Formal Modelling and Comparing of Disaster Plans

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ABSTRACT

Every municipality in The Netherlands has its own disaster plan. A disaster plan contains the blueprint of how to handle incidents in the municipality with the aim of preventing incidents to grow into disasters. Given that each municipality has its own organisations, enterprises, infrastructure, and general layout, the disaster plans also differ. On the other hand, the disaster plans have a lot in common. Some municipalities use a common starting point, others develop their own disaster plan from scratch. In this paper two independently developed disaster plan are compared using formal modelling techniques. The analysis reveals that some interesting differences do not stem from a difference in the makings of the municipality. These differences touch the fundamentals of the communication during incident management, and might well have a critical impact in dealing with pending disasters.

Keywords

Disaster plan, formal analysis, comparison.

INTRODUCTION

Every municipality in The Netherlands has its own disaster plan. A disaster plan contains the blueprint of how to handle incidents with the aim of preventing incidents to grow into disasters. The plan describes the relations with all organisations that might possibly be involved, like the mayor, the fire department, police, ambulances, hospitals, other municipalities, provincial government, national government. When comparing municipalities both commonalities and differences stand out. The commonalities encompass such basic elements as a local government, the availability of some kind of police force, fire department, and ambulance services. Small municipalities might not have their own forces of the kind mentioned, but have to share them with other municipalities. Big cities have subdivided their forces in smaller units that predominantly serve specific parts of the city. More fundamental differences involve the infrastructure of the municipality (e.g., forms of public transportation, the road plan, water ways, bridges), but also the enterprises and organisations available within the boundaries of the municipality like airports, factories, restaurants, stadiums and theatres. Given that each municipality has its own organisations, enterprises, infrastructure, and general layout, it seems self-evident that the disaster plans also differ. On the other hand, the disaster plans form only a blueprint of handling incidents. For every entity in the municipality that carries a predictable risk a more detailed plan has to exist, a so called disaster prevention plan. The advantage of separating disaster plans from disaster prevention plans is that the disaster plan is applicable in all situations and is a relatively compact document. This line of reasoning entails again that the disaster plans of different municipalities should have, and in fact do have a lot in common.

On the basis of the above, one might expect that disaster plans are developed from a common template. In general, they are not. Some municipalities use a common starting point; others develop their own disaster plan from scratch. It raises the question how comparable these disaster plans actually are. Due to their lack in detail, necessary for a plan that serves only as a blueprint, the human reader tends globally accept the reasonability of the plan. On that global level the different disaster plans look the same. However, this global reading leaves the reader unaware of how certain parts of the plan might turn out in practice, when people using the plan are under a lot of pressure (see for example [Breuer and Satish, 2003] for a study regarding performance of people under pressure). Municipalities test the quality of their plans by regularly organizing exercises on different scales. This approach is absolutely fundamental. However, the approach is not the same as rigorous testing of the plans under all possible circumstances. In fact, no incident is ever the same as a situation trained. Rigorous testing the plan in exercises is infeasible due to the many variables involved. In the context of the CIM project the authors investigate another approach: using formal techniques to analyze disaster plans, disaster prevention plans, exercises, and incident reports. The techniques involve the formal specification of the contents of plans, creating formal organisation models of the cooperating organisations mentioned in the plans, and creating high level simulation environments to enable rigorous testing of the plans in all envisioned possible variations. Note that even that is not the same as a complete testing of the plan, since any modelling endeavour entails the simplification with respect to reality. On the other hand, each of the fore mentioned formal steps reveals aspects of the plan, not considered during development. Furthermore, having formal specifications of the organisation and its dynamics in the incident management as prescribed by two disaster plans, allows the comparison of those two specifications on the abstract level of those plans, i.e., without having to revert to simulations. During each stage of this approach differences can be revealed:

- the formalization or modelling of a disaster plan raises questions with respect to intended meaning and possible consequences
- grouping comparable parts of the specification of two disaster plans brings to light differences that under close scrutiny might have unintended consequences
- logical proof theory can be used to prove or disprove that a disaster plan can have certain consequences, or that some properties of one disaster plan are entailed by the other plan. Logical proof theory also provides example settings that characterize unpredicted scenarios.

The aim of this paper is to develop a general method for formally specifying disaster plans so that they can be analyzed and compared using tools from logic. Here we partially rely on other research which we extend and adapt for the specific domain of disaster plans.

Two disaster plans are compared using this approach. The analysis reveals that some interesting differences do not stem from a difference in the makings of the municipality. These differences touch the fundamentals of the communication during incident management, and might well have a critical impact in dealing with pending disasters.

THE STEPS IN MODELLING AND COMPARING DISASTER PLANS

Before disaster plans can be compared, they must first be modelled. This section provides some general guidelines for extracting a formal model of the disaster plan from a textual disaster/incident plan and thus bridging the gap between informal and formal representation. In principle, any modelling approach for organisations and any formal language for modelling organisations can be used as a point of departure. For example, a formal language based on description logic for specifying disaster management is introduced in [Grathwohl, *et al*, 1999]. In this paper, the modelling approach of [Broek et al., 2005] and [Hoogendoorn et al., 2004] is extended in which the formal languages TTL and Leads-To as described in [Jonker and Treur, 2002] are used. Fundamental in this approach and these languages is the emphasis on modelling both the structure and the dynamics of organisations. The need for structure and the need to know how to handle the dynamics of incident management is the main reason for having disaster plans in the first place.

Based on experience in modelling disaster plans the following stages are advocated: phase identification, structure analysis and modelling, task & responsibility analysis, organisational change modelling. Each of these stages is explained in more detail. The comparison of disaster plans is discussed after the modelling steps.

Phase Identification

In each disaster plan a number of phases of incident management are identified. Typically they are grouped in three general phases depending on the severity of the situation:

- Small incident – no co-ordination between police, fire department and medical forces is needed, the highest level of decision-making and co-ordination only involves functionaries of these three institutions.
- Serious incident – involvement of the mayor is needed at the highest level of decision-making. Typically a disaster management team is formed at the city hall.
- Severe incident involving more than one municipality – co-ordination between the municipalities is needed. Typically the National Coordination Centre is also involved.

Within different disaster plans the particular phases considered can differ although experience shows that a general ontology can be built with all possible phases that can be included in a disaster plan ordered according to severity of the situation and coverage (local or regional). The first step in this modelling approach is to identify which particular phases are covered by the disaster plan

Structure Analysis and Modelling

Each phase of incident management has its own organisational structure. Therefore, the structure of the organisation has to be analysed and modelled for each phase. Structure analysis aims at identifying all parties involved and their relevant organisational roles and relationships.

- Disaster plans typically contain lists of all parties involved. Institutions like the fire department, ambulance services, police, municipal service and other associated institutions are almost always involved. These institutions exist irrespective of whether an incident occurs or not. However, disaster plans also refer to parties like the operation team, regional coordination centre, and management team, depending on the phase and scope of a disaster/incident and only exist during these phases. The structure can consist of roles that contain other roles and so forth. The way to model this structure is presented in the next section.

- After identifying the roles in the organisation at a certain phase, the communications between roles or composite roles need to be identified. For example, a policy team always maintains communication with fire department action centre. With respect to communication and interaction the disaster plans studied by the authors are typically incomplete, making it difficult and in some cases impossible to identify the exact links in the structural model.

Tasks & Responsibilities Analysis
Having identified the organisational structure in the different phases of incident management, the tasks and responsibilities of the roles have to be determined. Problems at this stage might be vague and unclear formulations of the tasks, no detailed information for the responsibilities per task and per role.

Organisational Change Modelling
Knowing the organisational structures during the different phases of incident management is not enough to model a disaster plan. The last but vital part of the modelling is the specification of organisational change. This entails the identification of all conditions of organisational change. They normally depend on the different incidents/disasters. Typical problems that occur during this phase are lack of information concerning the triggers that cause change. Often the decision to change the organisation is left to a deliberation group without stating specific definitions of the triggers.

The modelling process delivers a lot of information concerning how thoroughly a disaster plan is specified. In case some unclear parts are identified, the disaster plan can be improved in a number of ways, e.g., using experts and/or training. Another option is to organise a training dedicated to an unclear part.

Comparing of Disaster Plans
A comparison of disaster plans consists of the following elements: comparison of phases, comparison of organisational structures in comparable phases, comparison of the task structure in comparable phases, and comparison of the responsibilities scheme in comparable phases. The comparison of phases is a rather straightforward matter as can be seen in the section of the case study. Comparison of the organisational structures entails the identification of comparable and incomparable structures within the organisation at each of the phases of incident management, and a comparison of the ontologies used. The comparison of task structures concentrates on the tasks identified in each disaster plan, and discusses comparable and incomparable tasks. Given the comparable tasks, the comparison of responsibilities entails the allocation of responsibilities to roles.

The steps in modelling disaster plans refer to frameworks for modelling organisations. Each framework for modelling has its own formal textual and graphical languages. The use of formal languages enables the use of logical proof theory to compare properties of disaster plans against properties of other disaster plans and also enable the use of software tools to support checking properties of disaster plans against traces of incident management. The use of formal languages thus supports the comparison of disaster plans. The modelling framework of [Broek et al., 2005] and [Hoogendoorn et al., 2004] used in this paper refers to the TTL and Leads-To languages specified in [Jonker and Treur, 2002]. The next section shortly presents the modelling approach.

MODELLING ORGANISATIONS

The organization modelling approach has been adopted from [Broek et al, 2005] and [Hoogendoorn et al, 2004] with extensions enabling application to the specific domain of disaster plans formalization. The approach emphasizes two elements: modelling the structure of an organisation and modelling the dynamics of an organisation. The dynamics of an organisation entails both the tasks performed by an organisation and the change of an organisation. This section discusses the modelling of organizational structures, the specification of tasks and responsibilities, and the modelling of organisational change.

Modelling Organisational Structure

The structure of an incident management organisation can be described at different aggregation levels, which allows managing the level of complexity and refinement of an organisation representation. The aggregation levels refer to a level of the organisation consisting of roles and the interaction between those roles. A model of an organisation with several aggregation levels also contains a specification of the inter-level relations of those aggregation levels. Therefore, a model of an organisational structure consists of roles, interaction links, interlevel links, and structural properties regarding those elements.

(1) A *role* represents a subset of functionalities, performed by an organisation, abstracted from instances of real agents. At the highest aggregation level, the whole organisation can be represented as one role. Further, each role can be decomposed into several other roles, until the necessary level of aggregation is achieved. Graphically, a role is represented as an ellipse with white (input interfaces) and black (output interfaces) dots (see Figure 1). A role which is composed of (interacting) subroles, is called a *composite role*. Each role has an input and an output interface, which

facilitate in the communication with other roles. Although in this paper the emphasis is on the organisation structure of incident management, an organisation is realized by the agents (or sets of agents) fulfilling the roles.

(2) An *interaction link* represents an information channel between two roles. Graphically, it is depicted as a solid arrow, which denotes the direction of possible information transfer. For example, interaction links between roles Fire Department and Police in Figure 1 represent the possibility of communication between them.

(3) An *interlevel link* connects a composite role with one of its subroles. It relates two adjacent aggregation levels. Graphically, it is depicted as a dashed arrow, which shows the direction of interlevel transition (see Figure 1).

(4) Structural properties specify the number of instances of a specified role and the various role-subrole relations. Although the structure of an organisation can be specified partly using graphs (see Figure 1), a formal textual language is needed to specify the structural properties. Sorts are introduced for the basic elements of an organisation and relations between them (i.e., ROLE, AGENT, ORGANISATION, INTERLEVEL_LINK, and INTERLEVEL_LINK). Furthermore, a set of relations is defined to specify the structural aspects of the organisation. A complete overview is given in [Broek et al., 2005], here only a few examples are given:

is_role_in: ROLE x ORGANISATION	identifies a role in an organisation
has_subrole_in: ROLE x ROLE x ORGANISATION	defines a subrole of a composite role in an organisation.

Examples of structural properties are: is_role_in(FD,ORG1), has_subrole_in(FD,VC_FD,ORG1).

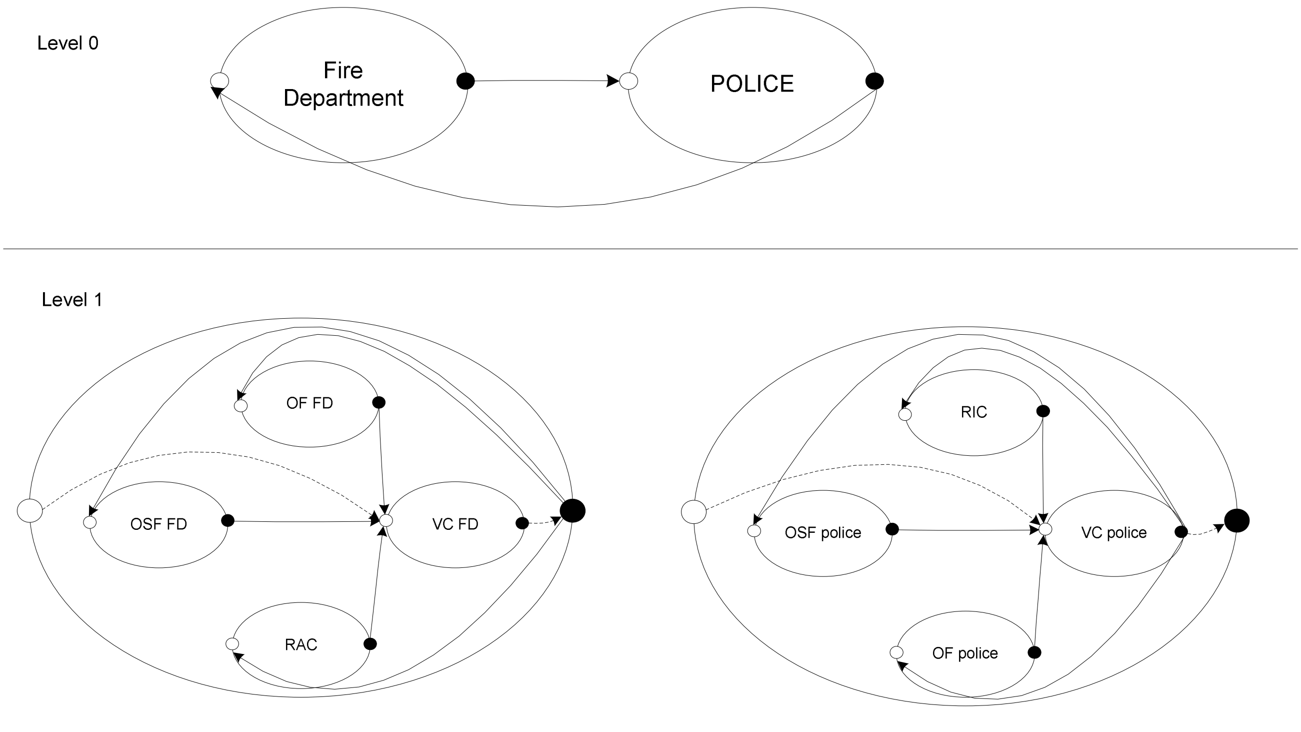


Figure 1. Example of an organisation structure, described at two adjacent aggregation levels

Often, structural properties are valid during the whole period of organisation existence and can be considered as static. But in rapidly developing and adapting organisations (e.g., incident management organisations) structural change processes gain special importance. Structural properties for such organisations will be described later.

Tasks and responsibilities

The dynamics of an organisation are formed by the execution of tasks by the organisation and the change of an organisation. To analyse and model the first of these, the tasks and responsibilities of the different structural elements of the organisational model have to be identified. An order-sorted predicate language is introduced that provides a way to express statements describing the hierarchy of tasks, responsibilities of roles for certain tasks in a particular situation and leadership within a composite role. The language is useful for any organisation that encounters change on a regular basis.

The main sorts are TASK, PHASE, ROLE, and ORGANISATION. Using these sorts, the language can be extended with a set of relations to specify task, responsibilities and the phases of an organisation.

- Primary co-ordination of task – which role co-ordinates the execution of the task

- Secondary co-ordination of a task – in some situations the primary co-ordinating role can be replaced by the secondary co-ordinating role. That might happen for example when the particular type of disaster has specifics that can more appropriately be handled by the secondary co-ordinating role.
- Primary execution of a task – the role(s) that execute the task
- Secondary execution of a task – for particular disasters where the emphasis is shifted towards an institution (role) not involved in the primary execution of the task, this institution can also become involved in it.
- Operational leadership within a complex role – the role that takes the leadership of the complex role (group, institution, etc.)

To specify such information the following relations re introduced:

is_organisation_in_phase:	ORGANISATION x PHASE, describes the phase an organisation is in.
is_subtask_of:	TASK x TASK, to describe the task-subtask ordering.
executes_task_primary:	ROLE x TASK, describes which role is the principle performer of a task.
executes_task_secondary:	ROLE x TASK, describes which role is the secondary performer of a task.
coordinates_task_primary:	ROLE x TASK, describes which role is the principle coordinator of a task.
coordinates_task_secondary:	ROLE x TASK, describes which role is the secondary coordinator of a task.
operational_leadership_in:	ROLE x ROLE, describes which role is the leader in a part of the organisation.

Examples:

is_organisation_in_phase(disaster_prevention_organisation,phase2)

is_subtask_of(preparation_care_centres,preparation_evacuation)

coordinates_task_primary(police,preparation_care_centres)

executes_task_primary(cityhall,preparation_care_centres)

So far three disaster plans have been analysed and discovered a certain level of similarity in the task and process hierarchy, which indicates that it is possible and beneficial to build a general ontology of tasks in disaster situations. A partial one was built on the information available from these three disaster plans and it is considered to analyse more in order to adjust and refine the ontology.

Organisational Change

Organisation change is a key factor within incident management organisations. Terminology such as up scaling and downscaling are often observed elements in disaster plans. A comparison between the organisation change specified in two disaster plans basically entails comparing two elements: (1) Comparing the triggers for organisation change; (2) comparing what the differences in the resulting changes are in case the trigger matches. To enable this comparison the formal approach for specifying organisational change of [Hoogendoorn *et al.*, 2004] is adopted. That approach is suitable for modelling organisational change in situations where people involved have some common knowledge of the changes and what they entail as is the case in incident management.

To formally specify changes to be performed within an organisation the language of the previous section is extended with the meta-sorts ORG_ELEMENT and ORG_CHANGE_ELEMENT. The relations to specify the organisation's structure and the tasks and responsibilities are used here as functions to form terms of sort ORG_ELEMENT. For example, next to the relation is_role_in: ROLE x ORGANISATION there is also a function

is_role_in: ROLE x ORGANISATION → ORG_ELEMENT

Functions are defined for adding, deleting, and modifying an organisation element:

add:	ORG_ELEMENT → ORG_CHANGE_ELEMENT, describes an organisational element being added.
delete:	ORG_ELEMENT → ORG_CHANGE_ELEMENT, describes an organisational element being deleted.
modify:	ORG_ELEMENT x ORG_ELEMENT → ORG_CHANGE_ELEMENT, describes that the first organisation element is modified to the second argument.

Besides the need to specify *what* needs to be changed also the *when* of change needs to be formally specified. For this the language is extended with the sorts TRIGGER and PHASE, and a relation is added:

is_trigger_for:	TRIGGER x PHASE x ORG_CHANGE_ELEMENT, describes that when a trigger occurs the phase is changed to PHASE and the organization is changed according to the specification.

CASE STUDY

In this section the attention is focussed on the two disaster plans that have been analyzed in details and the results of this analysis. First some background information is given and a brief summary of the specifics of the plans. Then some examples are given from the analysis and a summary and discussion of the results.

Eindhoven

The first disaster plan studied is that of Eindhoven [Gemeente Eindhoven, 1993]. Eindhoven is a relatively large city in the Netherlands with approximately 200,000 residents. The city contains several industrial areas (e.g., Royal Philips Electronics and a militairy airport). A large scale aviation accident occurred at the airport in 1996 [Abbink, *et al.*, 2004].

The disaster plan of Eindhoven has been investigated following the guidelines set in this paper. The Eindhoven disaster plan identifies five phases: (1) Local incident; (2) Local calamity or disaster; (3) Local incident, calamity, or disaster with use of regional coordination; (4) Inter-local incident; and (5) Inter-local calamity or disaster. For each of these phases the structure of the organisation has been identified; only the second phase is presented in this paper, see in Figure 2.

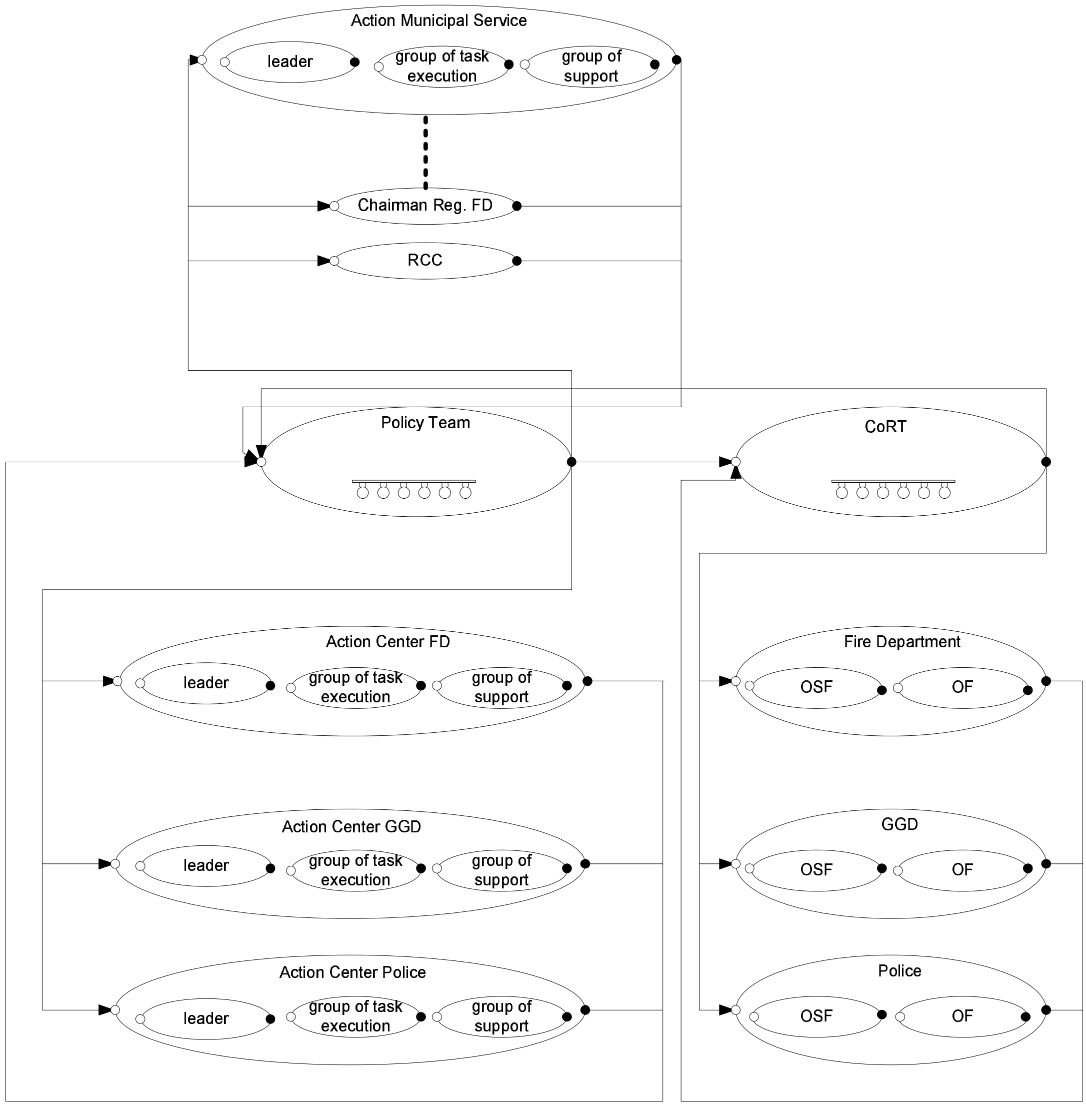
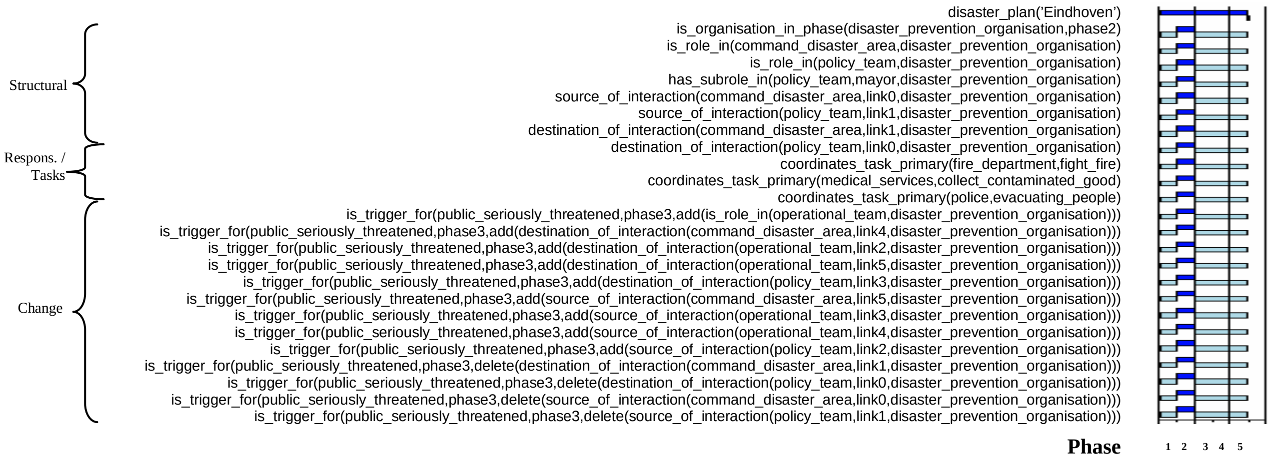


Figure 2: Structure of the Eindhoven disaster prevention organisation in the Local Incident phase.

The abbreviations used in the Figure are the following: OSF stands for On Scene Forces, Off Scene Forces are abbreviated to OF and GGD is an abbreviation for the Medical Services. Finally, CoRT stands for Command Disaster Area. Inter-level connections between composite roles and their subroles are often omitted because the disaster plan does not specify any of these relationships.

Next step in the modelling guidelines is to identify the responsibilities and tasks for each role, as described informally in the Eindhoven disaster plan. Some examples are: the fire department is in charge of the task of fighting the fire, the police is responsible for evacuating the people, and the medical services are responsible for collecting contaminated goods. These examples are formally represented in Figure 3.

Final step in the process is to specify organisational change, and the triggers that cause this change. The disaster plan of Eindhoven is vague about this: it is left to the mayor and its advisors to decide on the appropriate phase. However, the triggers can be derived by comparing the definitions of each of the phases. For example, going from phase 1 (a local incident) to phase 2 (a local disaster) means that the public is actually seriously threatened. The change of organisation involves the following elements: An operational team is added to the organisation which is responsible for the action centres of the regional emergency services. Furthermore some of the communication lines are changed. Figure 3 shows a specification of the disaster plan of Eindhoven, restricted to the examples given above.



The x-axis denotes the phases the disaster prevention organisation is in, the y-axis shows the atoms.
A dark box indicates when an atom is true within a particular phase, a lighter box indicates that this is not the case.

Figure 3: Part of a formal specification of a disaster plan

Uithoorn

Uithoorn is a much smaller town than Eindhoven. One potentially dangerous site on the territory of Uithoorn is the chemical complex Cindu/Nevcin where in 1992 an explosion caused a heavy incident with several casualties and fears for contamination of environment and agricultural produce. After this incident, special attention was directed to the development of a better disaster plan. Nowadays Uithoorn belongs to a group of municipalities including Amsterdam and 6 surrounding municipalities that base their disaster plans on a common template.

In the disaster plan of Uithoorn [Gemeente Uithoorn, 2003], the development of the situation is described by means of five phases ranging from phase 0 where the co-ordination between the police, fire department and medical forces is not necessary to phase 4 where inter-local co-ordination is required and the national co-ordination centre is involved. Figure 4 shows the organisation for phase 2. The transition between phases is decided by party(s) designated explicitly in the disaster plan based on specified criteria. Most of the specification of the other phases, of the tasks and responsibilities, and of the transition of phase is left out of this paper. The reader can contact the authors for a complete specification.

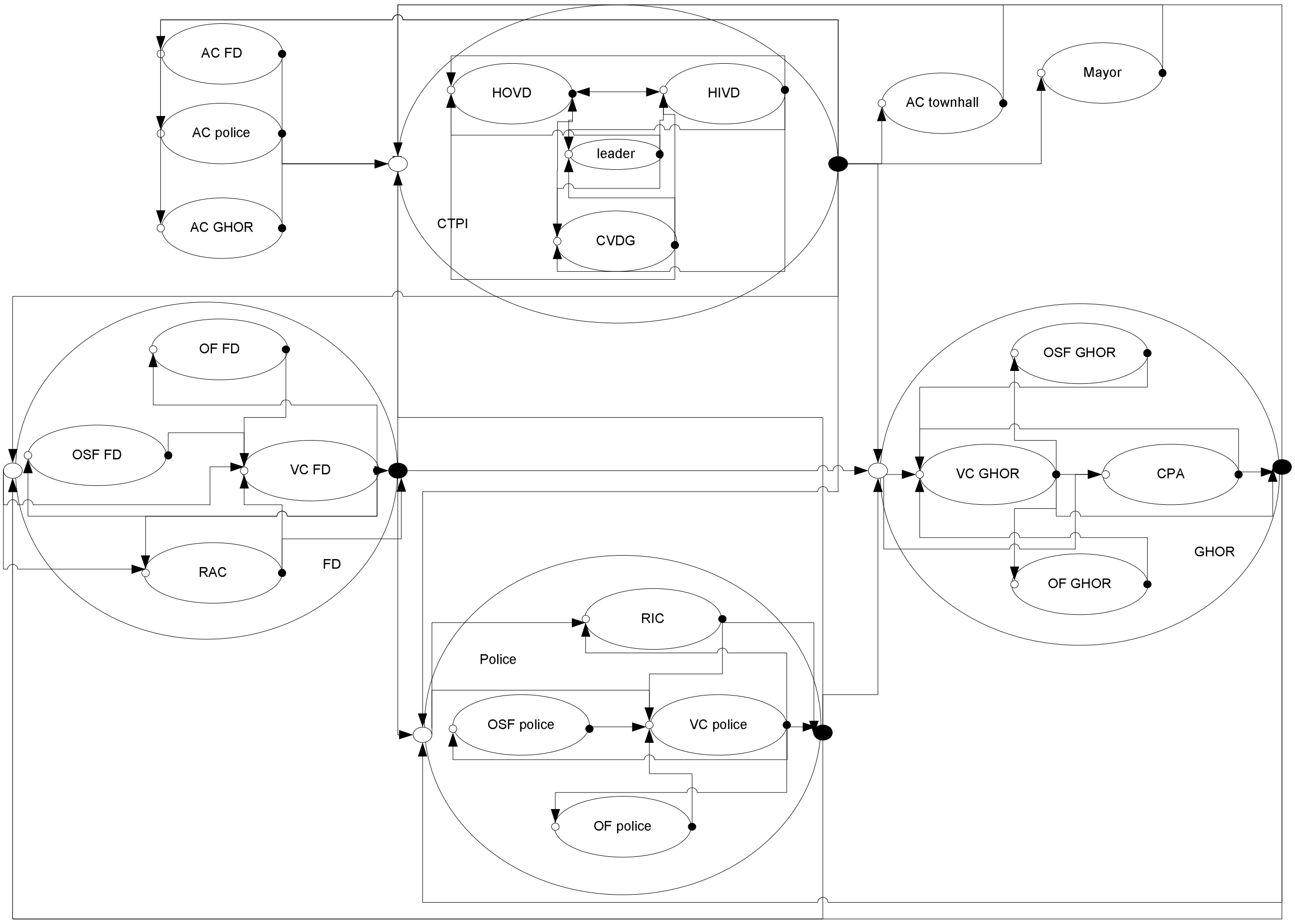


Figure 4: Structure of the Uithoorn disaster prevention organisation in phase 2.

Analysis and Comparison

For the purpose of comparison of the disaster plans described above a number of relevant properties have been identified. These properties constitute two groups: (1) local municipality properties and (2) regional coordination properties. The first group describes properties that do not influence the incident management organisation of other (neighbouring) municipalities and can therefore differ between these municipalities. Properties in the second group do influence the incident management organisation of other municipalities. In case of an inter-local incident these kind of properties have to be the same to enable a proper functioning of the disaster management organisation.

Consider an example of local municipality properties.

Property 1.

Informal form

The command centre of surroundings of the incident area (ComRT) is a part of the incident management organisation of municipality X in phase 4.

Formal form

state(γ_1,PHASE4) |= [is_role_in(ComRT,ORG4) $\wedge$ disaster_plan(X) $\wedge$ is_organisation_in_phase(ORG4,PHASE4)]

This property holds for X = Uithoorn and does not hold for X = Eindhoven.

Consider two examples of regional coordination properties.

Property 2.

Informal form

The mayor of the biggest municipality coordinates the work of the Managing Platform Centre (MPC) in the incident management organisation of municipality X in phase 4.

Formal form

state(γ_1,PHASE4) |= [coordinates_task_primary(biggest_municipality_mayor,regional_collaboration_in_MPC) $\wedge$ disaster_plan(X)]

This property holds for X = Uithoorn and does not hold for X = Eindhoven.

Property 3.

Informal form

The mayor of the municipality that was the first involved in an incident, coordinates the work of the Managing Platform Centre (MPC) in the incident management organisation of municipality X in phase 4.

Formal form

state(γ_1,PHASE4) |= [coordinates_task_primary(mayor_involved_first,regional_collaboration_in_MPC) $\wedge$ disaster_plan(X)]

This property holds for X = Eindhoven and does not hold for X = Uithoorn.

The formal approach in the comparison of disaster plans allows us to go further and analyze these differences and investigate whether they indeed lead to serious consequences. An example of such analysis is given in the following paragraphs. It is already known (see property 1) that the role ComRT is present in the disaster plan of Uithoorn but not in that of Eindhoven. This role represents the team responsible for activities in the surroundings of the disaster area including traffic regulation, isolation of the area, etc. In both plans the team CoRT is present which co-ordinates the on-scene operations. Is this difference fundamental? Maybe the tasks of ComRT for the case of Uithoorn are actually assigned to CoRT in the case of Eindhoven. This hypothesis is expressed in property 4, and decomposed into properties 5 through 8 to ease the formal proof process, as depicted in Figure 5. The formal relations are:

Property 5 $\wedge$ Property 6 |= Property 4

Property 7 $\wedge$ Property 8 |= Property 6

Only the formal specifications of the leaves of the tree in Figure 5 are given.

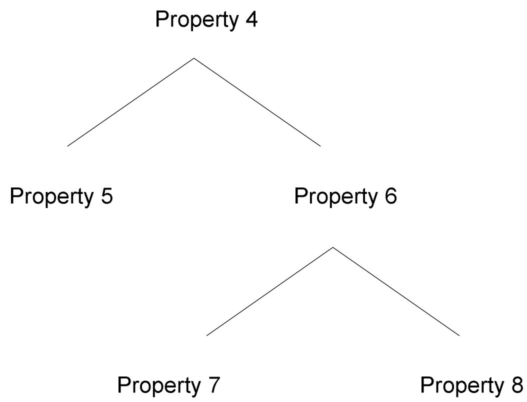


Figure 5: The decomposition of property 4 represented in an and-tree

Property 4.

Informal form

The set of tasks assigned to CoRT in the disaster plan of Eindhoven is the same as the set of tasks assigned to CoRT or ComRT in the disaster plan of Uithoorn.

Property 5.

Informal form

All tasks of CoRT in the disaster plan of Eindhoven are either tasks of CoRT or of ComRT in the disaster plan of Uithoorn:

Formal form

$\forall$ T:TASK:

state(γ_1,PHASE4) |= coordinates_task_primary(CoRT,T) $\wedge$ state(γ1, PHASE4) |= disaster_plan('Eindhoven')
$\Rightarrow$ [state(γ_2,PHASE4) |= coordinates_task_primary (CoRT,T) $\vee$ state(γ_2,PHASE4) |= coordinates_task_primary(ComRT,T)]
$\wedge$ state(γ_2,PHASE4) |= disaster_plan('Uithoorn')

Property 6.

Informal form

All tasks of CoRT or ComRT in the disaster plan of Uithoorn are also tasks of CoRT in the disaster plan of Eindhoven.

Property 7.

All tasks of CoRT in the disaster plan of Uithoorn are also tasks of CoRT in the disaster plan of Eindhoven.

$\forall$ T:TASK:
state(γ_1,PHASE4) |= coordinates_task_primary(CoRT,T) $\wedge$ state(γ1,PHASE4) |= disaster_plan('Uithoorn')
$\Rightarrow$ state(γ_2,PHASE4) |= coordinates_task_primary(CoRT,T) $\wedge$ state(γ_2,PHASE4) |= disaster_plan('Eindhoven')

Property 8.

All tasks of ComRT in the disaster plan of Uithoorn are also tasks of CoRT in the disaster plan of Eindhoven.

$\forall$ T:TASK:
state(γ1,PHASE4) |= coordinates_task_primary(ComRT,T) $\wedge$ disaster_plan('Uithoorn')
$\Rightarrow$ state(γ_2,PHASE4) |= coordinates_task_primary(CoRT,T) $\wedge$ state(γ_2,PHASE4) |= disaster_plan('Eindhoven')

By checking properties 5, 7 and 8, it is discovered that the functions of CoRT in the case of Eindhoven and CoRT and ComRT in the case of Uithoorn indeed overlap. Therefore, while the absence of ComRT is certainly a difference between the two disaster plans, in reality the difference is smaller than expected at first sight.

The comparison between the disaster plans of Uithoorn and Eindhoven revealed two differences in the regional coordination. The first concerns leadership: which mayor is in charge of the disaster management organisation in case of an inter-local incident. The Uithoorn plan states that the mayor of the biggest municipality is the leader. The Eindhoven plan states that the mayor of the municipality where the incident started is in charge. Imagine that these are neighbouring municipalities and that an incident that affects both municipalities is first discovered in Uithoorn, which is the smallest municipality of the two. According to the Eindhoven disaster plan Uithoorn remains in charge, and therefore does not take any initiative in forming an inter-local incident management organisation. Uithoorn however thinks Eindhoven will take the initiative as it is the biggest municipality involved in the incident. To prevent this kind of errors, such differences should be avoided. The second regional coordination difference concerns the incident phases described in the disaster plans. There does not exist a one-to-one mapping between these phases, therefore the municipality that has the lead in the incident management organisation might declare a certain phase that cannot be interpreted by the other municipalities involved. For example, in the Uithoorn disaster plan, a phase is present where there is multi-disciplinary coordination without the mayor being involved. In the Eindhoven disaster plan there doesn't exist any phase including multi-disciplinary coordination in which the mayor is not involved in the disaster prevention organization.

Differences in local municipality properties were also observed in the comparison of the disaster plans. These differences include elements such as splitting up the command of the disaster area in the disaster plan of Uithoorn while this remains one group in the Eindhoven disaster plan. These difference can however be formally mapped to each other, and are therefore not as crucial.

CONCLUSIONS AND FUTURE WORK

In this paper a formal framework for modelling and comparing disaster plans is presented and applied to a number of case studies. The framework extends earlier work of [Hoogendoorn et al., 2004] and [Broek et al., 2005] with specific constructs and reusable patterns for the domain of incident management, in specific for disaster plans. The approach uses formal graphical, and textual languages, in casu Leads-To and TTL (see [Jonker and Treur, 2002]). The parts specified in Leads-To can be simulated in Leads-To software environment. The parts that cannot be specified in Leads-To but only in TTL consists of properties that do not match the executable logical format as specified in [Jonker and Treur, 2002]. These properties are relevant for verification and validation purposes. The existing specialised checking software allows the checking of those parts of the model against simulation and transcribed real traces.

When compared with the work of [Grathwohl, et al., 1999] the framework presented in this paper is more generic from several perspectives. The first advantage is that the framework allows modelling on different levels of abstraction, and is, therefore, capable of modelling the Dutch disaster plans, which are on a highly abstract level of abstraction when compared to the plans that Grathwohl et al., modelled. The second advantage is that simulation of the models in different situations is possible. The third advantage is the software support for checking the model against simulation and transcribed real traces.

With respect to incident management this work contributed by proposing a formal approach for the modelling and comparison of disaster plans. The approach is explained in detail and tested in three case studies. The main results are the classification of differences into local differences and inter-local differences. The local differences effect only incident management in the municipality itself. The local differences can be fundamental or not when comparing the actual incident management. For example, two disaster plans differed in having only one or two zones around the epicentre of the incident. This difference has clear effects on the organisational structure prescribed in the disaster plans. However, the tasks associated with the zones are comparable. The same holds for the associated responsibilities. In other words, the organisational structure differs, but the dynamics are comparable. The inter-local differences are counterproductive when municipalities have to cooperate in case inter-local incidents. Comparing two disaster plans in this manner revealed a possible conflict regarding leadership. The consequence is clear: all neighbouring municipalities should use the same rules for determination of leadership. Therefore, all municipalities in The Netherlands should share those rules.

In the future, systems such as the IMI system [Lee and Vught, 2004] will contain many disaster plans. Making sure that these disaster plans are consistent with each other is of crucial importance for inter-local incident management. The plans in the system can be formalized, and verifying whether a new plan is consistent with the plans currently in the database would simply entail formalizing that plan and performing verification. In case the plan is indeed consistent the plan can be added to the database, including the formal description. On the long run an entirely different approach can be followed. Instead of taking an informal disaster plan as a point of departure, in future disaster plans should be first and foremost formal plans, from which an informal plan that is readable for human beings is automatically generated.

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