabilistic composition plays a similar role to the distance to a frontier in DEA (Charnes et al., 1978). Since DEA distances are calculated to a frontier formed by observed values, comparing probabilistic scores to the scores resulting from DEA models with constant inputs may be useful to highlight the advantage of fixing the extremes of the distributions, though, in practice, DEA efficiency scores include a large number of fully efficient tied options, making DEA less suitable for the fast selection of one option.

3 The Probabilistic Procedures

We deal here with the following framework. A set O of n options, $O_1, \ldots , O_n$, from which one is to be chosen and a set C of m decision makers or criteria applicators, $C_1, \ldots , C_m$. The *j-th* decision maker presents for the *i-th* option an evaluation e_{ij}.

For this set O of options and the set C of decision makers, a preferences composition rule is a mapping F that derives from the matrix E_{nXm} of individual evaluations e_{ij} a vector $(F(E)_1, \ldots, F(E)_n)$ of preferences for the n options. An option i for which $F(E)_i \geq F(E)_k$ for all k from 1 to n is a most preferred option for the preferences composition rule F and the matrix of individual preferences E. The idea behind such composition rule is to provide the decision makers group with preference values in such a way that, considering the values assigned to the preferred options and to those options with values close to it, a unique final option may be chosen. To call attention to discrepancies between the m evaluators preferences, the decision strategies here proposed are based on the comparison of the results of the application of a pair of such preference composition rules.

From $e_j = (e_{1j}, \ldots , e_{nj})$, the vector of evaluations according to the j-th evaluator, for each j, is derived a vector of vector of probabilistic preferences $P_j = (P_{1j}, \ldots , P_{nj})$. The probabilistic preference P_{ij} is given by the probability of, in a hypothetical vector of observations of n random variables $(E_{1j}, \ldots , E_{nj})$ with independent triangular distribution of extremes e_{0j} and e_{Lj} and modes respectively at $e_{1j}, \ldots , e_{nj}$, $E_{ij} \geq E_kj$ for all k from 1 to n.

Two cases of extremes for the triangular distributions will be compared here. First it will be assumed, for all j, e_{0j}=0 and E_{Lj}=10, in the case of the initial evaluations given in a Likert scale of 9 points and E_{Lj}=6, in the case of the initial evaluations in a Likert scale of 5 points. Alternatively, it will be assumed $e_{0j} = \min\{e_{1j}, \ldots , e_{nj}\}–1$ and $e_{Lj}=\max\{e_{1j}, \ldots, e_{nj}\}+1$.

The key computation in the evaluation of the probabilistic scores is the determination of the probabilities of each option being preferred to all the others. The probability of considering a particular option as the best one is a natural measure of the decision maker preference for that option. To compute the probabilities of being the best option all we need is a statistical measure of the uncertainty on each measurement.

To compensate the lack of empirical information on the probability distributions, simplifying and equalizing assumptions are the essence of Fuzzy Sets Theory. In the present situation, imposing analogously assumptions of independence between the disturbances affecting the different observations and, for the form, a triangular distribution with the same set of possible values, will provide the necessary framework. Thus, the transformation into probabilities of being ranked first starts here with the evaluation by each evaluator separately in a Likert scale. The imprecision in such evaluations is modeled by considering them as modes of triangular distributions with extremes at 0 and 10. Alternatively, extremes at the maximum value assigned by the evaluator plus 1 and the minimum minus 1 are considered.

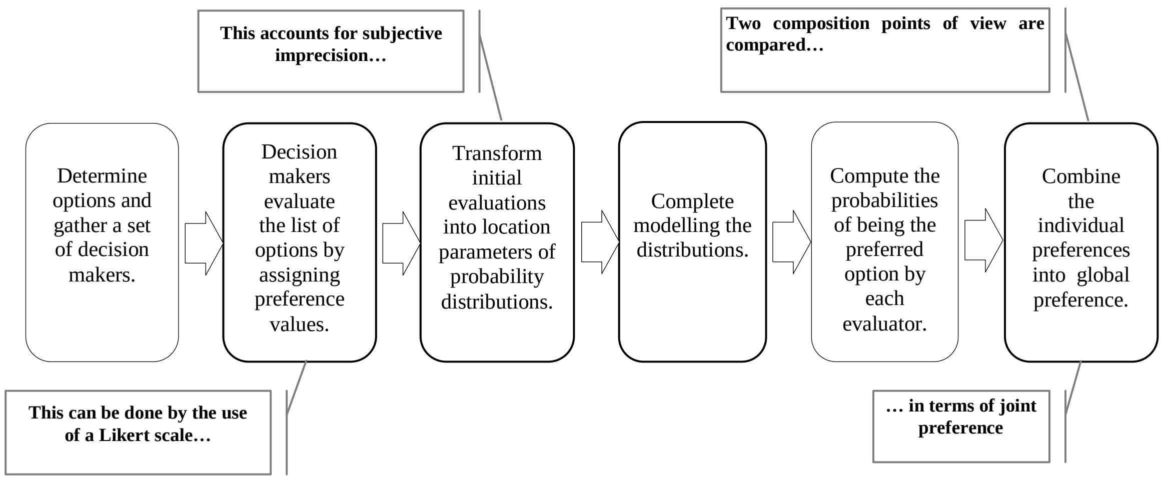
In both cases, these triangular distributions assign to good evaluations a larger probability of being biased towards the extreme of best evaluations while bad evaluations are assigned a larger probability of being biased towards the extreme of worst evaluations. But with absolute extremes flatter densities are generated, which result in more homogeneous vectors of probabilities of being the best, while in the second case the reduction in the range of the triangular distributions increases the effect of small differences in the evaluations.

After computing the probabilities of being the preferred option of each evaluator, it is easy to combine them into a unique measure of global preference. A way to do that consists of treating these probabilities as conditional on the choice of the respective evaluator and computing the total probability of preference by adding the products of these conditional probabilities by the probabilities of choice of each evaluator. The difficulty in this approach is to determine marginal probabilities of each evaluator being chosen.

Another strategy to combine the probabilistic preference is in terms of joint preference. The probabilities of attaining the first position in a replication can be combined into global measures without the need of assigning weights to the evaluators. Different joint probabilities may be employed, depending on the point of view adopted.

Two different points of view may be characterized in terms of choice between an extremely optimistic and an extremely pessimistic position. The optimistic approach consists of considering the choice by no more than one evaluator satisfactory. All evaluators are taken into account, but the joint probability computed is that at least one of them prefers the option. The composition employs the connective ‘or’. On the opposite end, the pessimistic preference goes for options that satisfy every evaluator. The connective is ‘and’. The joint probability computed is that of maximizing simultaneously the preferences of all the evaluators. The terms optimistic and pessimistic are related to the idea of confiding that the most favorable or the less favorable evaluator, respectively, will prevail.

The illustration bellow summarizes the probabilistic procedure.



4 Comparison of Model Assumptions

Two small examples are discussed in this section to enlighten the differences between the probabilistic composition with triangular distributions with fixed bounds and with bounds depending on the range of observed values.

The values assigned to three options O_1, O_2 and O_3 by three evaluators C_1, C_2 and C_3 are given in Table 1. For each i and j from 1 to 3, let us denote by C_{ij} the random variable associated to the evaluation of O_i by C_j. It may be there important to notice that the first evaluator has evaluated O_1 as very good, what corresponds to assign to C_{11} a mode of 9 and O_2 as very bad (mode 1 for C_{21}), while the other two evaluators, who are responsible for the global preference for O_2, evaluate this option as good (C_{22} and C_{32} with mode 7). One of them evaluates O_1 as regular (mode of C_{21} equal to 5) and the other evaluates it as very bad (mode of C_{31} equal to 1). O_3 is evaluated as very bad by C_1 and C_3 but is better evaluated by C_2 than O_1.

Assuming the observed values as the modes of independent triangular distributions with extremes at 0 and 10, the probability of the first option being the best for the first evaluator P[C_{11}>C_{21} and C_{11}>C_{31}] is the probability that a random variable with a triangular distribution of mode 9 and extremes 0 and 10 presents a value larger than that of two other independent triangular random variables both with extremes 0 and 10 and mode 1. The probability of O_2 being preferred by C_1 will be P[C_{21}>C_{11} and C_{21}>C_{31}] and the probability of O_3 being preferred by C_1 will be P[C_{21}>C_{11} and C_{21}>C_{31}], both give by the probability of a random variable with a triangular distribution of mode 1 and extremes 0 and 10 presenting a value larger than that of two other independent triangular random variables both with extremes 0 and 10, the first with mode 9 and the other with mode 1. Analogously for the other two evaluators.

Making the computations, these probabilities of being preferred by each evaluator are the values in the second, third and fourth columns of Table 2. Notice that theses values add to 1.

The scores derived from the pessimistic and from the optimistic approaches, are shown in the two last columns. By the pessimistic approach, the global preference by O_1 is the product of the probabilities of it being preferred by each evaluator, i. e,

$$P[C_{11}>C_{21} \text{ and } C_{11}>C_{31}] * P[C_{12}>C_{22} \text{ and } C_{12}>C_{32}] * P[C_{13}>C_{23} \text{ and } C_{13}>C_{33}]. \quad (1)$$

Numerically, 0.680 * 0.183 *0.331 = 0.041. Proceeding analogously for O_2 and O_3, the two last values of the fifth column are obtained.

By the optimistic approach, the global score of preference for O_1 is the probability of being preferred by at least one of the evaluators,

$$1–(1\text{-}P[C_{11}>C_{21} \text{ and } C_{11}>C_{31}])*(1\text{-}P[C_{12}>C_{22} \text{ and } C_{12}>C_{32}]*(1\text{-}P[C_{13}>C_{23} \text{ and } C_{13}>C_{33}]). \quad (2)$$

Numerically, 1-(1-0.680)*(1-0.183)*(1-0.331)=0.825. The two last values of the last column of Table 2 analogously give the optimistic scores for O_2 and O_3.

The discordance between the optimistic and the pessimistic vectors of scores reveals the difficulty of the choice. The pessimistic approach gives a heavier importance to the fact that two evaluators prefer O_2 against only one preferring O_1. The optimistic approach disagrees. Based on the probability of preference by at least one evaluator, it gives higher importance to the influence of the inner differences within the vectors of individual evaluations.

But this will happen only if the extremes are fixed at 0 and 10. If we apply the rule of setting the extremes of the distribution of each evaluator at a distance of 1 from the highest and lowest of such evaluator initial evaluations, the probabilities of preference are those in Table 3. There, it is seen a final preference for O_2, whether an optimistic or a pessimist approach is adopted. This happens because, as the possibility of the two last evaluators considering an option as very good is not taken into account, their classification of good for O_2 is enough to place this option in an effectively very good standing.

Table 1. Evaluations of 3 Options by 3 Evaluators.

	C_1	C_2	C_3
O_1	9	1	5
O_2	1	7	7
O_3	1	3	1

Table 2. Probabilistic Composition – Fix Bounds.

	C_1	C_2	C_3	pessimistic	optimistic
O_1	0.680	0.183	0.331	0.041	0.825
O_2	0.160	0.564	0.507	0.046	0.819
O_3	0.160	0.253	0.162	0.007	0.474

Table 3. Probabilistic Composition – Adjusted Bounds.

	C_1	C_2	C_3	pessimistic	optimistic
O_1	0.680	0.150	0.324	0.049	0.830
O_2	0.160	0.621	0.550	0.056	0.861
O_3	0.160	0.230	0.126	0.005	0.445

The same inversion occurs if a Likert scale of 5 points is applied with more distant extremes 0 and 6, for the case of fixed extremes. The results are in Tables 4 and 5.

Table 4. Probabilistic Composition – Values from 1 to 5 – Bounds at 0 and 6.

	C_1	C_2	C_3	pessimistic	optimistic
O_1	0.637	0.201	0.337	0.043	0.808
O_2	0.181	0.531	0.482	0.046	0.801
O_3	0.181	0.268	0.181	0.009	0.509

Table 5. Probabilistic Composition – Values from 1 to 5 - Bounds at 1 from Observed.

	C_1	C_2	C_3	pessimistic	optimistic
O_1	0.637	0.175	0.334	0.037	0.801
O_2	0.181	0.573	0.515	0.053	0.830
O_3	0.181	0.252	0.152	0.007	0.480

The second example has eight options for eight decision makers. To make it more realistic, consider the hospital admission problem with a health care team with different specialties called to choose among possible courses of action to treat a patient with a head injury. Options and evaluators are listed below.

O_1: Intensive care unit immediate admission
O_2: Immediate admission, preferably in intensive care unit
O_3: Immediate admission, not in an intensive care unit
O_4: Admission depending on immediate clinical tests
O_5: Admission depending on clinical tests, not immediate
O_6: Admission denied, immediate clinical tests requested
O_7: Admission denied, long run clinical tests requested
O_8: Admission and tests discarded
C_1: General practitioner

C_2: Neurologist
C_3: Nurse
C_4: Physiotherapist
C_5: Psychiatrist
C_6: Psychologist
C_7: Social Worker
C_8: Stretcher Bearer

Suppose the initial evaluations are those in Table 6.

Table 6. Evaluations of 8 Options by 8 Evaluators.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
O_1	3	5	1	7	1	1	7	9
O_2	3	9	1	7	1	1	9	7
O_3	5	1	1	7	1	1	1	1
O_4	5	9	3	3	1	1	3	1
O_5	5	3	3	3	1	1	3	1
O_6	7	1	5	1	5	5	1	1
O_7	9	1	7	1	7	7	1	1
O_8	1	1	3	1	1	3	1	1

The problem is effectively difficult as evaluators C_1, C_3, C_5 and C_6 strongly disagree of evaluators C_2, C_4, C_7 and C_8. It is also important to notice that C_7 and C_8, who belong to this second group of evaluators, strongly favor options O*1* and O*2*, while the other evaluators show less definite preferences. Besides, in the first group two evaluators, C_5 and C_6 refrain from evaluating any option as very good, while in the second group only one evaluator does not classify any option as very good. At the lower end, many 'very bad' options are always found.

An alternative not explored here due to the difficulty of valuing decision makers would consist on applying an additive rule. In that case, with or without probabilistic transformations, any weighting that does not give the highest weights to evaluators C_7 and C_8 will result in a higher global score for O_7.

The probabilistic composition, notwithstanding, presents, like in the previous example, different results as the optimistic or the pessimistic approach is taken. The same happens as we take the Likert scale of 9 points (Table 7) or that of 5 points (Table 8), what corresponds, as was already pointed out, to just shorten or enlarge distances to the frontier.

The inversion will not happen if the higher extreme is set at 8, in the case of the Likert scale of nine points, for those evaluators who do not find any option very good (Table 9), or, in the scale of 5 points, is set at 5 for those evaluators with a highest evaluation of 4 (Table 10). In that case, will prevail the choice of option O_7.

Thus, the probabilistic composition with fixed extremes will be the only method calling attention to O_2. Although O_7 would be the option taken by more evaluators, the preference for this option by C_7 and the evaluation of C_8, who classifies it as good and classifies O_1 as very good, implying an even higher evaluation of the severity of the injury, provide strong basis to ask for a clarification of these votes, that may result in important changes in the case formulation.

Table 7. Probabilistic Composition of 8 evaluators – 9 points - Fix Bounds.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	pessimistic	optimistic
O_1	0.070	0.117	0.082	0.212	0.089	0.087	0.208	0.384	0.000000087	0.76
O_2	0.070	0.199	0.082	0.212	0.089	0.087	0.372	0.217	0.00000015	0.78
O_3	0.101	0.061	0.082	0.212	0.089	0.087	0.063	0.067	0.0000000035	0.56
O_4	0.101	0.362	0.108	0.085	0.089	0.087	0.083	0.067	0.000000014	0.67
O_5	0.101	0.080	0.108	0.085	0.089	0.087	0.083	0.067	0.0000000032	0.52
O_6	0.174	0.061	0.159	0.065	0.174	0.169	0.063	0.067	0.000000018	0.63
O_7	0.331	0.061	0.270	0.065	0.292	0.284	0.063	0.067	0.00000012	0.81
O_8	0.053	0.061	0.108	0.065	0.089	0.115	0.063	0.067	0.00000000097	0.48

Table 8. Probabilistic Composition of 8 Evaluators – 5 Points - Fix Bounds.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	pessimistic	optimistic
O_1	0.079	0.123	0.088	0.199	0.095	0.092	0.199	0.337	0.000000099	0.74
O_2	0.079	0.191	0.088	0.199	0.095	0.092	0.326	0.208	0.00000016	0.76
O_3	0.108	0.070	0.088	0.199	0.095	0.092	0.073	0.076	0.0000000064	0.57
O_4	0.108	0.317	0.113	0.093	0.095	0.092	0.093	0.076	0.000000022	0.66
O_5	0.108	0.089	0.113	0.093	0.095	0.092	0.093	0.076	0.0000000062	0.55
O_6	0.169	0.070	0.157	0.073	0.170	0.165	0.073	0.076	0.000000021	0.64
O_7	0.287	0.070	0.242	0.073	0.261	0.254	0.073	0.076	0.00000013	0.78
O_8	0.062	0.070	0.113	0.073	0.095	0.119	0.073	0.076	0.0000000022	0.51

Table 9. Probabilistic Composition of 8 Evaluators – 9 Points - Adjusted Bounds.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	pessimistic	optimistic
O_1	0.070	0.117	0.066	0.249	0.073	0.070	0.208	0.384	0.000000054	0.76
O_2	0.070	0.199	0.066	0.249	0.073	0.070	0.372	0.217	0.000000093	0.78
O_3	0.101	0.061	0.066	0.249	0.073	0.070	0.063	0.067	0.0000000022	0.55
O_4	0.101	0.362	0.095	0.062	0.073	0.070	0.083	0.067	0.0000000060	0.64
O_5	0.101	0.080	0.095	0.062	0.073	0.070	0.083	0.067	0.0000000013	0.48
O_6	0.174	0.061	0.168	0.043	0.187	0.180	0.063	0.067	0.000000011	0.64
O_7	0.331	0.061	0.351	0.043	0.377	0.368	0.063	0.067	0.00000018	0.87
O_8	0.053	0.061	0.095	0.043	0.073	0.102	0.063	0.067	0.00000000041	0.44

Table 10. Probabilistic Composition of 8 evaluators – 5 Points - Adjusted Bounds.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	pessimistic	optimistic
O_1	0.079	0.123	0.076	0.226	0.083	0.080	0.199	0.337	0.000000074	0.74
O_2	0.079	0.191	0.076	0.226	0.083	0.080	0.326	0.208	0.00000012	0.76
O_3	0.108	0.070	0.076	0.226	0.083	0.080	0.073	0.076	0.0000000048	0.57
O_4	0.108	0.317	0.104	0.077	0.083	0.080	0.093	0.076	0.000000013	0.64
O_5	0.108	0.089	0.104	0.077	0.083	0.080	0.093	0.076	0.0000000036	0.52
O_6	0.169	0.070	0.165	0.056	0.181	0.175	0.073	0.076	0.000000019	0.65
O_7	0.287	0.070	0.297	0.056	0.320	0.312	0.073	0.076	0.00000018	0.82
O_8	0.062	0.070	0.104	0.056	0.083	0.111	0.073	0.076	0.0000000013	0.48

5 Conclusion

The cases studied here enlighten the advantage, in the choice considering multiple criteria, of evaluating the options in terms of probabilities of being preferred and of using as bounds for the probability distributions the most extreme possible values.

The probabilistic composition, whenever it bases the scores on the comparison of probability distributions with such bounds take all these distances into account in a sound basis given by the probabilistic distances to the frontiers. It can be observed in the two examples that the heavier tails induced by taking into account the possibility of values more definite than those observed place the measurements in more reliable scales. It can also be seen how the transformation into probabilities of preference accentuates the distances between the most preferable options, bringing to evidence options preferred by a small number of evaluators.

It could finally be illustrated the advantage of basing the decision on comparing the results of an optimistic and a pessimistic approach to the composition of probabilities of being ranked first of allowing for tracking the effect of extreme evaluations of some evaluators.

References

Charnes, A., Cooper, W. W., Rhodes, E. (1978), Measuring the efficiency of decisionmaking units. *European Journal of Operational Research*, 2, 429-444.

US Military (1949), *Procedures for Performing a Failure Mode, Effects and Criticality Analysis*, United States Military Procedure MIL-P-1629.

Larson, A. (2010), The Impact of Computer Decision Support on Military Team Decision Making. *Dissertation*. University of Minnesota, Minneapolis, USA.

Likert, R. (1932), A Technique for the Measurement of Attitudes. *Archives of Psychology* 140, 1–55.

Sant'Anna, A. P. (2002), Data Envelopment Analysis of Randomized Ranks. *Pesquisa Operacional*, 22, 203-215.

Sant'Anna, A. P., Nogueira, H. D., Rabelo, L. M. (2012), Probabilistic Composition for Fast Group Decision, *Brazilian Journal of Operations and Production Management*, 8, in press.

Walk, S. (2011), A new fast reliable filtering method for multicriteria decision making. *Management Decision*, 49, 810-822.

Zadeh, L. A. (1965), Fuzzy sets. *Information and Control*, 8, 338–353.

Zadeh, L. A. (1978), Fuzzy Sets as the Basis for a Theory of Possibility. *Fuzzy Sets and Systems*, 1, 3-28.

A Multi-criteria Approach To Cost-Sustainable Service Decisions Analysis of a Set of Infrastructure Transportation Projects

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Abstract: Brazil has progressed in the areas of carbon emission, green energy and biodiversity protection. This study includes all of these variables in order to create a procedure to help decision-makers set priorities for transportation infrastructure in Brazil. Multi-criteria and other qualitative methods available in the academic literature were used to create the procedure. The case study presented shows a real life situation of the Brazilian Government Agency choosing priorities for transportation infrastructure.

Keywords: Multi-criteria methods; TOPSIS; AHP; Cross-Impact method; Transportation infrastructure; Qualitative analysis.

1 Introduction

Transportation systems are an important agent of sustainable economic development. They involve: (a) planning a cost-sustainable passenger and freight transportation matrix, not only by lowering operating costs, and tariffs but also by improving the quality and flexibility of the service; (b) energy efficiency and reduced environmental impact; (c) functionality and access to network connections such as ports, airports, roads, railways, waterways, and pipeline terminals; (d) swift inspection procedures for freight status, documentation, and safety compliance at transfer facilities, with up-to-date contingency plans; (e) availability of energy, communications, and tracking services (infostructure); and (f) regulatory frameworks to align the transportation supply in a changing world with survival-sustainability-ethics goals (Silva, 2008).

Although transportation impact analysis has previously been restricted to local sound, visual and direct-action pollution (Banister, 2002), nowadays, analysis must be broad and universal, taking in to account aggression from acid rain, greenhouse gases, non-renewable fuels, the preservation of natural habitats and biodiversity, and other factors relating to human health and well-being. Facing these subjects, we present a procedure that can serve as an effective tool to support policy and decision-makers in their analyses and priority allocation as they make decisions to improve transportation infrastructure projects.T

The main results are presented based on a case study conducted with support and a grant from the Brazilian government transportation authorities. Such a case study validated this tool in a real situation. A brief methodological review shows traditional approaches based on Delphi and Cross-Impact (CI) qualitative forecasting methods, associated with TOPSIS and AHP multicriteria methods. It is important to note the high awareness of the researchers exploring the issues related to the ecosystem, an important matter in the 21st century. Finally, some recommendations are made for the future development of the decision-analysis support tool and its application to Brazil’s concerns in transportation system choices. (Godet, 2001).

2 Review of the methodological approaches in decision-making

For the past 30 years, researchers in decision-making have faced the challenge of transforming qualitative externalities into quantitative data. This concern has produced creative methods classified as Multi-Criteria Decision Making (MCDM) (Fishburn and Lavalle, 1999). This review starts with Goal Programming (Charnes and Cooper, 1961), based on Koopmans (1951), regarding the efficiency vector used in Multi-Objective Mathematical Programming. ELECTRE I (Benayoun et al., 1966) followed, in five successive versions. Lee (1972), Ignizio (1976), Keeney and Raiffa (1976) presented new proposals; Saaty (1980) produced the Analytic Hierarchy Process (AHP), based on pair-by-pair evaluation of criteria and application of the evaluated options through interaction with stakeholders. Lootsma (1993) proposed the Multiplicative AHP, a variation in which the transposition of a verbal scale to numerical values (used in AHP) was replaced by numerical values on a geometrical progression with a progression factor of 2. Hwang et al. (1981) presented the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), in which *m* alternatives are evaluated by *n* priority-assessment attributes determined by an indicator derived from the combination between approximation to an ideal (positive) situation and removal from a non-ideal (negative) situation. This method was enhanced by Yoon (1987) and Hwang and Liu (1993). PROMETHEE I (Brans, 1982), similar to the 1960s ELECTRE, was developed through versions I, II, III, IV, etc. AHP and PROMETHEE II are similar in that they both work with pairs of criteria, in which the importance of one over the other is defined in relation to a given alternative. They differ, however, in the scale employed, with AHP offering greater flexibility (Behzadian et al., 2010). VIKOR (Opricovic and Tzeng, 2007) is similar to TOPSIS; both evaluate alternatives in terms of distance between ideal and non-ideal values. One difference between the two is the normalization of the main matrices: TOPSIS employs vector normalization; VIKOR, linear normalization. One vulnerability of TOPSIS is the potential for error present in the criteria weightings. In attempts to neutralize this, Saghafian and Hejazi (2005) use triangular fuzzy numbers to minimize distortions in attributing values to criteria. Other studies are Janic and Reggiani (2002), evaluating hub airports; Soo *et al* (2006), regarding traffic signal control investments; and Liang (2007), applying fuzzy logic to a production/transportation problem.

The AHP and TOPSIS have been applied jointly. Variations use fuzzy logic, some with AHP and others with TOPSIS. Tzeng et al.(2005) evaluated alternative fuels for buses in public transportation, comparing a high number of alternatives with other applications. The results of using the Delphi and AHP methods were treated statistically to obtain mean values. Finally, they applied TOPSIS on the basis of values obtained by experts. The VIKOR method was also used to validate the results. Önüt and Soner (2007) conducted a study to choose appropriate sites for solid waste disposal, using the AHP to determine weightings to apply to the TOPSIS matrix of initial evaluations defined by triangular fuzzy numbers. Isiklar and Büyüközkan (2007) used both approaches in choosing alternatives among mobile telephones. Gumus (2008) used AHP and TOPSIS for selecting hazardous cargo transport firms, drawing on experts and using the Delphi method. Iç and Yurdakul (2008) applied the methods jointly to priority-setting in choosing machining centers. Lin et al. (2008) conducted a theoretical study of palmtop design to suit consumer needs. Wu *et al.* (2008) presented an application of AHP with TOPSIS to priority-setting in choosing the best alternative insurance sold by banks. Other studies - including Tsaur et al. (2002), on evaluating airlines; Chen and Tzeng (2004), on evaluating countries for conducting international business; Yang et al. (2007), on allocating personnel to production lines; and Sheu (2008), on managing global supply chains – show that combining AHP and TOPSIS is appropriate when subjective aspects need to be transformed into numerical references for consistent evaluation.

Delphi and Cross-Impact (CI) methods are among the more traditional qualitative forecasting approaches (Gordon, 1994). Scapolo and Miles (2006) use the Delphi and CI methods to evaluate the use of advanced telematics technology and its impact on traffic in European cities. Delphi is an important tool for initially extracting expert knowledge and experience in order to subsequently apply CI analysis. In addition to comparing methods, the intention is to ascertain how they can work toward a common goal. The Search method of Sapio (1995) extends these classics, making use of probabilities to analyze the impacts on the future market for an Italian firm's telematics services. CI is confirmed as a basic tool in scenario-drawing procedures and assisting decision-making (Schlange and Jüttner, 1997); in many cases, more than one method is used both for generating scenarios and for multicriteria evaluation (Godet, 2001).

3 Procedure

The proposed procedure, applied by a team of five researchers under supervision of the author, follows the 7 stages shown in Figure 1. Given that *"prescription is useful for steering the decision-making process, recognizing the normative imperatives in the limitations imposed by the decision-makers' skills"* (Silva, 2008), it uses methods grounded in prescriptive models, which are also used in diverse experiments and reported in highly credible journals, for application in the transportation planning environment. This offers a breadth of analysis compatible with the regional dimensions and characteristics of the subject, such as the current imperative of environmental sustainability and socioeconomic return on investments. Its key characteristic is the level of interaction with the problem environment. Accordingly, starting from the primary investigation, it goes on to extract knowledge from various sources and, on the basis of various stakeholders' expertise, to bring expectation and vision into convergence. The project's set of priorities are the results obtained by the proposed procedure whose impacts or influences appear in the selection of decision criteria.

The use of Delphi method (Scapolo and Miles, 2006), followed by the simplicity and mathematical objectivity of TOPSIS (Hwang and Yoon, 1981), resulting in a hierarchized list of projects. It permits the qualitative cross-evaluation properties of AHP (Saaty, 1980) to be applied to a small number of possibilities/projects.

The Cross Impact method applied by Schlange and Jüttner (1997) plays an important role in the final stage of the research. Its use permits the formatting of the final report, analyzing the influences of one criteria by others, for each project. In addition, it provides mapping and regional analyses of the projects. It also allows the explanation, confirmation or even reordering of the project implementation lists, once the decision priority rules are the main guides and are connected since their formulation as strategic objectives of the main decision-maker (in this case, the Government Agencies).

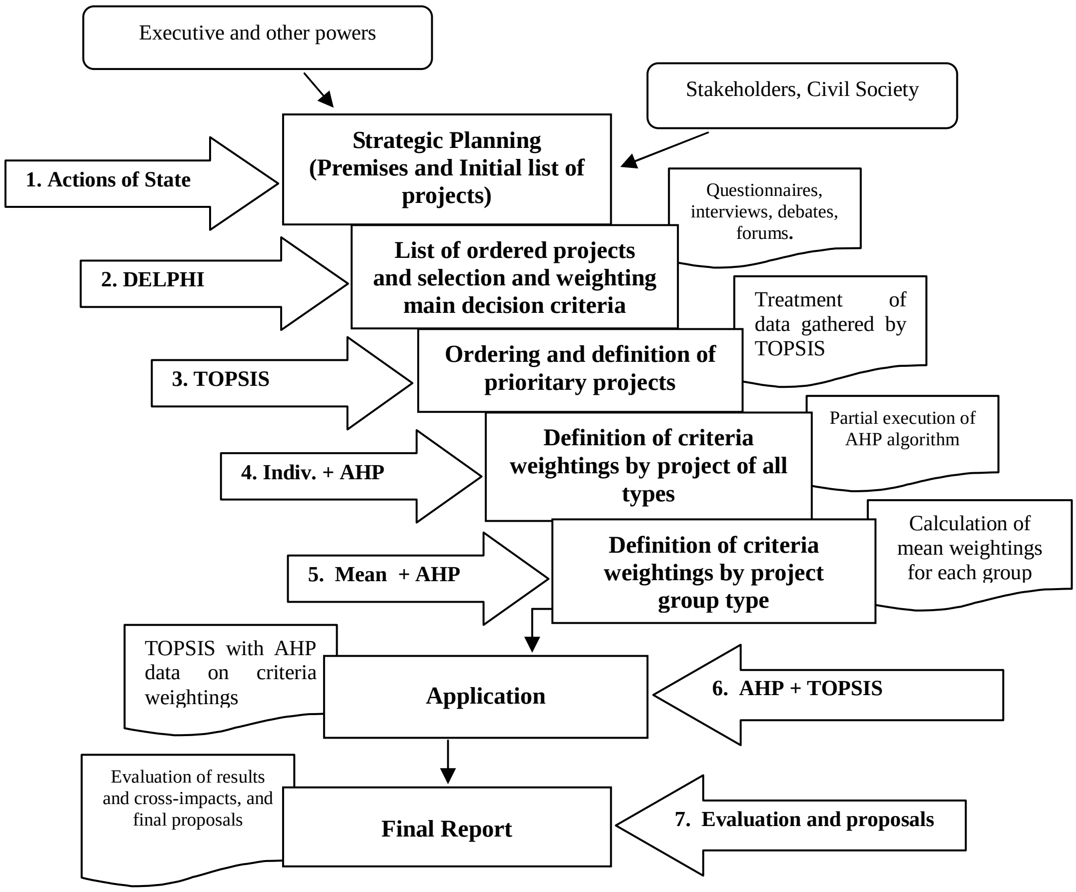

Fig.1: Multi-criteria analysis procedure in seven steps, from strategic decision to final report

The use of Delphi was essential to eliciting knowledge from experts and other stakeholders in order to select the projects to be evaluated with priorities proposals. At the end of the procedure the Cross Impact Method allowed a qualitative interpretation and validation of the results obtained with AHP+TOPSIS.

The combined use of AHP and TOPSIS permited to join some features of both methods, ie, the qualitative analysis from AHP criteria pair-wise with the TOPSIS calculation easiness. The weakness of AHP was compensated by the strength of TOPSIS although this one has no eigenvector calculation based on a logical algorithm. For a large number of alternatives AHP is not recommended due to number of comparisons (n(n-1)/2). Saaty (2006) suggests a maximum of seven elements per array. To analyse seven criteria and 25 projects were needed 2121 paired comparisons. On the other hand TOPSIS demands simple calculation even facing a large number of projects. So, if you calculate the main eigenvector with AHP for 7 criterias no more than 21 comparisons are necessary and it is possible to submit it to TOPSIS for evaluate and replicate to a large number of projects. The overall calculation was possible using Expert Choice software and a specific application in MS-Excel. In the first stage, state action, policy decisions are made regarding the country's transportation infrastructure needs and environmental constraints. Under pressure from public opinion, businesses, the legislative branch, trade unions and professional associations, environmental agencies and other stakeholders, the government departments and agencies define the guidelines for preparing a strategic plan, listing main project investments and elaborating on an initial list of projects.

In the second stage, DELPHI, the technical team plans and executes the stakeholder knowledge extraction and analysis, working within the government guidelines and project investment premises. They carefully define the composition of the set of service attributes or criteria and their weightings, for ordering and selecting the projects and priorities to be associated with the actual list of projects. In this stage, study preconditions regarding government strategic objectives have already been consolidated. The results from Delphi were adjusted by the stakeholders after three rounds in order to reach an acceptable level of consensus under the criteria weightings and priorities allocated in the initial list of projects. The third stage, classic TOPSIS, entails executing the method's algorithm and assigning priorities to the *n* alternatives (projects) by using a single table of weightings for the chosen criteria obtained in the DELPHI stage. Application of TOPSIS shown in Equation 1 returned the priority coefficients φ, defined as the ratio of the negative deviation Δ^- to the sum of the deviations ($\Delta^- + \Delta^+$), where Δ^- is the deviation in relation to the least ideal situation (the worst mean in the project/criterion correlation) and Δ^+ is the deviation in relation to the best project/criterion relationship. The smaller the Δ^-, the more favorable the evaluation; and vice versa for Δ^+.

$$\varphi = \frac{\Delta^-}{(\Delta^+ + \Delta^-)} \qquad \textbf{(1)}$$

At this point, after careful analysis, researchers pre-define a plan to cut the list of prioritized projects. The goal is to reduce the number of projects to be evaluated in the next step. The size and type of problem those requiring the application of this procedure to the ranking list of projects for its execution are particularly important given the practical limitations of the next stage.

In outlining the plan for cutting projects, all types of projects by region of the country must be represented. In the case of Brazil, considering the continental dimensions, evaluation needs vary greatly. In any case, the current stage generates an output of the first list of projects, ranked from highest to lowest priority.

In the fourth stage, partial AHP, these projects are evaluated by project for the degree of importance of one criterion over another, on the basis of the numerical scale of the table of Saaty (1980), at which time the inverse ratio is also established. When the degree of importance of one criterion over another is defined, with degrees ranging from 1 (equal importance) to 9 (absolute greater importance), with intermediate values of 2, 4, 6 and 8, the inverse ratio is automatically established. In summary, an appropriate analysis with AHP provides each project with a specific criteria weighting table.

The fifth stage, mean AHP, considers the results of the previous stage, associating the individual weightings with transportation project type (road, rail, water, etc.) per area or country region (project groups). The arithmetic means of the project group weightings are calculated, and the standards deviations allows validation of the results. The output of this stage is a table of criteria weightings for project type categories per region, or mode type groups (road, rail, water, bridge or viaduct, rail or highway bypass, for instance).

In the sixth stage, a combination of AHP and TOPSIS, TOPSIS is reapplied, with the weightings by group of projects obtained in the fifth stage. From the initial list, the entire project is reordered, and this table of weights made with reference to the first application of TOPSIS. This generates the second output of this stage, which is the end result to be evaluated in the next stage in order to compose a final report listing priorities for implementation.

In the seventh stage, evaluation and proposals, the outputs are analyzed, comparing the classic TOPSIS with the combination of TOPSIS and AHP. The project rankings are then compared with the individual and mean weightings, and the results are validated by Cross-Impact and supplementary mapping.

Finally, the report is drafted, containing the proposed set of considerations for the final decision maker at the government level, in view of execution priority. The reasoning is based on impacts, regional need focuses, and project preconditions or premises, besides the resulting configuration of the transportation network and its significance in production, consumption and other mappings. It also takes land use into consideration as an intended future goal of strategic planning.

4 Case Study

This case study involved hierarchizing Brazilian transportation infrastructure projects at a decision-making cross-sectional point (Silva, 2008). Its main purpose was to validate the procedure for general use in this type of decision-making. The scope of the problem corresponds to a country with a population of 200 million, an area of 8.5 million square kilometers, one of the world's ten largest GDPs (though simultaneously facing social and environmental disparities) and a transportation matrix in which highway flows truly predominate (ROAD = 58 %, PNLT (2007, p.8). Application of the International Standard ISO 26000 (2010) comprises part of the planning effort to offer modal waterway and railway alternatives and effective modal transfer, in order to reduce CO_2 emissions, domestic costs and the “Brazil Cost” while also preserving natural habitats and biodiversity. In light of that, investments scheduled until 2023 are directed toward achieving balance in the transportation matrix (ROAD=33%, RAIL=32%, WATER=29 %, PIPELINE=5%, AIR=1%), according to PNLT (2007, p.8). Cconsidering the CO_2/TKU emission data of transportation modes in Table 1 and the current cargo transportation production of the order of 1.028 trillion TKU, there will be a reduction of the order of 55 million metric tons.

Table 1. CO_2 emission/TKU by mode of transport

Mode	**CO_2/TKU, in g.**
Highway	164
Railway	48,1
Inland waterway	33,4

Source: EHG-Port of Ennshafen, Austria (Fialho, 2010)

Application of the procedure for validation purposes entailed initially conducting semi-structured interviews with 53 stakeholders selected from among managers of transportation enterprises of the federal government agency responsible for executing transportation projects; leaders of transportation and foreign trade sector professional associations; technicians and leaders of regulatory agencies and highway and waterway research institutes, in order to define the study preconditions. For this initial stage, the researchers tried to have a very representative group of government departments and agencies and other significant stakeholder groups. With this same purpose, three types of questionnaires were developed (Silva, 2008) and put to well-selected respondents. The three questionnaires requests, respectively: (i) transport projects priorities; (ii) which criteria could be used to evaluate priorities; and (iii) filling an AHP matrix pair-wise comparison between selected criteria. The results had been ranked by priority - on the basis of mean weights of the decision criteria - and by transportation mode groups (simplified in the case study from project groups per country region) against previous results, such as those from the TOPSIS stage.

Table 2 shows the criteria and their meanings, whose weights displayed the greatest significance both statistically and in meeting the project preconditions, and the expectations and needs expressed by the stakeholders.

Table 2. Decision criteria

Criteria	Interpretation	Weighting
Intermodal connection	Degree of contribution to developing connectivity and multimodality	0.30
Job creation	Measure of influence on creation of direct and indirect employment in regions affected	0.15
Social well-being	Effect in fostering benefits, particularly in education, health, safety and mobility	0.10
Environmental impact	Interferences in the environment, both adverse and beneficial	0.15
Recovery of environmental liabilities	Environmental quality gains, in other locations, resulting from project execution	0.10
Costs and benefits	Level of fund disbursement for execution in relation to resulting possible benefits	0.10
Execution timeframe	Time elapsed between need and full use and enjoyment of benefits	0.10

The TOPSIS application returned 0.68 as the best value for the priority coefficient φ and 0.13 as the lowest, corresponding to the 60th project. This limit was applied in this study because, from there on, values below of 0.50 were considered of little significance.

In the fourth stage of the procedure, of these 60 projects with significant priority values - those with values of φ from 0.50 and up - a set of 25 projects was chosen. In this set, responses to a pair-by-pair comparison of the criteria, by project, obeyed the table of Saaty (1980), which considers 0.10 as maximum acceptable ratio of inconsistency. That ratio proved an excellent yardstick for performing sensitivity analyses to obtain a solution with an acceptable consistency ratio.

TOPSIS was then reapplied with the weightings per criterion and mode-group obtained by partial application of AHP. The result was φ coefficients between 0.51 and 0.34. The subsequent application of the outputs from partial AHP execution to projects made it possible to correct trends introduced by the informal criteria adjustments initially used in the classic TOPSIS. Criteria weightings from the classic TOPSIS and the combination of TOPSIS and AHP are compared in Table 3.

Table 3. Classic TOPSIS and TOPSIS+AHP criteria weightings compared

Criteria	TOPSIS*	TOPSIS+AHP criteria weightings				
		Road	Rail	Water	Ports	Bypass[1]
Intermodal connection	0.30	0.18	0.20	0.20	0.22	0.21
Job creation	0.15	0.12	0.10	0.10	0.11	0.11
Social well-being	0.10	0.13	0.08	0.07	0.08	0.08
Environmental impact	0.15	0.21	0.18	0.24	0.23	0.22
Recovery of environmental losses	0.10	0.19	0.26	0.26	0.19	0.21
Costs and benefits	0.10	0.06	0.10	0.04	0.07	0.08
Execution time frame	0.10	0.11	0.08	0.09	0.10	0.09

* one criterion weighting for all modes
[1] Bypass or Contour projects

5 Discussion

This pilot case study sought to validate the procedure by allying the precision of AHP with the directness of TOPSIS. Thence came the proposal to group projects of similar type and obtain mean weightings by criteria derived from AHP for project or transportation mode groups. The grouped results for the 25 projects revealed major differences regarding criteria such as inter-modal connection (which had much greater influence in the classical TOPSIS) and the two direct environmental criteria, whose values denoted significant changes in the weightings (Table 3 above).

Table 4 compares the project rankings (ord.) by priority, as obtained from the classic TOPSIS (φ TOPSIS), and by TOPSIS+AHP, inputting the mean criteria weightings by group of projects (φ Mean). This analysis in the case study indicates that even the classic TOPSIS may be a reasonably adequate decision analysis tool in certain situations (for instance, where it is difficult to engage analysts and stakeholders in detailed work). This seemed a reasonable option since the 25 best projects - as ranked by the classical TOPSIS - figure among the projects with the highest priority rankings resulted from the final stage of the procedure.

Table 4. Comparison of rankings of projects

Project	**φ TOPSIS**	**Pos.**	**φ Mean TOPSIS+AHP**	**Pos.**
Ferronorte railway: construction Alto Araguaia-Rondonópolis Sections	0,68	**1**	0,50	**7**
São Paulo ring railway: north section	0,68	**2**	0,55	**2**
Rio de Janeiro ring road, including BR-101 road	0,64	**3**	0,57	**1**
Tucurui, PA locks	0,64	**4**	0,52	**4**
Santos road acess to port, right and left banks	0,64	**5**	0,54	**3**
BR-163 road, Guarantã do Norte, MT - Rurópolis/Santarém, PA section	0,63	**6**	0,47	**10**
Port of São Francisco do Sul, SC, berth construction and refurbishment	0,63	**7**	0,52	**5**
Port of Vila do Conde-PA, expansion	0,63	**8**	0,50	**9**
São Paulo ring road: south section	0,61	**9**	0,50	**8**
Porto of Itaqui, MA - dredging, expansion, refurbishment	0,59	**10**	0,33	**25**
Norte-Sul railway, Tocantins	0,59	**11**	0,42	**15**
Rail branch line: section Estreito-Balsas	0,57	**12**	0,44	**13**
Paraná-Paraguai waterway: dredging and rock removal	0,55	**13**	0,44	**12**
Port of Itaguai,RJ: dredging	0,55	**14**	0,43	**14**
BR-101/ES road, including Vitória bypass	0,55	**15**	0,36	**22**
Nova Transnordestina railway	0,55	**16**	0,39	**20**
Curitiba ring railway	0,54	**17**	0,61	**6**
BR-470 road expressway to port of de Itajai, SC	0,53	**18**	0,44	**11**
Porto of Suape, PE, road access	0,53	**19**	0,39	**18**
Porto of Paranaguá, PR: construction and refurbishment	0,52	**20**	0,40	**17**
Camaçari - Aratú, BA: ring railway	0,52	**21**	0,41	**16**
BR-230/ PA road, section Marabá, Altamira, Medicilândia, Rurópolis	0,52	**22**	0,39	**19**
BR-364/MT road: section Diamantino-C.N.dos Parecis	0,52	**23**	0,35	**24**
BR-153/TO road: Section GO/TO -Divisa TO/PA	0,52	**24**	0,35	**23**
Port of Santos, SP: dredging and rock removal	0,51	**25**	0,37	**21**

From this pilot onwards, complementary analyses were performed and final decisions made by project to a level of detail not present in this study case. This involved considering other data and assessing cross-impacts and regional priorities. However, at the time of the pilot, the executive group of the Government Agency validated the final set ranking by TOPSIS+AHP as forming a valuable basis for decision-making; it came close to what was actually intended for execution.

Complementary analysis is possible using CI forecasting method to obtain total cross impacts by multiplying the impacts received by each criterion (passive influence) by the impacts produced on the others (active influence) to produce the total influence. The CI matrix obtained for one individual priority project, the Rio de Janeiro Metropolitan Ring-Road (*Arco Metropolitano do Rio de Janeiro*, AMRJ), is shown in Table 5. This project, representing federal and state government investments of R$ 1.2 billion and currently in the final stage of execution, provides for a 145-km ring-road spanning 17 municipalities and interconnecting the north and south stretches of highway BR-101 with BR-040 and BR-116, thus diverting dense vehicle flow away from the urban area of Rio de Janeiro. In 2009, construction work unearthed 22 archeological sites, causing a delay in order for all the sites to be cataloged and the remains preserved. (Only one of those sites has been maintained; the material from the rest has been removed to museums.)

When the cross-impacts for the AMRJ project were analyzed, the cost-benefit criterion was noted to exert great total influence, certainly reinforced by two factors: (a) the project's environmental impact, limited by preventive measures and (b) recuperation associated with the environmental liability. In the latter case, the adverse effects of heavy vehicle traffic through the metropolitan zones of Rio de Janeiro and Niterói are substantially reduced. This benefit of “environmental gain” seemed to signal that the project’s overall environmental impact as assessed in the Environmental Impact Report might be moderated by the perceived cross-impact. The execution time frame criterion returned a significant total influence value, which can be corroborated by the delay observed in concluding and executing certain civil works, due to a number of localized issues regarding biodiversity and environmental preservation areas.

Table 5. Cross Impact matrix for evaluation of the AMRJ

Criteria	**A**	**B**	**C**	**D**	**E**	**F**	**G**	***Active influence***	**Total influence received**
A	0	3	2	2	2	3	3	15	165
B	0	0	3	2	1	3	1	10	120
C	1	1	0	1	2	1	1	7	105
D	1	2	2	0	3	3	3	14	154
E	3	1	3	2	0	2	1	12	168
F	3	3	3	1	3	0	3	16	240
G	3	2	2	3	3	3	0	16	192
Passive influence	11	12	15	11	14	15	12		

A - Intermodal connection
B - Job creation
C - Social well-being
D - Environmental impacts
E - Recovery of environmental losses
F - Cost and benefits
G - Execution time frame

The Beltway Metropolitan São Paulo (MRSP) is a route of 177 km, divided into four sections: West, South East and North. Two sections – the West and the South – are currently in operation. The southern stretch is the newest, opened in 2010 at a cost of R$5 billion. It is a very important roadway to the metropolitan region of São Paulo, the world's fourth largest, with nearly 20 million inhabitants. The ring road has high impact in the region because the city is located in the midst of large transportation demanders such as the port of Santos, the industrial region of Campinas, SP, Vale do Paraíba (SP and RJ) and other developed regions with great DGP (Domestic Gross Product).

The cross-impact analysis of the MRSP shown in Table 6 presents partially similar results to those obtained for the AMRJ; some points differ between them. The average between active and passive influences for the MRSP reached a value of 177.4, with a standard deviation of 23.4. In AMRJ, these numbers were respectively 163.4 and 44.9. These numbers evidence the uniformity in the exchange of impacts identified in the MRSP. As with AMRJ, the cost-benefit criterion was predominant despite great resistance from environmental sectors - the south section crosses the Billings dam region, the main water reservoir for the population of São Paulo and surrounding areas. The time spent in the construction of the stretch was also highlighted as a significant impact. Considering the amount of cargo that passes through this area, another criterion highlighted is the intermodal connection. The southern stretch allows the installation of large logistics parks, starting points for the redistribution of cargo.

There is a balance between the impact caused by the work and mitigating carbon dioxide in the urban area of São Paulo, which remains high due to other impacting factors such as industrial emission, climate characteristics, and an excessive vehicles fleet.

Table 6. Cross Impact matrix for evaluation of the MRSP

Criteria	A	B	C	D	E	F	G	*Active influence*	Total influence received
A	0	3	3	3	2	3	2	14	182
B	3	0	2	1	1	3	1	11	165
C	1	3	0	2	2	1	1	10	160
D	1	2	2	0	3	2	3	13	156
E	2	1	3	3	0	2	1	12	168
F	3	3	3	1	3	0	3	16	224
G	3	3	3	2	3	3	0	17	187
Passive influence	13	15	16	12	14	14	11		

A - Intermodal connection
B - Job creation
C - Social well-being
D - Environmental impacts
E - Recovery of environmental losses
F - Cost and benefits
G - Execution time frame

6 Conclusion

The assertive methodological review and this pilot study confirmed the suitability of using Delphi, AHP and TOPSIS – and Cross-Impact – jointly. The case study results indicate that the mixed multi-criteria-qualitative forecasting procedure is appropriate for meeting the challenge of selecting a space-time sequence project set from a high number (over 400, in some cases) of alternatives. Some of the applications mentioned in this article have generally been limited to a small number of alternatives and technically-defined criteria. Meanwhile, the simplicity of TOPSIS facilitates participatory planning despite its defined weakness, which is its use of the same weighting scale for all options evaluated. However, in its application to some projects, the final list could be neutralized by AHP pair-by-pair comparative analysis of the criteria. It should be pointed out that AHP procedure demands some expertise and knowledge with a suitable consistency level, often calling for extra adjustment and orientation until a significant partial result enables the analysis to proceed. Mathematical resources such as triangular fuzzy number logic and multi-criteria approaches are certainly a step ahead for such evaluation. In the stage that uses AHP cross-evaluation of criteria importance by project - resulting in the mean weightings - PROMETHEE II and VIKOR would be equally useful, probably with no final loss. As remarked before, the main goal of the pilot was to validate the procedure. For this reason, and in addition to it, the selection of the 25 projects for the application of AHP and 7 impact attributes was closely related to the target, which was measuring the impact on the optimal set sets of not accurately differentiating the relative importance of each pair in view of the study preconditions. This pilot did not examine the cross impacts for all projects in the chosen set. However, its application to some projects on the final list produced the conclusion that the impacts (active and passive influences) resulting from actions designed to make a project or group of projects meet each criterion, over and above the other criteria, permit an evaluation unperceived in quantitative treatments by other methods. New proposals for developing the application will be designed to make greater use of CIs as a support tool, not only in complete final list evaluations but rather from the first two stages of the procedure onwards; for instance, focusing the criteria selection, as originally proposed by formerly cited authors.

Brazil's transportation and development policies clearly favor highly technologically-based investments, which are expensive but greatly reduce environmental impacts. The desired balance in the transportation matrix for 2023 is to be achieved through a multimodal network in which inter-urban circuits (with high-speed train components) will integrate with regional medium-speed networks in connection with the (refurbished) existing network (Vilaça, 2011). In addition, gains resulting from the use of renewable fuels and green energy sources will be increasingly present in the transportation supply - not just for cargo, goods and valuables, but for passenger services as well. Already, the criteria established in this study permit an analysis suggesting that sizable investments in the cargo and passenger rail transportation system would stimulate employment generation (job creation) and intermodal connections, in urban centers as well. The environmental sustainability of “green transportation projects” and project sets planned for progress toward the desired configuration of efficient cargo and passenger flows with a redesigned land use model for Brazilian territory, according to a suitable space-time schedule, can determine the appropriateness of incurring high medium-term implementation costs which produce highly worthwhile, long-term results for Brazil and the ecosystem. These long-term results can only be accomplished by enacting industrial, trade and agricultural policies in support of broad-minded national strategic goals and by pursuing ethical preservation of environmental biodiversity.

References

Banister, D. (2002), *Transport Planning*. Routledge. London.

Behzadian, M. et al. (2010), PROMETHEE: a Comprehensive Literature Review on Methodologies and Applications. *European Journal of Operational Research*, 200, 1, 198-215.

Benayoun, R. et al. (1966), Electre: Method for a Guided Choice in Presence of Multiple Points of View. *Direction Scientifique*, Working Note 49, EMS, Paris.

Brans, J.P. (1982), L’Ingéniérie de la Décision. Elaboration d’Instruments d’Aide à la Décision. Méthode PROMETHEE. In: Nadeau, R., Landry, M. (eds.), *L’Aide a la Décision: Nature, Instruments et Perspectives d’Avenir*, pp.183-214. Presses de L’Université Laval, Quebec.

Charnes, A.,Cooper, W.W. (1961), *Management Models and Industrial Applications of Linear Programming, Vol.1*. Wiley & Sons, New York.

Chen, M.F., Tzeng, R.I. (2004), Combining Grey Relation and TOPSIS Concepts for Selecting an Expatriate Host Country. *Mathematical Modeling and Computer*, 40, 1473-1490.

Fialho, F.A.B. (2010), O Papel da ANTAQ na Definição do Marco Regulatório do Setor Portuário. In*: III Seminário de Direito Portuário*. Brasília.

Fishburn, P., Lavalle, I. (1999), MCDA: Theory, Practice and the Future. *Journal of Multi-Criteria Decision Analysis*, 8, 1, 1-2.

Godet, M. (2001), Creating Futures: Scenario Planning as a Strategic Management Tool. *Economica*. London.

Gordon, T. J. (1994), Cross-Impact Method, Futures Research Methodology. *The Millennium Project*, American Council for United Nations University, Washington.

Gumus, A. T. (2008), Evaluation of Hazardous Waste Transportation Firms by Using a Two-Step Fuzzy AHP and TOPSIS Methodology. *Expert Systems with Applications*, doi: 10.1016/j.eswa.2008.03.013.

Hwang, C.L. et al. (1993), A New Approach for Multiple Objective Decision Making. *Computers and Operations Research*, 20, 889-899.

Hwang, C.L., Yoon, K. (1981), Multiple Attribute Decision Making: Methods and Applications. In: *Lecture Series in Economics and Mathematical Systems*. Springer-Verlag. Berlin.

Iç, Y.T., Yurdakul, M. (2008), Development of a Decision Support Systems for Machining Center Selection. *Expert Systems with Applications*, doi: 10.1016/j.eswa.2008.02.022.

Ignizio, J. (1976), *Goal Programming and Extensions*. Lexington Books. Lexington.

International Standard ISO 26000 (2010), ISO 26000:2010-Guidance on Social Responsibility, http://www.iso.org/iso/catalogue_detail?csnumber=42546. (*last accessed on 15 January 2011*)

Isiklar, G., Büyüközkan, G. (2007), Using a Multicriteria Decision Making Approach to Evaluate Mobile Phone Alternatives. *Computer Standards & Interfaces*, 29, 265-274.

Janic, M., Reggiani, A. (2002), An Application of the Multiple Criteria Decision Making (MCDM) Analysis to the Selection of a New Hub Airport. *European Journal of Transport and Infrastructure Research*, 2, 2, 113–142.

Keeney, R.L., Raiffa, H. (1976), *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*. John Wiley & Sons. New York.

Koopmans, C.T. (1951), Activity Analysis of Production and Allocation. *Cowles Commission for Research in Economics*, Monograph 13. Wiley & Sons. New York.

Lee, S.M. (1972), *Goal Programming for Decision Analysis.* Auerbach. Philadelfia.

Liang, T.F. (2007), Applying Fuzzy Goal Programming to Production/Transportation Planning Decisions in a Supply Chain. *International Journal of Systems Science*, 38, 4, April.

Lin et al. (2008), Using AHP and TOPSIS Approaches in Customer-driven Product Design Process. *Computers in Industry*, 59, 17-31.

Lootsma, F. (1993), Scale Sensitivity in the Multiplicative AHP and SMART. *Journal of Multi-Criteria Decision and Analysis*, 2, 87-110.

Önut, S., Soner, S. (2007), Transshipment Site Selection Using the AHP and TOPSIS. *Waste Management*, doi: 10.1016/j.wasman.2007.05.019.

Opricovic, S.,Tzeng, G.H. (2007), Extended VIKOR Method in Comparison with Outranking Methods*. European Journal of Operational Research*, 178, 514-529.

PNLT (2007), *Plano Nacional de Logística e Transporte*. Ministério dos Transportes e Ministério da Defesa. Brasilia.

Saaty, T. L. (2006), Fundamentals of Decision Making and Priority Theory. RWS Publications. Pittsburgh, PA.

Saaty, T. L. (1980), *The Hierarchy Analytic Process*. McGraw-Hill. New York.

Saghafian, S., Hejazi, S.R. (2005), Multi-criteria Group Decision Making Using a Modified Fuzzy TOPSIS Procedure. In*: Proceedings of the 2005 International Conference on Computational Intelligence for Modeling, Control and Automation*. IEEE Computer Society.

Sapio, B. (1995), Search (Scenario Evaluation and Analysis through Repeated Cross Impact Handling): a New Method for Scenario Analysis with an Application to the Videotel in Italy. *International Journal of Forecasting*, 11, 113-131.

Scapolo, F., Miles, I. (2006), Eliciting Experts' Knowledge: a Comparison of Two Methods. *Technological Forecasting and Social Change*, 73, 679-704.

Schlange, L.E., Jüttner, U. (1997), Helping Managers to Identify the Key Strategic Issues. *Long Range Planning*, 30, October, 777- 786.

Sheu, J.B. (2008), The Hybrid Neuro-Fuzzy Approach to Analytical Mode Choice of Global Logistics Management. *European Journal of Operational Research*, 189, 971-986.

Silva, R.B. (2008), Análise Estruturada das Dimensões do Desenvolvimento Sustentável e a Interdependência com a Função Transporte: Proposta de Metodologia para Orientar Decisões Estratégicas na Implantação de Projetos Prioritários para a Infra-estrutura de Transporte no Brasil. *D.Sc. Dissertation*, COPPE - Federal University of Rio de Janeiro. Rio de Janeiro.

Soo, H. Y. et al. (2006), A DSS Framework for Advanced Traffic Signal Control System Investment Planning. *Journal of Public Transportation*, 9, 4, 87-106.

Tsaur, H.S., Chang, T.Y., Yen, C.H. (2002), The Evaluation of Airline Service Quality by Fuzzy MCDM. *Tourism Management*, 23, 107-115.

Tzeng, R.I.et al. (2005), Multi-Criteria Analysis of Alternative-Fuel Basis for Public Transportation. *Energy Policy*, 33, 1373-1383.

Wu, C.R. et al. (2008), Selecting the Preferable Bancassurance Strategic Alliance by Using Expert Group. *Expert Systems with Applications*, doi: 10.1016/j.eswa.2008.02.016.

Yang, T., Chen and M.C., Hung, D.C. (2007), Multiple Attribute Decision-Making Methods for the Dynamic Operator Allocation Problem. *Mathematics and Computers in Simulation*, 73, 285-299.

Yoon, K. (1987), The Reconciliation among Discrete Compromise Situations. *Journal of Operational Research Society*, 38, 21-30.

Vilaça, R. (2011), Projetos para Trens de Passageiros Somam R$ 85 bi, http://www.mundologístico.com.br. *(last accessed on 14 February 2011)*

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