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INFLUENCE OF PRODUCT AND BUSINESS ENVIRONMENT CHARACTERISTICS ON MANAGING SUPPLY CHAIN VULNERABILITY – A CONCEPTUAL FOUNDATION

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Abstract: Increased changes of trading rules in a global economy, more frequent adverse weather events due to climate change, and other unexpected events add more uncertainty to the ever-present logistics challenges for companies to manage their supply chains. Thus, there is increased theoretical and practical interest to prevent disturbances of logistics operations, as well as to manage disturbances when they occur and avoid supply chain vulnerability. Decreased vulnerability of supply chains is desired as it leads to robust and resilient supply chains. The objective of this paper is to understand how contextual factors, i.e., product and business environment related factors affect relationship between redesign strategies and vulnerabilities in the supply chain. We consider typical redesign strategies, such as the adoption of assurance systems, the use of proactive control, use of redundancy, or enhancing flexibility in supply chains. Seen from the lens of contingency theory, the findings from our literature review suggest that contextual factors affect the link between redesign strategies and vulnerabilities in the supply chain, but further research is needed to examine how each of the contextual factors affect selection and implementation of each redesign strategies used to manage supply chain vulnerabilities.

Keywords: contingency theory, prevention of disturbances, impact reduction.

1. Introduction

Studies in the supply chain management discipline conducted over the past decades show that an increased focus on efficiency and leanness of supply chain processes has resulted in an increased vulnerability of supply chains to risks and disturbances (Stecke and Kumar, 2009). Vulnerable supply chains suffer from a negative impact to their performance, i.e. they are not robust (Kleindorfer and Saad, 2005). Ability to recover from these disturbances or to improve performances beyond previous levels, indicate their resilience (Christopher and Peck, 2004; Vlajic, 2017), while ability to sustain desired performance range while affected by a disturbance indicates their robustness (Vlajic, Van Der Vorst and Hendrix, 2010). Robust and resilient supply chains are able to predict and detect relevant disturbances in their processes, to respond fast, and to redesign their supply chains quickly (Blackhurst *et al.,* 2005).

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However, the literature suggests that choice and success of implementation of redesign strategies might be a subject to contextual factors (Sousa and Voss, 2008). This approach indicates suitability of contingency theory to explain effects of the contextual factors. The contribution of our study is the application of this theory in the area of supply chain vulnerability, as most of the identified studies applied contingency theory to the manufacturing strategy (Sousa and Voss, 2008).

Thus, the research objective of the study is to investigate how contextual factors related to the product and business environment characteristics affect link between prevention and mitigation redesign strategies and vulnerability of a supply chain.

The remainder of the paper is structured as follows: First we present a literature review and a theoretical foundation. Subsequently, we briefly present the choice of a methodology to help achieving our research objective. In the concluding section we present the key idea, the propositions that result from the literature and possible future research.

2. Literature Review and Theoretical Foundation

First, we explain the key components of a model, a supply chain scenario and its vulnerability, as well as redesign strategies.

In line with (Vlajic, van der Vorst and Haijema, 2016; van der Vorst, 2000), we define a *supply chain scenario* as the configuration of four elements of the supply chain: 1) *the managed system*: the physical design of a network of facilities and all other elements that perform logistic activities (e.g. equipment, vehicles, and people), including inventory; 2) *the managing system*: the planning, control and co-ordination of logistic processes in the supply chain while aiming to achieve strategic supply chain and logistics objectives within the restrictions set by the network design; 3) *the information and decision support systems* within each decision layer of the planning and control system, as well as the information technology infrastructure needed; and 4) *the organizational structure* within the supply chain as well as the coordination of tasks in order to achieve defined objectives. All these elements of the supply chain scenario are subject to various risks and disturbances that negatively affect supply chain performance and cause its vulnerability *(Vlajic et al.,* 2013). Application of right redesign strategies reduces supply chain vulnerability by achieving robustness or resilience. This is in line with the resource based view (RBV), a theory that explain how firm's resources (Barney, 1996), as well as bundled capabilities lead to the competitive advantage (Sirmon, Hitt and Ireland, 2007), i.e. improvement of a firm's performances. In line with (Brandon-Jones *et al.,* 2014; Sousa and Voss, 2008) we associate redesign strategies employed to achieve robustness or resilience of a supply chain with the bundles of specific capabilities a firm develops to achieve competitive advantage. Here, vulnerability, or robustness and resilience represent a performance variable measured via performance of the supply chain scenario. For instance, failure of a production or logistics equipment, decision making errors, supplier failures, accidents, etc. are typical examples within a wide range of possible risks and disturbances. To manage this vulnerability, redesign strategies can be implemented. For example, Hopp (2008) recommends strategies to manage disturbances in the context of their likelihood and consequences: in the case of minor consequences, regardless of the likelihood of disturbances, companies should do nothing; in the case of medium to severe consequences a choice of strategies depends on the likelihood of these disturbances: buffering/pooling is recommended in the case of a high likelihood, contingency planning in the case of a medium likelihood and crisis management in the case of a low likelihood. While this can be accepted as a general principle, buffering appears to be costly for high value products (Lovell, Saw and Stimson, 2005), and very limited in the case of perishable products (Ketokivi, 2006). The success of pooling might depend on the readiness for collaboration between various supply chain members (Cao and Zhang, 2011). Thus, the use of redesign strategies to manage disturbances is context dependent, and contingency theory might explain this dependency (Sousa and Voss, 2008). Thus, to manage supply chain vulnerability, it is important to understand how contextual factors affect choice and the use of redesign strategies to manage vulnerabilities of the supply chain scenario. This is in line with (Chang, Ellinger and Blackhurst, 2015; Hofer, 1975) who stated that a 'one size fits all' approach does not fit with the selection, application and effectiveness of the redesign strategies.

Generally, we propose that contextual factors might act as vulnerability sources or they can hinder application of redesign strategies, which might amplify supply chain vulnerability. They can also enable or contribute to easier implementation of redesign strategies that prevent or mitigate disturbances and result in robust and resilient supply chains. A supply chain is considered to be robust when a disturbance of supply chain processes does not impact significantly the supply chain performances (Vlajic, van der Vorst and Haijema, 2016), and it is considered resilient when a disturbance of supply chain processes impacts the supply chain performances, but they are restored to the same or better level after the recovery period (Christopher & Peck, 2004).

In this paper, we consider product and business environment related factors as the relevant contextual factors to manage supply chain vulnerability (Inman and Blumenfeld, 2013), and a set of guiding principles that can help managing supply chain vulnerability by increasing its robustness and/or resilience. In the remainder of the paper, we explain this in more detail.

2.1. Guiding Principles Towards Reduction of Vulnerability via Increasing Robustness and Resilience of Supply Chains

In general, the most common guiding principles to manage disturbances in logistics processes correspond to traditional risk management approaches. Two basic principles are a) reduction of the probability/frequency of a risk or disturbance occurrence and b) reduction of the severity of an impact (Norrman and Jansson, 2004). We explain these concepts in more detail below.

- Cause oriented, preventive guiding principle and related strategies

The *cause-oriented principle* attempts to reduce the probability a disturbance occurring by addressing its causes; this principle is preventive in nature (Wagner & Bode, 2009; Vlajic *et al.*, 2016). It is based on the premise that if possible, probable causes of disturbances need to be avoided or minimized (Waters, 2007). General views associated with this principle are:

1) proactive redesign strategies are used in relatively more predictable environments (Ketokivi, 2006) and 2) disturbance prevention should precede disturbance impact reduction (Kleindorfer and Saad, 2005). However, as Lewis (2003) argues, the complexity of causal events and the variability associated with negative consequences suggest that prevention alone will never suffice. Some events can never be predicted and some stakeholders will always face losses. Lewis also observed that too much reliance on prevention and mitigation actually results in a less effective overall recovery.

Typical strategies that belong to this group are assurance and reliability systems and proactive control and monitoring.

Assurance systems. Generally, best practices in an industry represent strategies typically employed as assurance systems, e.g. wide known ISO 9000. For example, they typically tackle use of primary packaging to protect a products from a damage (Williams and Wikström, 2011), training staff to conduct proper material handling, or standardize production and logistics activities in line with the industry requirements e.g. Hazard Analysis Critical Control Point (HACCP) and good agricultural practices, (Speier *et al.,* 2011).

Proactive control and monitoring. Proactive control is based on the consideration of supply chain risks in the decision-making process (Inman and Blumenfeld, 2013), in such a way that vulnerability sources are avoided or probability of a detrimental unexpected events is minimized. Typical examples of proactive control are: strategic sourcing, vendor rating, strict supply contracts, information sharing and integrating practices, as well as monitoring suppliers and controlling business opportunities (Harland *et al.,* 2003), product simplification and improved demand forecasts (Inman and Blumenfeld, 2013). Proactive control relies on tools based on statistical process control and control charts (Christopher and Lee, 2004), data mining, intelligent web agents and expert systems (Blackhurst *et al.,* 2005), Big data (Waller and Fawcett, 2013; Wieland, Handfield and Durach, 2016)as well as potential for tracking and tracing provided by Internet of Things, and Block chain technology (Christopher, 2019; Saberi *et al.,* 2019).

- Effect oriented, impact reductive guiding principle and related strategies

The *effect-oriented principle,* also known as the impact reductive principle (Kleindorfer and Saad, 2005; Vlajic, van der Vorst and Haijema, 2016) attempts to limit or mitigate the negative consequences of disturbances (Wagner and Bode, 2009). Generally, it is grounded on two ideas:

To make supply chains sturdy and strong, so that their performances are not affected by disturbances, i.e. build supply chain robustness (Vlajic, van der Vorst and Haijema, 2012); the key strategy here is related to building *redundancy* in the supply chains (Sheffi and Rice Jr., 2005). This is typically ensured by increasing inventory or time buffers (Inman and Blumenfeld, 2013), keeping multiple suppliers (Rice Jr. and Caniato, 2003; Tang, 2006), and adding capacity (Chopra and Sodhi, 2004; Zsidisin and Wagner, 2010)

To enable fast recovery of supply chain performances after the disturbance occurred (resilient supply chains); the key strategy here is related to enhancing flexibility (Zsidisin and Wagner, 2010), i.e. having ability to change elements of a supply chain scenario by ensuring that a disturbance is identified (Barker and Santos, 2010) (information sharing aspect) and a response is put in place (responsiveness aspect). Key strategies related to flexibility are switching suppliers or transport modes in the case of supplier or transporter failure (Stecke and Kumar, 2009), emergency deliveries (Inman and Blumenfeld, 2013) postponement, multiple purpose resources (Hopp, 2008) or flexible manufacturing systems (Gunasekaran, Patel and Tirtiroglu, 2001).

While the first idea requires the high investment costs and tie capital into inventory, the second idea requires collaborative efforts to ensure fast recovery, information exchange (Bode *et al.,* 2011) and it is more difficult to implement. Both approaches contain reactive redesign strategies, which are found more often in the relatively low predictability environments (Ketokivi, 2006).

2.2. Contextual Factors – Contingency Theory Lens

Contingency theory suggests that the business decisions are subjects to internal and external contextual factors, i.e. contingencies (Grötsch, Blome and Schleper, 2013). Contingencies, i.e., contextual variables, response variables and performance variables. Sousa & Voss (2008, p.703) define *contextual variables* as "situational characteristics usually exogenous to the focal organization or manager", *response variables* as "the organizational or managerial actions taken in response to current or anticipated contingency factors" and *performance variables* as the dependent measures which represent "specific aspect of effectiveness that are appropriate to evaluate the fit between contextual variables and response variables for the situation under consideration". Contingencies might act as enablers or constraints to response variables (Ketokivi, 2006).

In line with Blome et al. (2014), Ketokivi, (2006) we consider product and supply business environment as contextual factors that shape the effects of the redesign strategies on the supply chain scenario.

- Product characteristics

Product characteristics represent properties of raw materials or final products (Kirezieva *et al.,* 2013). In further text, we present product characteristics reported in the literature. *Durability and physical characteristics* of products indicate a complexity of its production and requirements for logistics processes in terms of packaging needs, storage conditions, material handling and warranty date and conditions. Generally, more fragile products, susceptible to environmental influences and less durable, the higher chance for product damage and disposal cost is. *Product assortment* represent external variety (Pil and Holweg, 2004), i.e., a number of different stock keeping units or end-product configurations available to customers. Increased product assortment is typically consequence of variety in packaging sizes, labels and brands (Van Donk, 2001). Though large product assortment results in increased inventory costs (Closs, Nyaga and Voss, 2010), it enables product substitution to avoid situations of inventory shortage, obsolescence and low customer service. *Product customization* might occur in any point of a supply chain and it requires certain type of processing, ranging from simple operations such as cutting or mixing to more complex operations that require specialized resources. (Olhager, 2003) states that product customization might affect supply chain scenario as well. Both product assortment and customization have been identified as a means to achieve a competitive advantage (Scavarda *et al.,* 2010). *The number of components* needed to build a product is strongly related to the number of production steps, which affects production complexity (Inman and Blumenfeld, 2013) and indicates the type of a network structure. Inman and Blumenfeld found that the higher the number of parts, the higher the risk of a missing part is and the higher the risk of disturbance in production is.

Based on Blome *et al.,* (2014), identified product characteristics indicate product complexity. Similar to Ketokivi (2006), they considered that the shorter product durability, more fragile or perishable product features, the higher the customization, the number of components and assortment, the higher the complexity is. Though product complexity might affect effectiveness of redesign strategies on the supply chain scenario (Eckstein *et al.,* 2015), it is rarely considered how it affects vulnerability, robustness and resilience of supply chains (Inman and Blumenfeld, 2013).

- Business environment

Business environments consider the supply and demand conditions. In this paper, we focus on supply conditions and its relevant characteristics. *Market capacity risk* occurs when there are only a few supply sources available (Zsidisin, 2003), which exposes supply chains to a product shortage. This is especially the case of strong competition, when suppliers may switch customers. *Geographical dispersion* of suppliers (Brandon-Jones, Squire and Van Rossenberg, 2015) might contribute to higher risks of disturbances, as internationally located suppliers require long shipping lead times due to border crossings, consolidation/deconsolidation centers and mode changes (Inman and Blumenfeld, 2013). Inman and Blumenfeld highlight that these environmental factors increase not only the probability of a disturbance, but also its impact. *Uncertainty in supply* occurs due to unexpected events that affect timing, quantity or quality of inputs, such as delays due to traffic accidents, supplier's failure or mistakes in order picking (Vlajic *et al.,* 2013). As such, it affects inventory or supplier management procedures. Changes in domestic or international trading *regulations* can open or restrict sourcing possibilities, thus influencing efficiency of purchasing function, as well as supply chain and logistics operations. Moreover, regulations can impose the form of information exchange and communication between supply chain partners. For example, information exchange with suppliers can take the form of non-structured and structured communication. In make-to-order systems non-structured communication improves supply chain performances, while structured communication increase costs in a situation of a high supply complexity (Gimenez, Van Der Vaart and Van Donk, 2012).

Based on (Gimenez, Van Der Vaart and Van Donk, 2012) and related studies, identified characteristics of business environment indicate *supply complexity,* which may impact effectiveness of redesign strategies applied on the supply chain scenario. The literature suggests that the higher marker capacity risk, larger geographical dispersion of suppliers, higher uncertainty in supply and frequent changes of regulations contribute to higher complexity of the supply chains. Similar to (van Donk & van der Vaart 2004) who found that higher supply complexity results in higher integration of the supply chain and improvement of performances, it is still an open question whether a higher complexity in supply implies an increased effectiveness of redesign strategies applied to the supply chain scenario.

3. Conclusion

The supply chain and operations management literatures suggest that supply chain designs are shaped by contextual factors, i.e. high-inertia contextual variables. In most cases these variables are possible to change only in the long term and with the substantial effort (Sousa and Voss, 2008). However, there is a scarce literature that provides more insights how these contextual factors shape effectiveness of redesign strategies when applied to supply chains to manage their vulnerability. In particular, product complexity is not much studied in connection to supply chain vulnerability (Inman and Blumenfeld, 2013), nor how to manage vulnerability, or achieve robustness and resilience. There are studies that analyze impact of supply complexity on supply chain integration (van Donk and van der Vaart, 2004; Gimenez, Van Der Vaart and Van Donk, 2012) or flexibility (Blome, Schoenherr and Eckstein, 2014), and there is a general notion that increased complexity increases vulnerability of supply chains (Wagner and Bode, 2006). However, Brandon-Jones et al. (2014) found that though supply complexity affects redesign strategies aimed to increase robustness and resilience and ultimately reduce supply chain vulnerability, not all factors that constitute supply complexity significantly affect relationship between redesign strategies and performance. Similarly, (Brandon-Jones, Squire and Van Rossenberg, 2015), not all factors that constitute supply complexity significantly affect frequency of supply chain disruptions.

In this study, we propose more detailed research to investigate:

- To what extent product and supply complexity cause supply chain vulnerability, as well as provide benefits from application of specific redesign strategies by increasing supply chain robustness and/or resilience;
- How specific product or supply related factors affect link between specific redesign strategies and supply chain vulnerability, and robustness/resilience and
- Does the disturbance prevention or mitigation related strategies are more effective and efficient in the case of high product complexity and/or high supply complexity.

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