Development of a Connectivity Map for Measurement of Total Supply Chain Value

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Abstract:

Organisations intend to optimise their supply chain (SC) by following the most suitable SC strategies that serve their business interest to gain a competitive advantage. This paper reviews the literature to extract the relationship between leagile attributes and SC drivers to estimate total supply chain value (TSCV). As a result, three leagile attributes efficiency & flexibility (E&F), decoupling point (DP) and virtual network (VN) along with four main SC drivers consisting of production, distribution, inventory and information have been deployed. Effects of leagile attributes to the SC drivers are evaluated to measure TSCV using four performance metrics i.e., cost, quality, service and lead time. This research developed a conceptual connectivity map to measure the average value of each driver at a micro-level (upstream/downstream) to evaluate TSCV at the macro-level for SC optimisation. The proposed connectivity map would support supply chain managers to implement the leagile strategy by measuring TSCV.

Keywords: Supply Chain; Optimisation; Lean; Agile; Leagile; Performance Metrics; Connectivity Map.

Reference to this paper should be made as follows: Khoei, S.Z. and Ghosh, S. (2021) ‘Development of a connectivity map for measurement of total supply chain value’, *Int. J. Agile Systems and Management,* Vol. 14, No. 1, pp.140 -169.

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1. Introduction

Companies are constantly seeking process optimisation within their SC to improve all the levels in their SC for responding to customers' demands effectively and reach competitive advantage over their competitors. A new business notion is that the competition is not among the individual companies anymore but their supply chain (Christopher and Towill, 2001). The business failures in the integration of optimisation strategies in SC would affect the viability and performance of SCs in the market (Nakandala and Lau, 2019). Integration of optimisation strategies for integrating SC functions, processes, and structure between companies in SC are vital (Christopher, 2016). Because the moment customers receive an unsatisfactory service level, sluggish delivery lead-time, low-quality product at a high price, they would switch, and probably do not return in the future (Patel et al., 2020 and Raj et al., 2018). Consequently, understanding the demand and constraint of the marketplace and the major concerns of the companies in SC is critical for the development and implementation of SC strategies (Mason-Jones et al., 2000a).

Many companies are pursuing lean and agile SC strategies to reduce costs and improve customer demand to reach a competitive advantage (Qamar et al., 2018). The lean concept is about doing more with less and is primarily concerned with the elimination of waste or "Muda" to maximise profit (Womack and Jones, 1996). Muda in production exists in seven forms: 1. Defects in production 2. Unnecessary movement 3. Unnecessary processing 4. Overproduction 4. Inventory 5. Unnecessary transportation 7. Unnecessary Waiting (Ohno, 1988). Shah and Ward (2003), defined the lean manufacturing as a set of strategies such as Just-In-Time (JIT) and Total Quality Management (TQM), working together synergistically to create a high-quality streamlined system. Conversely, the agile concept is about flexibility and rapid response to demand variation in a changing market environment be it in product variety, volume, or mix (Christopher and Towill, 2002). Although both concepts are inherently different and independent from one another, however, they can, coexist in one continuum and be combined to form a total operational SC known as "leagile" (Naylor et al., 1999). Leagile strategy is a hybrid of conventional Lean and Agile strategies to help companies to take advantage of both strategies in terms of efficiency and flexibility in SC (Bhamra et al., 2020). However, implementing the leagile strategy in an SC is one of the main challenges of SC integration optimisation. Fadaki et al. (2019) argued that there is a significant deviation between the companies' real practices within an SC with conceptual leagile strategy. According to Bhamra et al. (2020) still, this gap has remained in literature and scholar should develop the appropriate practices for implementing leagile strategy within SCs.

According to Fisher (1997), there is a strong relationship between the type of SC and the type of product, thus, the structure of SCs must match with the product's type. Otherwise, SCs would be exposed to the risk of mismatch between the product's type and SC's type. He categorised the products into two main groups, "functional" and "innovative". Functional products or standardised products (e.g. basic clothing, oil, and gas, grocery items, etc.) have a stable demand and long-life cycle. While innovative products (e.g. computers, fashion apparel, mobile phones, etc.), have an unstable demand and a short life cycle. Mason-Jones et al. (2000b) recognized eleven attributes to distinguish among lean and agile SCs as shown in Table 1. About 80% of the products in the marketplace are designated as functional products/modules/components and around 20% of the products in the marketplace are categorised as innovative products after further customisation (Barker, 2001).

<<Insert Table 1 here>>

Qamar et al. (2020) shown how the ambidexterity concept could be used for lean and agility trade-offs based on the processes and capabilities of the companies in SC. They emphasised that ambidexterity is one of the main challenges that managers face when choosing between efficiency and flexibility. However, their results proved that the companies in the automotive industry do not focus on the trade-off between flexibility and efficiency in their processes and capabilities. So, this study aims to present how SC managers could trade-off between lean and agile strategies to enhance the total supply chain performance. To this end, the interaction between leagile SC and product types (innovative and functional) has been explored in this paper.

This paper contributes to the understanding of leagile strategy and the roles of SC drivers for implementing leagile SC. The relevant literature has been reviewed to identify how leagile strategy could be developed and deployed by companies through SC from upstream (supplier) to downstream (marketplace). This study primarily focuses on exploring the leagile attributes and the key drivers of a leagile SC having a significant impact on the operational side of a SC. Then different practices of the leagile attributes and their relationship with the SC drivers from upstream to downstream sides of SC were represented according to the outcomes of the publications in this area. Finally, in this study, the connectivity map is developed for evaluating the SC performance through the measurement of TSCV. Consequently, this paper has demonstrated the direct/indirect impact of leagile attributes with regards to SC drivers.

Also, performance metrics are provided not only for estimating SC drivers at the microlevel but also to find the value of SC drivers within the SC to determine the TSCV of the SC at macro-level. Leagile SC can set the aims and objectives of SC for SC drivers and use a benchmark (customer's value expectation) to assess how well each SC driver is functioning. The rest of this paper is organised as follows. In Section 2, the literature of leagile attributes and SC drivers was reviewed. Section 3 elaborates on the relationship between leagile attributes and SC drivers and represents the proposed connectivity map. Finally, Section 4 provides the findings of the paper and some directions for further research.

2. Literature review

In a leagile SC, the upstream side of the SC would adopt the push concept based on the lean strategy. This is because the market and demand are stable and predictable. Also, the production and supply output is forecasted based on historical data, thus, the companies that are positioned in the upstream side of the SC are adopting a Make-To-Stock (MTS) approach (Alinezhad et al. 2019). In contrast, the downstream side of the SC implements Make-To-Order (MTO) method as it faces different market conditions which are associated with instability and demand uncertainty. Therefore, the companies' managers aim to adopt the pull concept for advancing customer satisfaction level through customisation (Olhager and Prajogo, 2012, Naylor et al., 1999). Halawa et al. (2017) argue that SCs' managers should decide on how to integrate the MTS and MTO through the SC for applying leagile strategy. Nevertheless, little attention has been paid from a practical viewpoint to support MTS and MTO practices in leagile SC (Halawa et al., 2017).

DP also known as a differentiation point, represents a key point inside leagile SC which separates the lean from the agile concept (Figure 1), wherein the activities appertaining to forecast-driven scenarios at the upstream and the activities associated with order-driven scenarios intersect (Bhamra et al., 2020). The key idea behind the DP positioning is to produce functional products/modules/components as efficiently as possible at the upstream and hold strategic inventory as a buffer at the DP while leaving the rest of the process assembly/production/customisation to the downstream side to figure out the actual requirement of the customers (Naylor et al., 1999, Mason-Jones et al., 2000a, Olhager, 2003).

<<Insert figure 1 here>>

Also, besides the material DP, Mason-Jones and Towill (1999), have also identified information DP; they have argued, to maximise the performance of leagile SC, the traditional material DP should be distinguished from information DP. The traditional SC model places the information DP at the same point as material DP, which effectively positions the information DP as close as possible towards the end consumer. Mason-Jones and Towill (1999), have claimed that this strategy is ineffective as it results in information distortion at the upstream. Therefore, the information DP should be positioned as far upstream as possible. So, the entities at the upstream can make their decisions based on undistorted information and increase forecast accuracy (Mason-Jones and Towill, 1999).

Material DP is primarily concerned with the method of production (MTS and MTO) instead of purity of demand data (Hedenstierna and Ng, 2011). Recently, Bhamra et al. (2020) reviewed the relevant literature to address the main attributes and characteristics of the leagile SC and provided insights for implementing leagile strategy effectively. The applicability of the DP as a tool for implementing leagile SC need to be studied for different industries (both manufacturing and services). For example, according to Bhamra et al. (2020), more attention should be paid to companies (SCs) in the public and health care sectors. Indeed, the scholars/managers should focus on DP as a tool for determining a certain point among lean and agile strategies through SC. Therefore, further development on the concept of DP is necessary for a deeper understanding of leagile in various SCs (Bhamra et al., 2020). In this paper, we develop on the relationship between DP and information and type of product (i.e., functional or innovative). Moreover, the relationship of DP with the other drivers of the SC and the correct positioning of the DP is also examined in this paper.

The position of the DP can be changed based on pinpointing a proper balance between productivity and flexibility (Rudberg and Wikner, 2004). Location of DP is determined by prioritisation of cost and service level (Figure 2) as well as the condition of the market, therefore, when there is less variation in demand and marketplace is stable, cost becomes the main priority (winner), thus, the DP is pushed downwards towards the marketplace, if demand fluctuation is high and requires a high product mix, then the service level becomes a top priority (winner) and DP is pushed upwards towards the suppliers. This study aims to illustrate the relationship between the SC' drivers and the position of the DP through SCs (i.e., from upstream to downstream). Indeed, the position of the DP could change the SC strategy from pure lean strategy to pure agile strategy upon various SCs' drivers (Fadaki et al., 2019a).

<< Insert figure 2 here>>

According to Gunasekaran et al. (2004a), many SCs have not yet fully maximised the potential of their chain's capabilities due to failure in the adaptation of suitable metrics to evaluate their SC's performance. Naylor et al. (1999) identified the performance metric of leagile SC including lead-time, service, cost, and quality as shown in Figure 3. In a leagile SC, upstream adopts lean concept where the focus is on the principles of cost-efficiency (leanness). Therefore, when SC is efficient and processes are lean, the cost would be a winner and lead-time, quality and customer service would be qualifiers; while the downstream section relates to customer's demand volatility and is mainly focused on responsiveness (agility), so, the market winner is customer service and market qualifiers are quality, cost, and lead-time (Mason-Jones et al., 2000b).

<<Insert figure 3 here>>

2.1. Supply chain drivers

SC optimisation is the efficient and effective management of the production flow of services and products from the source to end-user. It is optimising the overall processes of SC right from upstream activities such as sourcing, design, and production to downstream processes like assembly, customisation, and delivery (Hosseini et al., 2019). Contemporary Supply Chain Management (SCM) goes beyond the traditional approaches of management by embracing inter-organisational latitude to bring the members of the chain together, with a mutual goal of efficiency and optimisation (Virmani et al., 2018). According to Hicks (1999), the goal of strategic SC is to serve the market by designing an efficient and profitable SC. SCM involves integration and coordination between production, distribution, packaging, inventory and material handling processes in an SC (Rauch et al., 2017).

To illustrate the relationship between leagile attributes and supply chain drivers, in this paper initially, the most important interdependent SC drivers related to SC operation have been identified and adopted through the synthesis of the literature. Due to the main goals of this study, the key drivers that would have the most significant impact in the operational side of SC particularly to leagile SC's attributes have been selected (Fadaki et al., 2019a). Therefore, the chosen drivers that would suit the agenda of this research are including production, distribution, inventory, and information.

Secondly, the paper explained the role of each driver in the context of a leagile structure. According to Vidal and Goetschalckx (1997), there is a lack of research addressing the integration of each SC drivers (i.e., Purchasing, Production and Scheduling, Inventory, Warehousing, Transportation) into the overall SC structure. They further stated that the most comprehensive strategic challenge for managers is the optimisation of the whole SC (Vidal and Goetschalckx, 1997). Christopher (2016) defined three levels of SCs' drivers based on functional, internal, and external integration. He argued that the evolution of integrations in SCs had happened from a complete functional independency to functional, internal, and external integration whereas each company in SC aimed to extend their connections to upstream (suppliers) and downstream (customers). Hence, he defined three main drivers including production (manufacturing management), inventory (material management), and distribution and logistics management (Christopher, 2016, p18).

Cerchione and Esposito (2016) reviewed the supply chain literature and found out the SC context have been growing intensely from 1970 up to the present day. In the last decade, globalization, the pursuit of sustainability, uncertainty, risk, and disruptions have increased the complexity of the production, distribution, information, and inventory management processes in SCs. Today's SCs are multi-dimensional systems crossed by information, financial, and material flows.

Managing inventory, production, and distribution in such complex SCs expose the necessity of the Information and Communication Technology (ICT) for responding to the new SCs' challenges. Nguyen et al. (2018) reviewed the big data analysis approaches as an information management tool in the context of the SCM. They emphasized that the information factor plays a critical role in the success of the SC in a competitive environment as well as production, inventory, and distribution drivers. Hence information management researches have been aroused by developing the ICT.

Hugos (2018, P10) classified five drivers which directly affect the performance of the SCs and can enhance the capability of the SCs. He argued that the drivers have an independent effect on the SC and are including production, inventory, information, distribution, and location. Since this study tries to evaluate the relationship between the SCs' drivers and leagile attributes, four drivers consisting of production, inventory, information, and distribution have been selected. While the location driver comprised of different factors such as the cost of facilities, labour, tax, and infrastructure (Hugos, 2018), the leagile's attributes would not have a significant impact on it. Therefore, four drivers of SC have been selected to present their relationship with the leagile attributes. Finally, this research discusses why each driver is interdependent on one another and why collaboration between each driver is vital to the successful establishment of a leagile SC to optimise the performance of the SC.

Production: The customers increasingly require producers to customise and improve the quality of their products while reducing the costs and shortening lead-time (Chan and Qi, 2003). Therefore, producers are under pressure to increase efficiency (Yusup et al., 2015), and effectiveness (Khatri et al., 2019), to remain/become competitive in the marketplace. From a manufacturing perspective, Neely (1991), defined effectiveness as the ability to respond to customer demand, and efficiency as a measurement of how resources of an organisation are utilised economically enough to reflect on the level of customer's satisfaction.

Distribution: Facilitates the flow of products throughout the chain whether in the form of a component or finalised product. Distribution system determines the retrieval and transportation of products from the supplier to the final customer (Wang et al., 2018). According to Gunasekaran et al. (2001), most of the research has been done as regards to distribution systems, emphasising the importance of cost-effectiveness and efficiency. Therefore, he suggested the development of a profile associated with the cost of distribution, to find a proper balance between different cost variables.

In traditional SCs, manufacturers sell products to retailers and retailers sell them to the end-users. In another scenario, first manufacturers dispatch the products to the Distribution Centre (DC) and then transport the final products to retailers. Retailers act as a sole distributor which helps the manufacturer by providing their customers with one-stop-shop experience, creating advertisements and promotional displays, providing shelf space, and holding inventory. However, this method increases the cost of acquirement for eventual customers (Narayanan et al., 2019).

The distribution system has gone through an upheaval since the advent of the internet, in contemporary SC, some companies tend to cut the intermediaries and sell directly to the end customer. In this way, not only they can reduce the cost of purchasing for the end clients but also, they can acquire direct feedback from final customers and capture the latest trend more effectively (Choi et al., 2019). For example, Dell by adopting a similar strategy has successfully increased the efficiency of its distribution networks while keeping responsiveness by offering wide product variety at low prices (Zhang and Wang, 2018).

Inventory: Inventories consist of modules, components, and finished products held in the SCs (Gunasekaran et al., 2001). Companies stock products in their inventory as a buffer against uncertainty, providing companies with the capability to become flexible and so respond more rapidly to changes within the market (Amiri, 2006). However, keeping inventory can be expensive, in fact, Harrington (1996), identified inventory as one of the major cost element in most businesses, therefore, determining the optimal inventory level at each stage of SC is important (Hugos, 2018). Effective management of inventory is becoming increasingly more significant as the final customers require a higher level of customer service, therefore, assessment of associated costs with inventory and appropriate trade-offs, with suitable performance measures (Cost, Quality, Service-level, Lead-time), should be implemented (Gunasekaran et al., 2001).

Information: Information flow in SC is a mechanism that facilitates coordination among SC members, which enables synchronisation between production scheduling, distribution planning, and inventory control (Lee et al., 1997a). Wu and Cheng (2008), indicated that the increase in information sharing between the partners decreases the cost of inventory, production, and distribution. According to Chandra and Kumar (2000), members of the SC coordinate their processes with one another through feedforwards/backward information-sharing mechanism. One of the dynamics of SC optimisation is enabled by using information sharing to make better decisions regarding production planning, assigning capacity, order processing, and material planning (Huang et al., 2003, Mavengere, 2013). Childerhouse et al. (2003) states, lack of information sharing in an SC could lead to chaotic behaviour, panic, uncertainty, and an increase in preventable costs.

One of the major issues in SCs is demand-order variability, this phenomenon is referred to as the "bullwhip effect", which is when the order variability received by the supplier exceeds the actual demand variability, this occurrence reflects the distortion and amplification of demand in an SC (Grabara and Starostka-Patyk, 2009). According to Lee et al. (1997b), the passage of information can minimise the detrimental effect of the bullwhip effect throughout the chain, Mason-Jones and Towill (1999), argued for highly visible and streamlined information flow through coordination between the entities within a chain to simplify the material flow.

The extent of information sharing varies and depends on the nature of a business within a chain in relation to outsourcing and the level of trust amongst the partners as members always run the risk of sharing sensitive information such as manufacturing scale, production schedule or inventory level (Williams et al., 2002, Rahman, 2004). Although the lack of trust is an important factor and it is still considered by many researchers as an SC risk (Raj Sinha et al., 2004). Nevertheless, contemporary SCM practices encourage building cooperative and meaningful long-term relationships among partners of SC, urging them to be willing to share risks among each other in a reasonable way (Nishat Faisal et al., 2006, Sahay and Maini, 2002).

This is achieved through the demonstration of a persistent and positive attitude of partners over an extended period (Hart and Johnson, 1999, So and Sculli, 2002).

2.2. Leagile attributes

Naylor et al. (1999), Mason-Jones et al. (2000b), Bruce et al. (2004), and Zhang et al. (2012) have argued that when it comes to leagile SC evaluation, the leagile concept possesses a widespread, value-adding configurability, such as resolving conflicts between efficiency (low cost) and effectiveness (fast response) in an SC, virtual information sharing and order guidance through the upstream and downstream, shortening the length of SC, strategic DP to avoid stock obsolescence and stock out, and encourages close collaboration among the partners. So, in the following paragraph, the main attributes of the leagile SC and their features would be described.

Efficiency & Flexibility (E&F): The firms at the upstream will be adopting a lean management approach to be as efficient as possible. This is achieved by minimising the costs through diminishing waste and maximising productivity (Womack and Jones, 1997). On the other hand, at the downstream side of the chain, the focus will be on flexibility, which is referred to as the quality of businesses to bend to customers' demands without breaking (adaptability), which is in-line with the agile strategy (Stevenson, 2013 and Li et al., 2008). By incorporation of both concepts in a hybrid stance, the way is paved to become jointly efficient as well as flexible, leading to production capacity within the chain, which can handle variations in demand while maintaining cost-effectiveness (Naylor et al., 1999 and Qamar et al., 2019). Therefore, this paper identified E&F as one of the leagile attributes.

Decoupling Point: In a leagile scenario, the upstream where leanness is practised is separated from the downstream where agility is applied by the DP. This point is the critical stocking point which means upstream firms will be producing and delivering the components up to this point based on a forecast since the demand is fairly visible due to stability in the marketplace and from the DP position onwards (downstream), the SC will produce and deliver customised goods based on demand (Naylor et al., 1999, Mason-Jones et al., 2000b).

As presented in (Table 1) different products types (functional/innovative) require a different SC strategy (lean/agile/hybrid) (Fisher, 1997). Therefore, in a leagile SC, the functional components will be produced in accordance with the lean principle (forecast-driven) and innovative products will be produced by following the agile principle (order-driven) (Moynihan and Dai, 2011 and Cannas et al., 2019). According to Mason-Jones et al. (2000b), the cost for Product Delivery Process (PDP) are the summation of the physical PDP and Marketability costs. Physical PDP costs are associated with storage, production, distribution costs, while marketability is the cost of stock-out and stock obsolescence. The physical PDP costs will be a dominant cost at the upstream and marketability costs will be a dominant cost at the downstream. Therefore, in accordance with the initial forecast, the entities at the upstream can continue manufacturing and delivering of semi-finished or not yet fully assembled products/components, until the DP position (Virmani et al., 2018).

As it is almost impossible to produce high variety or a high volume of innovative products solely based on demand forecasts (MTS) due to the high costs associated with stock-out and stock obsolescence. It is also not feasible to produce innovative products in a leagile SC based on MTO due to high lead time and detrimental impacts on the service level, the postponement concept is applied (Yang and Burns, 2003). Postponement is positioned on DP to delay the customisation of the final product until real information (volume, quality, and function) of demand is revealed. However, this strategy only works when the final products share the same component/material (Feitzinger and Lee, 1997, Waller et al., 2000, Goldsby et al., 2006). Postponement enables enterprises to become flexible in producing different variety of the products using the same modules/components to modify/differentiate products to respond to the market’s volatility (Maharaja et al., 2018).

According to Zinn and Levy (1988a), Lee and Billington (1992) and Van Hoek et al. (1999), there are three types of postponement, one is referred to as the “Time postponement” concept which is based on deferred of forwarding of stock flow. The second postponement concept is centred on delay in assembly, production, labelling and packaging and is known as “Form postponement”. The third postponement concept is “Place postponement” which refers to holding customised products at a distribution point until the order is received.

In this way, the primary manufacturers at the upstream that produce modules/components focus on efficiency, and economies of scale are decoupled from the assemblers/producers at the downstream that use the modules/components to produce a wide range of products to respond to consumer’s demand fluctuation. Waller et al. (2000), have classified all three concepts into 1. Postponement on upstream 2. Postponement on downstream 3. Postponement on distribution.

1. In a leagile SC at the upstream side of the SC, the ‘Time postponement’ will be applied to postponement flow of procurement until the DP position ($DP_{Position}$). So, the manufacturer can postpone the orders for raw materials until the actual orders are received from downstream (Bagchi and Gaur, 2018).

1. In a leagile SC at the downstream, the 'Form postponement' will be applied until the specification of the order is received, so the customisation phase can be initiated (Yang et al., 2004)

2. In a leagile SC, 'Place postponement', refers to a postponement of delivering of final products by holding the strategic stock at a central location until the orders from downstream are transmitted (Van Hoek et al., 1999).

This paper used the following principles for successfully applying the postponement concept in a leagile SC:

1. Selection of only a single postponement concept, as it is not possible to operate more than one concurrently with any other postponement concept.
2. The postponement always falls on material DP.
3. The material DP should be positioned as close as possible to the marketplace.
4. Selection of any postponement strategy depends on product type and SC strategy.

This is because if a manufacturer/assembler decides to position time postponement through postponing the placement of raw-material orders until the order is received, they cannot apply another form postponement nor another place postponement on its material inventory. Since the order has been received already and therefore another postponement would be impractical. While the information flow through SC is necessary under leagile strategy, only the material flow could be restricted to improve the overall performance of the SC (Galankashi and Helmi, 2016). Hence the SCs' managers aim to control the material flow by postponement concept.

Also, by positioning the DP as close as possible to the marketplace, not only the companies could take advantage of the lean strategy at the upstream side but also they could respond to the market's expectations at the downstream respectively (Alinezhad et al. 2019). However, the postponement type and DP positioning depends on the types of product and features of the SC (Table 1). Therefore, we have proposed 3 scenarios for postponement in SC.

1. If a leagile SC adopts time postponement, then the assemblers at the DP will not place an order from the upstream manufacturers until an order has been received. If the manufacturers at the upstream and downstream are not vertically integrated, the costs associated with the inventory could be passed on to the producers at the upstream and also the assembler could practice mass customisation as it won't be restricted to use the same set of modules/components to create its products. It could first see what the

requirements of the product are and then start outsourcing accordingly, however, there are two main issues with this approach. In the first instance, the required components/modules might not be immediately available in the marketplace, secondly, it must wait for the delivery of the products before embarking on customisation processes. Both issues have a negative impact on the lead-time. Therefore, this type of postponement is most suitable for agile SCs where mass customisation is required, and the customers are willing to wait for longer lead-times.

2. If a leagile SC adopts form postponement, it will place the orders for components/modules from upstream manufacturers and stock the components/modules at a central strategic location at a generic level which reduces stock-keeping variance, in this way the assembler can postpone the customisation/assembly of products until the orders have been received, this increases the flexibility as the same components/modules could be utilised to produce a variety of products, however, the assembler(s) has to make sure that the same components/modules will be used throughout the customisation processes.
3. If a leagile SC adopts place postponement, it has to produce a variety of products before placement of any orders, which can result in a highly responsive SC, and decrease lead-time as a result of elimination of waiting time for customisation and subsequently, increase customer service level, however, due to high marketability costs associated with this practice, it seems to be a very risky strategy for innovative products. This strategy is the most suitable approach for functional products which are based on Make-To-Ship (MTS).

Fadaki et al. (2019a) argued that the DP position is a promising indicator for balancing hybrid lean and agile strategy in SCs. The left-hand side of the extreme point of the DP reveals the pure lean strategy, while the right-hand side of the extreme point of the DP indicates the pure agile strategy in a SC. Also, the midpoint signifies a balanced leagile SC that both leanness and agility have an equivalent share in a SC (Fadaki et al., 2019b). Based on form postponement strategy, DP would be positioned at the manufacturer/assembler level in a SC as shown in figure 4. In this way, the SC would be balanced based on lean and agile strategies. In contrast, the time and place postponement strategies would deviate the balance of a leagile SC to agile and lean strategies respectively (scenario I and III). Given the outcome of our assessment of postponement functions on three different leagile SC scenarios ($DP_{Position}$), it seems that the form postponement is the most suitable strategy for trading off lean and agile strategies.

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Virtual Network: In a VN, independent companies within an SC work together jointly based on common principles and shared values to exploit a business opportunity (Manthou et al., 2004). According to Naylor et al. (1999), the lean and agile concept considers market knowledge, SC integration, stream/virtual corporation, and lead-time compression at the same level of importance. VN reflects on the ability of managers of a SC to design a network in a way that utilises the core competencies of partners in a chain through collaboration, process integration, joint product development, and distribution and inventory management (Li et al., 2008). Virtual Integration (VI), Network-Based (NB), Market Sensitive (MS) and Process Integration (PI) concepts have been proposed by Christopher et al. (2004) for the formation of agile SCs (Figure 5), however, this paper argues that at least 3 of the agile foundations (VI, NB, PI) should be incorporated for the construction of a holistic VN, which is a prerequisite to operational excellence in a leagile SC. Whilst MS is important to the downstream members of the chain, to be able to analyse the Point-Of-Sales (P.O.S) data for the replenishment of inventory as well as responsiveness, this paper finds against its inclusion because the lean side of the SC (upstream) is not market-orientated and therefore, doesn't need to be responsive to market sensitivity due to stability in the market.

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In a leagile SC, all the members of the chain require a high degree of PI to integrate upstream and downstream members to form an NB leagile SC allowing the chain to be responsive to market fluctuation as well as maintaining cost-effectiveness. This is achieved through the implementation of the VI so the real-time information enables the entities upstream and downstream to align their processes (Production, Inventory, and Distribution) with one another so the entire SC can be as optimised as possible. However, the passage of information must be carefully planned as not all the real-time information would be useful for the enterprises at the upstream. For example, a company like Zara that outsources its labour-intensive activities to more than 300 small-medium sized manufacturers, sharing the real-time demand data with all the manufacturers in its chain, could create a bullwhip effect throughout the chain. This would be mainly because the companies at the upstream might not be able to interpret the data accurately because it would not be clear to them which of the sales data reflects directly on their production output. Consequently, it is Zara's responsibility to analyse the data initially to determine which of its suppliers, each sale belongs to, and then disseminate the information accordingly to ensure the right supplier can replenish its inventory to the right level, in this way not only can Zara significantly reduce its inventory level but also the firms at the upstream can make more accurate projections.

Mason-Jones et al. (2000b) emphasized that information sharing is the most important feature of a VN. Indeed, to achieve competitiveness, the formation of an “enriched information” SC is an obligatory task in the composition of leagile SCs (Mason-Jones et al., 2000b). The electronic connection enables SCs to improve customer responsiveness as well as effective operational coordination amongst the entities within the chain (Walton, 1994).

To stay competitive, it is essential to integrate IT into the business model and to have adequate IT knowledge to enable IT-driven SC (Gunasekaran and Ngai, 2004b). According to Chandra and Kumar (2000), organisations’ communication capability rises because of IT integration, whereby collaborators can mutually access shared information data amongst each other through a shared database which is updated in real-time. However, National Research (2000), identified some of the barriers of IT integration, such as the capital requirement for suitable IT infostructure and costs associated with training and education and the lack of trust in sharing information between organisations.

The term ICT and IT are often used interchangeably (Howard, 2005). For this study, we will be using the term ICT, ICT is generally referred to as a collective umbrella term which involves computer-based information systems to integrate different hierarchies, markets, and groups (Howard, 2005). According to Zhang et al. (2011), Researchers have attempted to evaluate the indirect impact of ICT on SC performance. Findings of Kent and Mentzer (2003), Sanders and Premus (2005) indicates that there is a positive correlation between ICT and SC performance. The scattered SC partners can be linked through ICT systems, which is likely to put a meaningful impact on collaborative partners to work towards a common goal, instead of confrontational price-driven relationships (Nedelko, 2013).

As the authors of this paper are interested in the relationship between or among the entities of a leagile chain, thus, we have focused exclusively on inter-organization ICT effect on a leagile SC performance. This focus is logical as inter-organisational ICT is naturally relating to SCM which is about the passage of information beyond the enterprise’s border (Zhang et al., 2011).

There are many different ICT systems available to be integrated at the inter-organisational level, one of the widely used technology is referred to as Electronic Data Interchange (EDI) (Hughes et al., 2003). However, according to Fisher (1997), instalment of any Electronic Data Interchange (EDI) system is not necessarily adequate for SC enhancement but rather the installed information system has to be designed in a way that matches the exact necessities of SC's specifications.

3. Optimisation of the identified SC drivers in a leagile scenario

Figure 6 explains the practices adopted in lean and agile SCs in regards to the 4 main identified SC drivers, the process of optimising the upstream/downstream side of the SC in relation to the DP position (Figure 1). The analysis of leagile attributes in respect to the main identified SC drivers has been done independently to illustrate the impact of each leagile attribute on each SC driver with the ultimate aim of unifying them into one leagile SC structure and demonstrate their functioning mechanism.

<<Insert figure 6 here>>

3.1. The impact of E&F on the SC drivers

3.1.1. E&F in production

E&F in a leagile SC production system is attained through the amalgamation of the lean and agile production system, functioning jointly in a continuum with a designated differentiation point known as DP (Figure 7). The aim of this is to lead the SC to market exploitation opportunities in a cost-efficient and flexible means (Krishnamurthy and Yauch, 2007). The efficiency of the production facilities in the upstream side of a leagile SC is achieved through lean implementation to minimise waste or Muda through the elimination of unnecessary production, unnecessary processes, overproduction (Womack and Jones, 1996, Narasimhan et al., 2006).

- From the production point of view, JIT is applied to achieve the following: 1) bottleneck elimination to reduce unnecessary delay in production 2) cellular manufacturing layout to reduce lead time and enhance capacity utilisation (Shah and Ward, 2003). ***Efficiency directly affects Production***
- From the operational perspective, TQM is applied for continues/sustainable improvement of product quality which leads to the minimisation of production defects. (Shah and Ward, 2003, Dahlgaard and Mi Dahlgaard-Park, 2006) **Efficiency *directly affects Production***

The flexibility of the production/assembly facility and the product type in the downstream side of the SC is an important factor of production.

- The production flexibility refers to the capability of the manufacturing line to cater to fluctuation in production processes, the scale of production and diversity of product's range (Upton, 1995).
- According to Naim and Gosling (2011), the customisation process could potentially be problematic to the manufacturer and result in the occurrence of a higher cost of production as it requires additional production adjustments and processes, thus, the capability of manufacturer/assembler with existing production capacity in the downstream side of the chain to respond to the market shifts by producing a variety of products with various production processes and technics to accommodate to changes in demand within the marketplace is imperative to the successful implementation of a leagile SC. ***Flexibility directly affects Production***

<<Insert figure 7 here>>

3.1.2. E&F in Distribution

The distribution channels are a set of interdependent organisations that are primarily responsible to deliver a service/product to the end consumer (Gundlach et al., 2006). Lean distribution is the ability to minimise waste and make the right product available to the customer at the right location and time (Reichhart and Holweg, 2007), hence, geographical dispersion has an impact on JIT delivery of lean producers Doz (1987), the manufacturers are seeking for suppliers with close proximity, for example, Dell has positioned most of its supplier's base close to the assembly plants, for JIT delivery, which aids the organisation to replenish inventory as frequently as 90 minutes (Hoffman, 2004).

- The main role of JIT in the upstream is to facilitate production with the minimum amount of inventory, through on-time and frequent deliveries in small batches, preferably at a close proximity coupled by synchronisation of orders between suppliers and manufacturers through EDI and adoption of multiple transportations and mixed loading methods when necessary (Chun Wu, 2003). The lean concept is applied to DC to reduce waste through holding minimum inventory and increasing distribution centre's utilisation rate (e.g. JIT and Kanban) (Rushton et al., 2014). ***E&F directly affects Distribution/Inventory***
- In the downstream, the agile concept is applied to DC to increase responsiveness, however, the dilemma for the managers is to strike an appropriate balance between inventory level and service level in relation to financial indicators and market expectations as the inventory will be applied as a buffer against the uncertainty in the

marketplace to improve service level (Helo et al., 2006). One way to achieve this is through the instalment of the flexible transportation system with different transportation modes (trucks, planes, freight, etc.) and multiple transport route to enhance speed and reliability to boost the distribution channels' responsiveness to market changes such as shift in volume demand and lead-time demand (Govindan et al., 2015). ***E&F directly affects Distribution***

3.1.3. E&F in Inventory

E&F strategies in Inventory have to be implemented in a way that leads to cost-effectiveness as well as responsiveness to reduce costs while taking proportional actions against changes within the marketplace (Claycomb et al., 1999, Simchi-Levi et al., 2018). JIT is about the provision of components/modules/products on a timely manner with the aim of inventory minimisation through reliance on suppliers' and carriers' capability to constantly procure an appropriate quantity of components/modules/products within a fixed time frame (Daniel and Reitsperger, 1996). Therefore, leagile SC should embed both Sourcing Flexibility (SF) and Vendor Flexibility (VF) strategies for inventory. The SF and VF approach is an essential aspect of a successful SC (Purvis et al., 2014).

- The SF for Inventory in a leagile SC, confers to the capability of the system's operator to reshape and re-configure the SC through selection and de-selection of vendors, this is for the formation of a wider supplier base which leads to greater market adaptability and resilience (Gosling et al., 2010, Purvis et al., 2014). ***Flexibility directly affects the Inventory***
- The VF approach on the inventory of a leagile SC refers to the inventory's capability of each vendor to be independently flexible. Having its own internal flexible inventory system in place with regards to every node of a SC, being connected to warehousing, transportation, and manufacturer (Gosling et al., 2010, Purvis et al., 2014) ***Flexibility directly affects Inventory***
- In the downstream side of a leagile SC, the selection and deselection process of suppliers should be carried out under the consideration of unpredictable demand and instability, decision making is carried out under the supervision of the managers to assess the supply and demand in the marketplace to select and deselect suppliers (Gosling et al., 2010, Purvis et al., 2014). ***Flexibility directly affects Inventory***

Handling of procurement and costs associated with the function of an inventory facility and the location of an inventory is a strategic challenge for the SC members.

To attain Efficiency and Flexibility in a leagile SC's inventory the following activities should be considered:

- At the upstream side of the SC the main aim is to generate a high rate of utilisation and minimisation of inventory throughout the upstream side of the chain (Vonderembse et al, 2006), since, at this stage of the SC production is based on a forecast, all the relevant order information is passed directly to the producer for more accurate extrapolation, so no excess stock is held in the inventory for the upstream departments (Goldsby et al., 2006). ***Efficiency directly affects the Inventory/Production and ICT indirectly affects Inventory***

- At the DP, sufficient inventory must be held as a strategic buffer to respond to market changes effectively (Goldsby et al., 2006). ***Flexibility directly affects Inventory***

- At the downstream side of the SC, no finish products are held as inventory in the manufacturing plant; once the customisation/assembly is taken place the final products are dispatched towards the retailers or the end customers directly (Goldsby et al., 2006). ***EF directly affects Inventory***

3.1.4. E&F in information

ICT in a leagile SC is implemented to boost E&F to further optimise the SC. The inter-organisation ICT enables information sharing between the members of an SC (Hong, 2002).

- At the upstream side of a leagile SC, ICT facilitates a smooth flow of demand and supports the organisations in a SC to level schedule their production planning in accordance with the data coming from the downstream which results in more efficiency in production, distribution, and inventory. ***Efficiency facilitated indirectly by Information to impact Production/Distribution/Inventory***
- At the downstream side of a leagile SC, organisations hold most of the inventory as Work-In-Progress (WIP) to respond to the marketplace changes. As soon as a client places an order, ICT system feeds in the information to the relevant inventory department to send the awaiting stocks for configuration/development to manufacturing/assembly plants. ICT enables downstream SC members to respond more quickly to market instability/uncertainty. However, the information must be passed in

a timely and accurate manner. ***Flexibility facilitated indirectly by ICT to impact Production/Distribution/Inventory***

3.2. The impact of DP on the SC drivers

3.2.1. DP and Production

The implementation of DP and form postponement is a prerequisite to achieving "leagility" in production (Naylor et al., 1999). In most cases, these two points are effectively positioned at the same place in a leagile SC.

- In a leagile SC, marketing advantage of customisability aspect of production, MTO at the downstream side of a SC is through the implementation of 'Form postponement' on the DP, in order to postpone the assembly/manufacturing until customers place an order and stipulate the product's exact specification and demanded volume, in this way the component/modules will be prepared at a central stocking point, ready to be customised (Van Hoek et al., 1999). ***DP directly affects Production/Distribution***

It is also important to point out the level of postponement in regards to manufacturing here, according to Bagchi and Gaur (2018), estimation of demand becomes more accurate as the postponement in production increases, however, according to Bucklin (1965), there should be a limit to the extent of postponement. As the excessive surge in postponement level leads to higher lead-time and higher cost of production (Waller et al., 2000). This is a sign of inefficiency, and because excessive postponement is not aligned with the leagile SC's philosophy, thus, excessive postponement in production must be avoided.

3.2.2. DP and Distribution

Once the customisation process is completed the orders will be shipped directly towards the customers, the final products could be shipped either to the DC and then to the retailers or directly to the retailers or from the DC to the end customers, depending on the business model. ***DP directly affects Distribution***

3.2.3. DP and Inventory

In a leagile SC, the critical stocking point is held at the DP, to maintain a balance between responsiveness and costs associated with the inventory. At this phase, standardised goods stay undifferentiated for as long as possible in the form of strategic buffer (Van Hoek et al., 1999).

- The manufacturer at the downstream side of a SC delays the customisation/assembly for as long as possible at the inventory level until the exact attributes/scale of the product's requirement is identified. As soon as demand is realised and accepted, the customisation/assembly phase will initiate. Once the customisation process is completed the final products will be shipped out immediately as the orders are known, as a result, no inventory/minimum inventory will be held in the form of finished products at the assembly plant. ***DP directly affects Inventory/Production***

3.2.4. DP and Information

Information DP penetrates the chain as upstream as possible to improve the information quality and avoid demand distortion and bullwhip effect Mason-Jones and Towill (1999), the ICT act as an agent facilitator to elevate transparency in regards to demand information as well as increasing accuracy in forecasts, resulting in postponement value enhancement (Robinson and Elofson, 2001). Advancement of the ICT system has yielded more value to postponement strategy by projecting data from downstream to upstream and vice-versa (Yang et al., 2004).

- The ICT systems aid the upstream side of a leagile SC by receiving data for the amount of procurement required in the downstream side of SC which results in forecasts with greater precision. Also, companies at the upstream side of the chain are responsible to pass down accurate data regarding their production planning and inventory level to the companies closer to the end customers. ***DP indirectly facilitated by ICT to impact Production/Inventory***
- ICT aids upstream/downstream side of a leagile SC by receiving order data and capture the latest trends in a timely and accurate manner so the firms can postpone the final stage of customisation/assembly until the actual orders are received through the ICT system. This leads to the attainment of a higher response rate towards market shifts. ***DP indirectly facilitated by ICT to impacts Production***

3. 3. The impact of VN on the SC drivers

3.3.1. VN in Production

In a collaborative environment with SC visibility, leagility encourages the sharing of operational information as well as customer demand at the upstream and downstream side of an SC between the members through a linked VN, operationalised by ICT systems to exchange demand/supply information back and forth. The leagile SC is optimised in respect to collaboration and coordination among the supply partners through the formation of VN, resulting in more accurate forecasting and improved production schedule in a bid to lessen the costs of production and inventory at the upstream. Simultaneously, the SC accomplishes agility with the aid of quick responses to the customer's demand, and improvements in the flexibility to handle the disturbances. ***VN indirectly affects Production/Inventory facilitated by the ICT system***

3.3.2. VN in Distribution

Leagile SC should design an intermodal transportation system which is driven by the development of the virtual distribution network by implementing an ICT system that is connected to the regional DC. It was also revealed that an ICT based logistic system equates to a considerable decrease in carbon emission, energy usage, and transportation costs alike as a result of the elimination of unnecessary motion, higher utilisation of fright space and optimised routes (Wang et al., 2015). ***VN indirectly affects Distribution/Inventory facilitated by ICT system***

The distribution channels should be synchronised with the inventory departments through the implementation of ICT system to improve distribution's performance as misalignment between the two could increase inventory/distribution costs through inventory challenges such as stock depreciation, stock obsolescence, and stock damage/loss which are obstacles to the clients responsiveness and consequently lead to poorer SC performance. ***VN indirectly affects Distribution/Inventory facilitated by the ICT system***

3.3.3. VN in inventory

According to Soosay et al. (2008), joint planning and collaboration with the customers enables a SC to carry its flow without any interruptions and manage the inventory effectively at the DC by assigning inventory capacity for larger orders or seeking provision for excess capacity. One example is the implementation of Kanban strategies such as Continues-Replenishment-Inventory (CRI) programme that aids the supplier to know when and how much to replenish the buyer's inventory by taking the liberty of utilising the incoming demand signals. This is achieved through the implementation of Vendor-Managed-Inventory (VMI) system, by positioning a pre-developed protocol between the partners in a SC that signals the inventory that has been consumed to the supplier and gives the responsibility and authority to the supplier to manage the customer's inventory (Disney et al., 2004). Once the customer has transmitted the POS data through installed ICT system, the supplier becomes aware of the time and the scale of replenishment, then automatically it would contact the buyer to seek consent and confirm the delivery time and the scale of the orders (depending on the protocol). ***VN indirectly affects Inventory facilitated by the ICT system***

3.3.4. VN and information

ICT as the main tool of information sharing in a SC is a facilitator for the formation of a VN in a leagile SC since the members of SCs are scattered in many parts, the increased virtual integration in a SC has made the organizations become physical at one end whilst virtual on the other end.

- Leagile SC encourages a high level of transparency through the projection of important data to aid decision-making processes and planning with the aim of SC optimisation (Mason-Jones and Towill, 1999). ***VN through direct utilisation of ICT system indirectly affects Production/Distribution/ Inventory.***

The current research study has recognised 4 main SC drivers and evaluated each independently and then after the identification of leagile attributes, analysed each SC's drivers (Production, Distribution, Inventory and, Information) in respect to their connection to leagile attributes (E&F, DP, VN). Subsequently, the authors have developed a connectivity map to assess the direct/indirect impact of each attribute with regards to each driver and then assigned 4 performance metrics for the assessment of each driver at the micro level to find the value of each driver within the chain to calculate the total value of the SC at a macro level. Leagile SC can set the aims and objectives of SC with respect to each stage of the chain and use a benchmark (customer's value expectation) to assess how well each phase of the chain is functioning.

The interactions of SC drivers (including production, distribution, inventory, and information) and the leagile attributes (i.e., E&F, DP, VN) and its effect on the SC performance in terms of TSCV has been shown in Figure 8. TSCV comprised of four measures including cost, quality, service, and lead-time were identified to evaluate the impact of the leagile strategy on the overall performance of the SC. To develop the proposed connectivity map, the relevant papers in the literature have been reviewed and interrelationship among factors was extracted. Solid line arrow and dotted line arrow are used to represent the direct and indirect impact of leagile attributes on the SC drivers. While the E&F and DP attributes have a direct impact on the production, distribution, and inventory, they have an indirect impact on the information, the

VN has an indirect impact on the production, distribution, and inventory while it has a direct impact on the handling of information.

<<Insert figure 8 here>>

4. Conclusion and future research direction

This paper identified the most important SC drivers including Production, Distribution, Inventory, and Information that affect leagile SC strategy and SC performance through a detailed literature review. Also, the interdependencies of the drivers have been explored to underline the role that each driver plays in the operationalisation of a leagile SC. To this end, three leagile attributes were identified consisting of E&F, DP, and VN through a critical review of the literature that enabled the authors to examine the direct and indirect impact of each SC's attribute on each SC's driver individually, both at the upstream and downstream phase of the SC. This study found that the E&F and DP directly affect Distribution, Inventory, and Production and facilitated indirectly by Information to impact Production, Distribution, and Inventory. On the other side, VN indirectly affects Production, Inventory, and distribution facilitated by the information system.

To figure out the impact of leagile attributes on the performance of leagile SC, four performance metrics including Cost, Quality, Service, Lead-time have been assigned to measure the average value of each leagile SC driver at the upstream/downstream of the SC (i.e., TSCV). Finally, a leagile connectivity map has been developed to evaluate the performance of leagile SC based on the TSCV. The outcome of the paper was to propose a conceptual connectivity map to evaluate TSCV for the purpose of SC optimization and therefore limited to theoretical analysis based on literature. Lack of previous studies on the interdependencies of SC drivers for leagile SC, their effects on the leagile attributes and SC performance along with their operationalisation and measurements were the main limitations of this research. To tackle these issues, the future study comprises of operationalising the conceptual model by collecting data from 3 industry clusters. This would enable to test and validate the proposed model based on the real data.

References

Alinezhad, A., Kazemi, A., & Khorasani, M. (2019). Presenting a model for decoupling points in supply chain networks. *International Journal of Logistics Systems and Management*, 33(3), 383-403.

Amiri, A. 2006. Designing a distribution network in a supply chain system: Formulation and efficient solution procedure. *European Journal of Operational Research,* 171**,** 567-576.

Bagchi, S. S. & Gaur, J. 2018. Optimization of postponement process for a two stage modular manufacturer. *Journal of Global Operations and Strategic Sourcing,* 11**,** 39-54.

Barker, R. C. 2001. Development of demand pull type control methods: the design of block action production control methods to reduce throughput time and improve supply chain synchronization. *Production Planning & Control,* 12**,** 408-417.

Bhamra, R., Nand, A., Yang, L., Albregard, P., Azevedo, G., Corraini, D., & Emiliasiq, M. (2020). Is leagile still relevant? A review and research opportunities. *Total Quality Management & Business Excellence*, 1-25.

Bruce, M., Daly, L. & Towers, N. 2004. Lean or agile: a solution for supply chain management in the textiles and clothing industry? *International journal of operations & production management,* 24**,** 151-170.

Bucklin, L. P. 1965. Postponement, speculation and the structure of distribution channels. *Journal of marketing research***,** 26-31.

Cannas, V. G., Gosling, J., Pero, M., & Rossi, T. (2019). Engineering and production decoupling configurations: An empirical study in the machinery industry. *International journal of production economics*, 216, 173-189.

Cerchione, R., & Esposito, E. (2016). A systematic review of supply chain knowledge management research: State of the art and research opportunities. *International Journal of Production Economics*, 182, 276-292.

Chan, F. T. S. & Qi, H. J. 2003. An innovative performance measurement method for supply chain management. *Supply chain management: An international Journal,* 8**,** 209-223.

Chandra, C. & Kumar, S. 2000. Supply chain management in theory and practice: a passing fad or a fundamental change? *Industrial Management & Data Systems,* 100**,** 100-114.

Childerhouse, P., Hermiz, R., Mason-Jones, R., Popp, A. & Towill, D. R. 2003. Information flow in automotive supply chains–identifying and learning to overcome barriers to change. *Industrial Management & Data Systems,* 103**,** 491-502.

Choi, T. M., Chen, Y., & Chung, S. H. (2019). Online-offline fashion franchising supply chains without channel conflicts: choices on postponement and contracts. *International Journal of Production Economics*, 215, 174-184.

Christopher, M., Lowson, R. & Peck, H. 2004. Creating agile supply chains in the fashion industry. *International Journal of Retail & Distribution Management,* 32**,** 367-376.

Christopher, M. & Towill, D. 2001. An integrated model for the design of agile supply chains. *International Journal of Physical Distribution & Logistics Management,* 31**,** 235-246.

Christopher, M. & Towill, D. R. 2002. Developing market specific supply chain strategies. *The international journal of logistics management,* 13**,** 1-14.

Christopher, M. (2016). Logistics & supply chain management. Pearson UK.

Chun Wu, Y. 2003. Lean manufacturing: a perspective of lean suppliers. *International Journal of Operations & Production Management,* 23**,** 1349-1376.

Claycomb, C., Germain, R. & Dröge, C. 1999. Total system JIT outcomes: inventory, organization and financial effects. *International Journal of Physical Distribution & Logistics Management,* 29**,** 612-630.

Dahlgaard, J. J. & Mi Dahlgaard-Park, S. 2006. Lean production, six sigma quality, TQM and company culture. *The TQM magazine,* 18**,** 263-281.

Daniel, S. J. & Reitsperger, W. D. 1996. Linking JIT strategies and control systems: a comparison of the United States and Japan. *The International Executive,* 38**,** 95-121.

Disney, S. M., Naim, M. M. & Potter, A. 2004. Assessing the impact of e-business on supply chain dynamics. *International Journal of production economics,* 89**,** 109-118.

Doz, Y. 1987. International industries: Fragmentation versus globalization. *Technology and global industry***,** 96-118.

Fadaki, M., Rahman, S., & Chan, C. (2019a). Leagile supply chain: design drivers and business performance implications. *International Journal of Production Research*, 1-23.

Fadaki, M., Rahman, S., & Chan, C. (2019b). Quantifying the degree of supply chain leagility and assessing its impact on firm performance. *Asia Pacific Journal of Marketing and Logistics*.

Feitzinger, E. & Lee, H. L. 1997. Mass customization at Hewlett-Packard: the power of postponement. *Harvard business review,* 75**,** 116-123.

Fisher, M. L. 1997. What Is the Right Supply Chain for Your Product? *Harvard Business Review,* 75**,** 105-116.

Galankashi, M. R., & Helmi, S. A. (2016). Assessment of hybrid Lean-Agile (Leagile) supply chain strategies. *Journal of Manufacturing Technology Management*.

Goldsby, T. J., Griffis, S. E. & Roath, A. S. 2006. Modeling lean, agile, and leagile supply chain strategies. *Journal of Business Logistics,* 27**,** 57-80.

Gosling, J., Purvis, L. & Naim, M. M. 2010. Supply chain flexibility as a determinant of supplier selection. *International Journal of Production Economics,* 128**,** 11-21.

Govindan, K., Azevedo, S. G., Carvalho, H. & Cruz-Machado, V. 2015. Lean, green and resilient practices influence on supply chain performance: interpretive structural modeling approach. *International Journal of Environmental Science and Technology,* 12**,** 15-34.

Grabara, J. & Starostka-Patyk, M. 2009. The Bullwhip Effect in Supply Chain. *Advanced Logistic Systems. Theory and Practice,* 3.

Gunasekaran, A. & Ngai, E. W. T. 2004b. Information systems in supply chain integration and management. *European journal of operational research,* 159**,** 269-295.

Gunasekaran, A., Patel, C. & McGaughey, R. E. 2004a. A framework for supply chain performance measurement. *International journal of production economics,* 87**,** 333-347.

Gunasekaran, A., Patel, C. & Tirtiroglu, E. 2001. Performance measures and metrics in a supply chain environment. *International Journal of Operations & Production Management,* 21**,** 71-87.

Gundlach, G. T., Bolumole, Y. A., Eltantawy, R. A. & Frankel, R. 2006. The changing landscape of supply chain management, marketing channels of distribution, logistics and purchasing. *Journal of Business & Industrial Marketing,* 21**,** 428-438.

Halawa, F., Lee, I. G., Shen, W., Khan, M. E., & Nagarur, N. (2017). The Implementation of Hybrid MTS\MTO as a Promoter to Lean-Agile: A Simulation Case Study for Miba Sinter Slovakia. In IIE Annual Conference. Proceedings (pp. 1006-1011). Institute of Industrial and Systems Engineers (IISE).

Harrington, L. 1996. Untapped savings abound. *Industry Week/IW,* 245**,** 53.

Hart, C. W. & Johnson, M. D. 1999. A framework for developing trust relationships. *Marketing Management,* 8**,** 20-22.

Hedenstierna, P. & Ng, A. H. C. 2011. Dynamic implications of customer order decoupling point positioning. *Journal of Manufacturing Technology Management,* 22**,** 1032-1042.

Helo, P., Xiao, Y. & Roger Jiao, J. 2006. A web-based logistics management system for agile supply demand network design. *Journal of Manufacturing Technology Management,* 17**,** 1058-1077.

Hicks, D. A. 1999. The state of supply chain strategy. *IIE solutions,* 31**,** 24-30.

Hill, T. J. 1992. Incorporating manufacturing perspectives in corporate strategy. *Voss, C. Manufacturing Strategy: Process and Content, Chapman e Hall, London***,** 3-11.

Hoffman, W. 2004. Dell Gets Domestic. *Traffic World*.

Hong, I. B. 2002. A new framework for interorganizational systems based on the linkage of participants' roles. *Information & management,* 39**,** 261-270.

Hosseini, S., Ivanov, D., & Dolgui, A. (2019). Review of quantitative methods for supply chain resilience analysis. *Transportation Research Part E: Logistics and Transportation Review*, 125, 285-307.

Howard, M. 2005. Collaboration and the '3DayCar': a study of automotive ICT adoption. *Journal of Information Technology,* 20**,** 245-258.

Huang, G. Q., Lau, J. S. K. & Mak, K. L. 2003. The impacts of sharing production information on supply chain dynamics: a review of the literature. *International Journal of Production Research,* 41**,** 1483-1517.

Hughes, M., Golden, W. & Powell, P. 2003. Inter-organisational ICT systems: the way to innovative practice for SMEs? *Journal of Small Business and Enterprise Development,* 10**,** 277-286.

Hugos, M. H. 2018. *Essentials of supply chain management*, John Wiley & Sons.

Kent, J. L. & Mentzer, J. T. 2003. The effect of investment in interorganizational information technology in a retail supply chain. *Journal of Business Logistics,* 24**,** 155-175.

Khatri, A., Garg, D., & Dangayach, G. S. (2019). A comparative analysis of factor analysis model for pinpointing agile developers. *International Journal of Agile Systems and Management*, 12(2), 91-107.

Krishnamurthy, R. & Yauch, C. A. 2007. Leagile manufacturing: a proposed corporate infrastructure. *International Journal of Operations & Production Management,* 27**,** 588-604.

Lee, H. L. & Billington, C. 1992. Managing supply chain inventory: pitfalls and opportunities. *Sloan management review,* 33**,** 65-73.

Lee, H. L., Padmanabhan, V. & Whang, S. 1997a. Information distortion in a supply chain: The bullwhip effect. *Management science,* 43**,** 546-558.

Lee, H. L., Padmanabhan, V. & Whang, S. 1997b. The bullwhip effect in supply chains. *Sloan management review,* 38**,** 93-102.

Li, X., Chung, C., Goldsby, T. J. & Holsapple, C. W. 2008. A unified model of supply chain agility: the work-design perspective. *The International Journal of Logistics Management,* 19**,** 408-435.

Maharaja, R., Devadasan, S. R., & Sakthivel, M. (2018). Supply chain performance measurement: a future research agenda for acquiring competitiveness through the implementation of leagile manufacturing paradigm. *International Journal of Services and Operations Management*, 30(1), 39-50.

Manthou, V., Vlachopoulou, M. & Folinas, D. 2004. Virtual e-Chain (VeC) model for supply chain collaboration. *International Journal of Production Economics,* 87**,** 241-250.

Mason-Jones, R., Naylor, B. & Towill, D. R. 2000a. Lean, agile or leagile? Matching your supply chain to the marketplace. *International Journal of Production Research,* 38**,** 4061-4070.

Mason-Jones, R. & Towill, D. R. 1999. Using the information decoupling point to improve supply chain performance. *The International Journal of Logistics Management,* 10**,** 13-26.

Mason-Jones, R., Naylor, B. & Towill, D. R. 2000b. Engineering the leagile supply chain. *International Journal of Agile Management Systems*, 2**,** 54-61.
Mavengere, N.B., Information technology role in supply chain's strategic agility, International *Journal of Agile Systems and Management*, 2013, 6(1), pp. 7-24
Moynihan, P., Dai, W., Agile supply chain management: A services system approach, *International Journal of Agile Systems and Management*, 2011, 4(3), pp. 280-300
Naim, M. M. & Gosling, J. 2011. On leanness, agility and leagile supply chains. *International Journal of Production Economics,* 131**,** 342-354.
Narasimhan, R., Swink, M. & Kim, S. W. 2006. Disentangling leanness and agility: an empirical investigation. *Journal of operations management*, 24**,** 440-457.
Narayanan, A., Sahin, F., & Robinson, E. P. (2019). *Demand* and order-fulfillment planning: The impact of point-of-sale data, retailer orders and distribution center orders on forecast accuracy. *Journal of Operations Management*, 65(5), 468-486.
National Research, C. 2000. *Surviving supply chain integration: Strategies for small manufacturers*, National Academies Press.
Naylor, J. B., Naim, M. M. & Berry, D. 1999. Leagility: Integrating the lean and agile manufacturing paradigms in the total supply chain. *International Journal of production economics,* 62**,** 107-118.
Nedelko, Z. 2013. The role of information and communication technology in supply chain. *Logistics & Sustainable Transport*, 1**,** 1-13.
Neely, A. D. 1991. Production Management: A Two-dimensional Function? *International Journal of Operations & Production Management*, 11**,** 49-54.
Nguyen, T., Li, Z. H. O. U., Spiegler, V., Ieromonachou, P., & Lin, Y. (2018). Big data analytics in supply chain management: A state-of-the-art literature review. *Computers & Operations Research*, 98, 254-264.
Nishat Faisal, M., Banwet, D. K. & Shankar, R. 2006. Supply chain risk mitigation: modeling the enablers. *Business Process Management Journal,* 12**,** 535-552.
Ohno, T. 1988. *Toyota production system: beyond large-scale production*, crc Press.
Olhager, J. 2003. Strategic positioning of the order penetration point. *International journal of production economics,* 85**,** 319-329.
Olhager, J. & Prajogo, D. I. 2012. The impact of manufacturing and supply chain improvement initiatives: A survey comparing make-to-order and make-to-stock firms. *Omega,* 40**,** 159-165.
Patel, B. S., Tiwari, A. K., Kumar, M., Samuel, C., & Sutar, G. (2020). Analysis of agile supply chain enablers for an Indian manufacturing organisation. *International Journal of Agile Systems and Management*, 13(1), 1-27.
Purvis, L., Gosling, J. & Naim, M. M. 2014. The development of a lean, agile and leagile supply network taxonomy based on differing types of flexibility. *International Journal of Production Economics,* 151**,** 100-111.

Qamar, A., Hall, M. A., & Collinson, S. (2018). Lean versus agile production: flexibility trade-offs within the automotive supply chain. *International Journal of Production Research*, 56(11), 3974-3993.
Qamar, A., Gardner, E. C., Buckley, T., & Zhao, K. (2019). Home-owned versus foreign-owned firms in the UK automotive industry: Exploring the microfoundations of ambidextrous production and supply chain positioning. *International Business Review*, 101657.
Rahman, Z. 2004. Use of internet in supply chain management: a study of Indian companies. *Industrial Management & Data Systems,* 104**,** 31-41.

Raj, A.S., Jayakrishna, K., Vimal, K.E.K., Modelling the metrics of leagile supply chain and leagility evaluation, *International Journal of Agile Systems and Management*, 2018, 11(2), pp. 179202

Raj Sinha, P., Whitman, L. E. & Malzahn, D. 2004. Methodology to mitigate supplier risk in an aerospace supply chain. *Supply Chain Management: an international journal,* 9**,** 154-168.

Rauch, E., Dallasega, P., & Matt, D. T. (2017). Distributed manufacturing network models of smart and agile mini-factories. *International Journal of Agile Systems and Management*, 10(3-4), 185-205.

Reichhart, A. & Holweg, M. 2007. Lean distribution: concepts, contributions, conflicts. *International journal of production research,* 45**,** 3699-3722.

Robinson, W. N. & Elofson, G. 2001. Electronic broker impacts on the value of postponement in a global supply chain. *Journal of Global Information Management (JGIM),* 9**,** 29-43.

Rudberg, M. & Wikner, J. 2004. Mass customization in terms of the customer order decoupling point. *Production planning & control,* 15**,** 445-458.

Rushton, A., Croucher, P. & Baker, P. 2014. *The handbook of logistics and distribution management: Understanding the supply chain*, Kogan Page Publishers.

Sahay, B. S. & Maini, A. 2002. Supply chain: a shift from transactional to collaborative partnership. *Decision,* 29**,** 67-88.

Sanders, N. R. & Premus, R. 2005. Modeling the relationship between firm IT capability, collaboration, and performance. *Journal of business logistics,* 26**,** 1-23.

Shah, R. & Ward, P. T. 2003. Lean manufacturing: context, practice bundles, and performance. *Journal of operations management,* 21**,** 129-149.

Simchi-Levi, D., Wang, H. & Wei, Y. 2018. Increasing supply chain robustness through process flexibility and inventory. *Production and Operations Management,* 27**,** 1476-1491.

So, M. W. C. & Sculli, D. 2002. The role of trust, quality, value and risk in conducting e-business. *Industrial Management & Data Systems,* 102**,** 503-512.

Soosay, C. A., Hyland, P. W. & Ferrer, M. 2008. Supply chain collaboration: capabilities for continuous innovation. *Supply Chain Management: An International Journal,* 13**,** 160-169.

Stevenson, M., The role of services in flexible supply chains: An exploratory study, *International Journal of Agile Systems and Management,* 2013, 6(4), pp. 307-323

Upton, D. 1995. What really makes factories flexible? *Harvard business review,* 73**,** 74-84.

Van Hoek, R. I. 1998. Logistics and virtual integration: postponement, outsourcing and the flow of information. *International Journal of Physical Distribution & Logistics Management,* 28**,** 508-523.

Van Hoek, R. I., Vos, B. & Commandeur, H. R. 1999. Restructuring European supply chains by implementing postponement strategies. *Long Range Planning,* 32**,** 505-518.

Vidal, C. J. & Goetschalckx, M. 1997. Strategic production-distribution models: A critical review with emphasis on global supply chain models. *European Journal of Operational Research,* 98**,** 1-18.

Virmani, N., Saha, R., & Sahai, R. (2018). Empirical assessment of critical success factors of leagile manufacturing using fuzzy DEMATEL approach. *International Journal of Agile Systems and Management*, 11(4), 293-314.

Vonderembse, M. A., Uppal, M., Huang, S. H. & Dismukes, J. P. 2006. Designing supply chains: Towards theory development. *International Journal of production economics,* 100**,** 223-238.

Waller, M. A., Dabholkar, P. A. & Gentry, J. J. 2000. Postponement, product customization, and market-oriented supply chain management. *Journal of Business Logistics,* 21**,** 133-160.

Walton, L. W. 1994. Electronic date interchange (EDI): a study of its usage and adoption within marketing and logistics channels. *Transportation Journal***,** 37-45.

Wang, Y., Sanchez Rodrigues, V. & Evans, L. 2015. The use of ICT in road freight transport for CO2 reduction–an exploratory study of UK's grocery retail industry. *The International Journal of Logistics Management,* 26**,** 2-29.

Wang, M., Jie, F., & Abareshi, A. (2018). Improving logistics performance for one belt one road: a conceptual framework for supply chain risk management in Chinese third-party logistics providers. *International Journal of Agile Systems and Management*, 11(4), 364-380.

Williams, L. R., Esper, T. L. & Ozment, J. 2002. The electronic supply chain: Its impact on the current and future structure of strategic alliances, partnerships and logistics leadership. *International Journal of Physical Distribution & Logistics Management,* 32**,** 703-719.

Womack, J. P. & Jones, D. T. 1996. Lean Thinking, New York. *US: Simon and Schuster*.

Womack, J. P. & Jones, D. T. 1997. Lean thinking—banish waste and create wealth in your corporation. *Journal of the Operational Research Society,* 48**,** 1148-1148.

Wu, Y. N. & Cheng, T. C. E. 2008. The impact of information sharing in a multiple-echelon supply chain. *International Journal of Production Economics,* 115**,** 1-11.

Yang, B. & Burns, N. 2003. Implications of postponement for the supply chain. *International Journal of Production Research,* 41**,** 2075-2090.

Yang, B., Burns, N. D. & Backhouse, C. J. 2004. Postponement: a review and an integrated framework. *International Journal of Operations & Production Management,* 24**,** 468-487.

Yusup, M. Z., Mahmood, W. H. W., Salleh, M. R., & Yusof, A. S. M. (2015). Review the influence of lean tools and its performance against the index of manufacturing sustainability. *International Journal of Agile Systems and Management*, 8(2), 116-131.

Zhang, T., & Wang, X. (2018). The impact of fairness concern on the three-party supply chain coordination. *Industrial Marketing Management*, 73, 99-115.

Zhang, X., Pieter van Donk, D. & van der Vaart, T. 2011. Does ICT influence supply chain management and performance? A review of survey-based research. *International Journal of Operations & Production Management,* 31**,** 1215-1247.

Zhang, Y., Wang, Y. & Wu, L. 2012. Research on demand-driven leagile supply chain operation model: a simulation based on anylogic in system engineering. *Systems Engineering Procedia,* 3**,** 249-258.

Zinn, W. & Levy, M. 1988a. Speculative inventory management: a total channel perspective. *International Journal of Physical Distribution & Materials Management,* 18**,** 34-39.

List of figures and tables

Table 1. Comparison of lean supply with agile supply: the distinguishing attributes

Distinguishing attributes	Lean supply	Agile supply
Typical products	Commodities	Fashion goods
Marketplace demand	Predictable	Volatile
Product variety	Low	High
Product life cycle	Long	Short
Customer drivers	Cost	Availability
Profit margin	Low	High
Dominant costs	Physical costs	Marketability costs
Stockout penalties	Long term contractual	Immediate and volatile
Purchasing policy	Buy goods	Assign capacity
Information enrichment	Highly desirable	Obligatory
Forecasting mechanism	Algorithmic	Consultative

Source: Mason-Jones et al. (2000b)

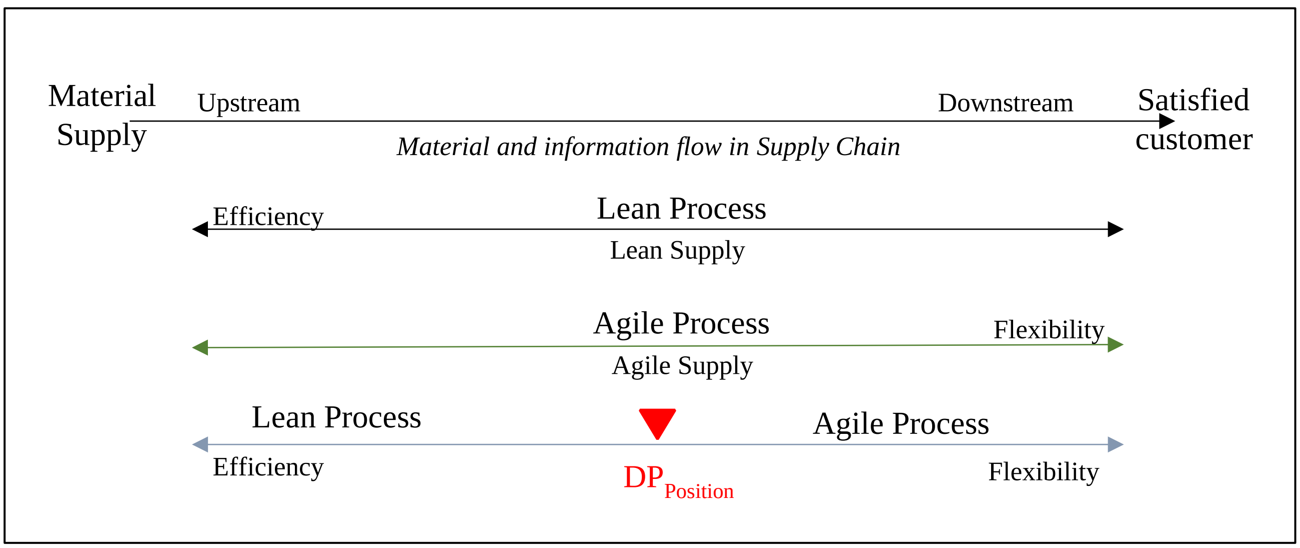

Figure 1. Block diagram representing lean, agile, and leagile. [Source : Mason-Jones, et al, 2000a]

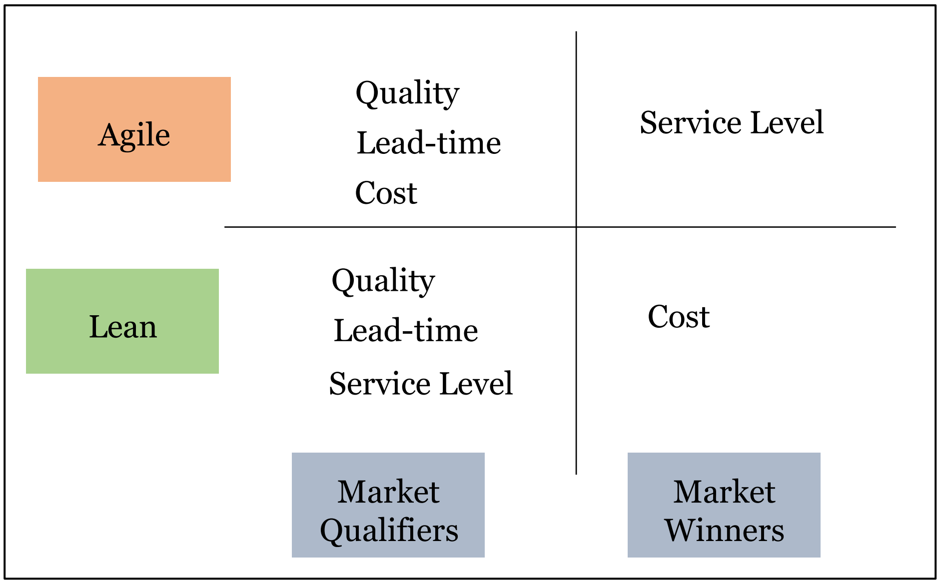

Figure 2. Market winners and market qualifiers for agile versus lean supply. [Source : Mason-Jones et al., 2000b1

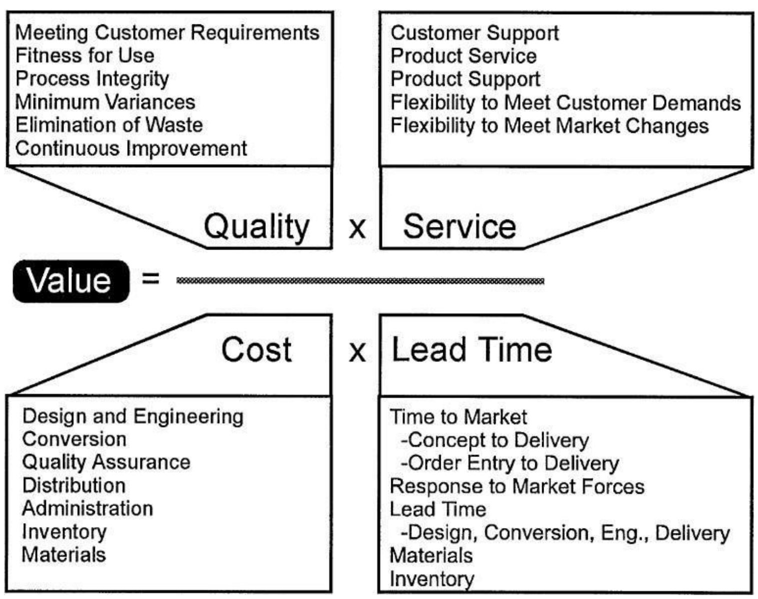

Figure 3 TSCV Metric [Source : Naylor, et al., 1999]

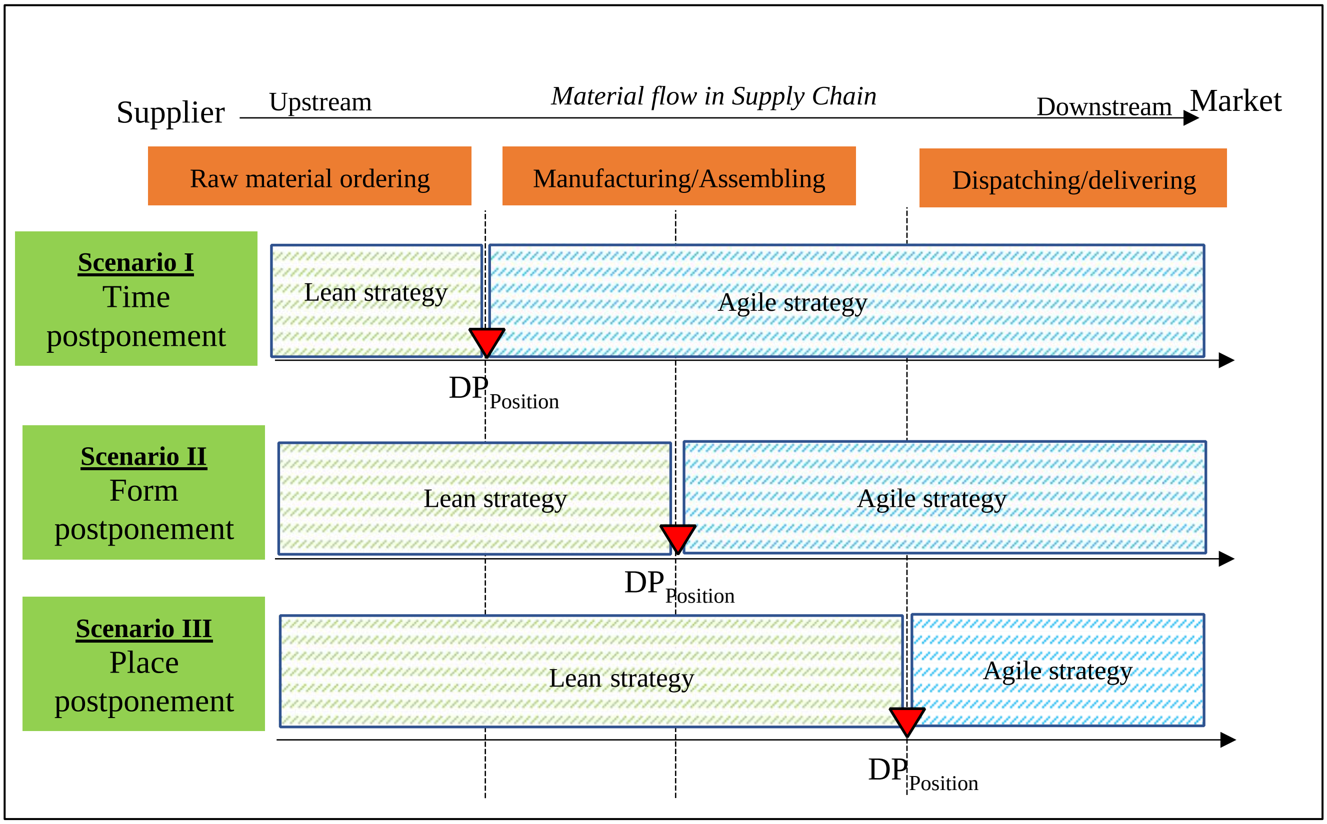

Figure 4. The postponement functions and leagile SC scenarios ($DP_{Position}$); [Source: Author]

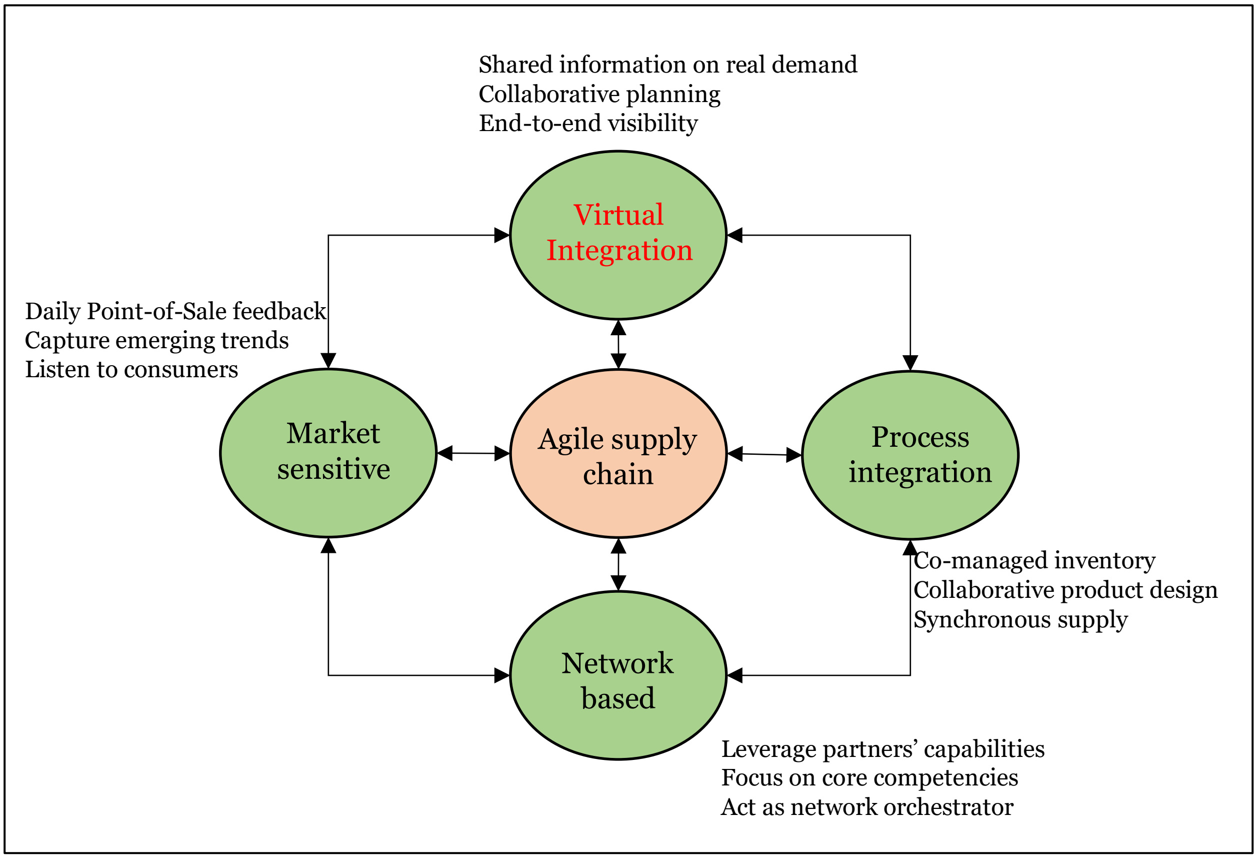

Figure 5. The foundation of Agility (Source: Christopher et al., 2004)

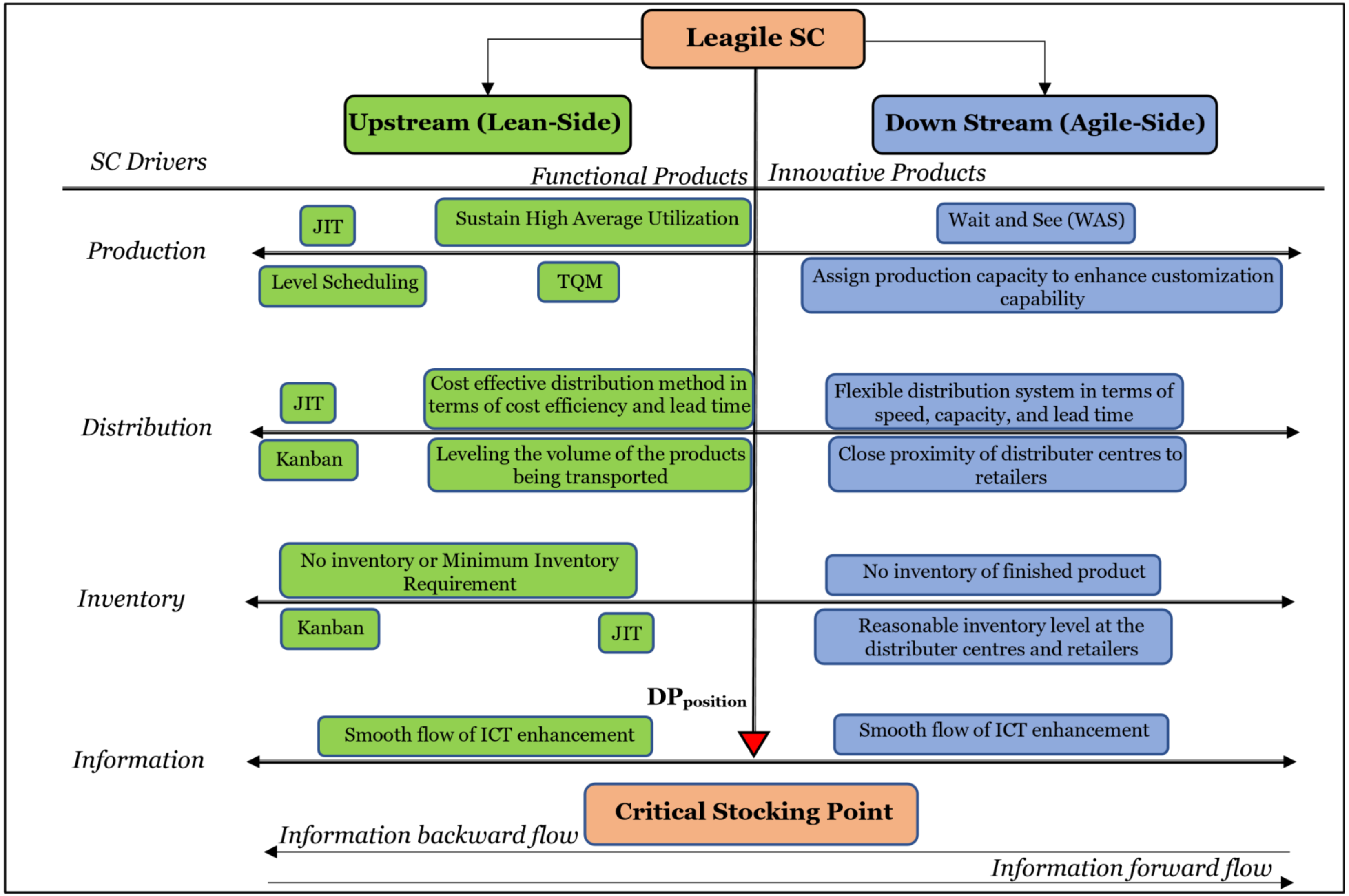

Figure 6. Optimization matrix (Source: Authors)

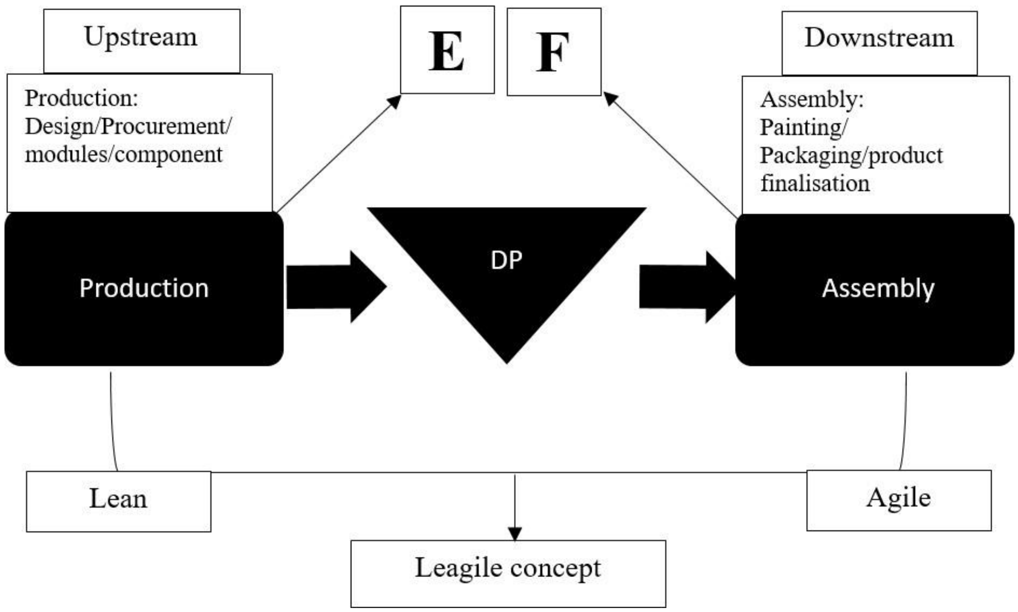

Figure 7 Leagile Production Paradigm [Source: Authors]

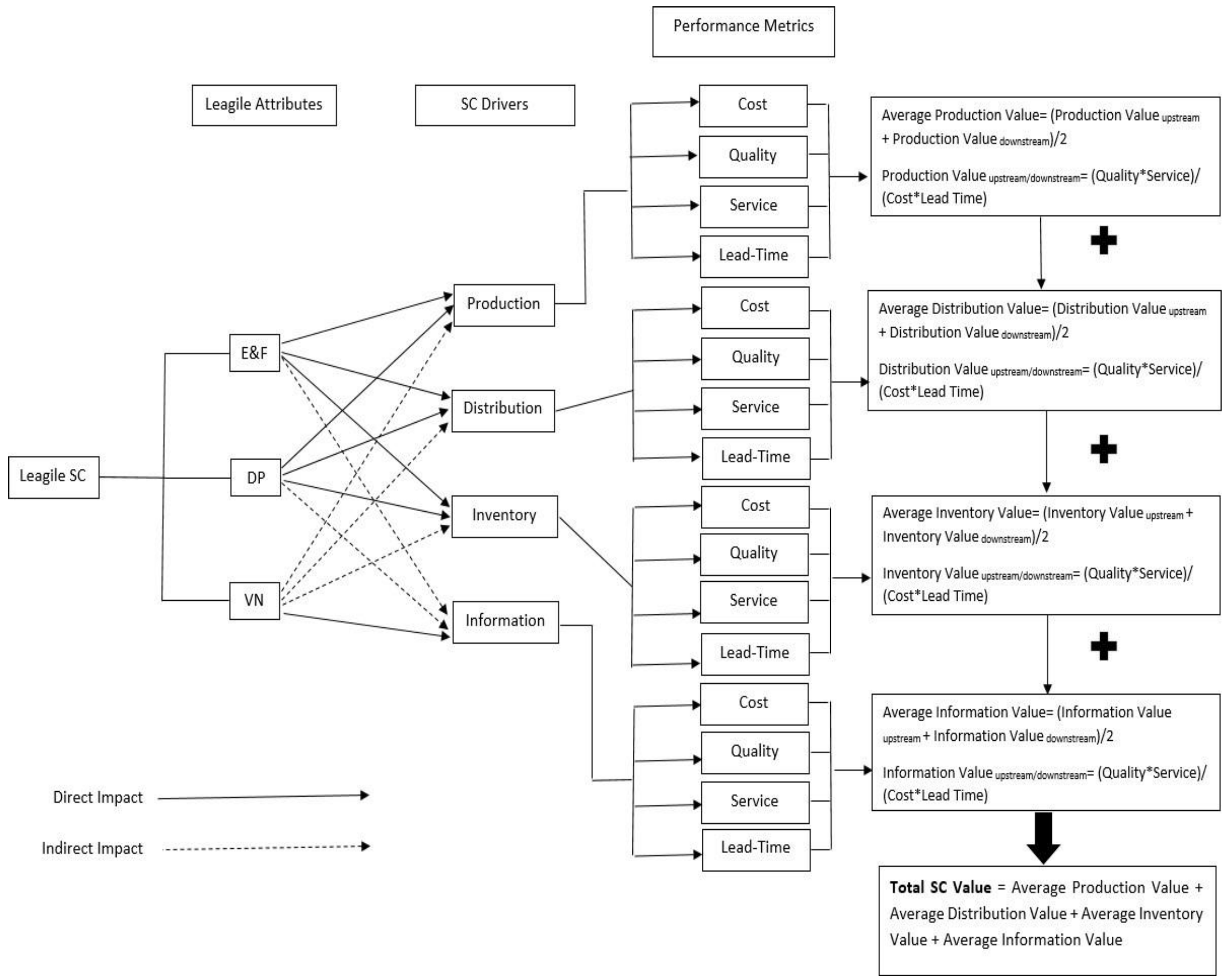

Figure 8 Leagile Connectivity Map - A Conceptual Model [Source: Authors]