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SLACK: WHAT IS LACKING ON SUPPLY CHAIN RESILIENCE STRATEGIES?

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ABSTRACT

In complex systems, supply chains are more exposed to variability and uncertainties that lead companies to suffer negative effects on their performance and may even collapse. The civil construction sector is seen as a complex socio-technical system, therefore it must consider strategies that deal with these disturbances. Slack and resilience in the supply chain are topics that have already been discussed in several sectors of the industry and deal with these variables, however the literature is recent for the civil construction sector. It is understood that Slack can provide an improvement in the effect of supply chain resilience, however, there is no theoretical discussion that points out similarities and complementarities between slack and the concept of resilience in the supply chain to shed light on the uses and limitations of the practices. The study in question makes a theoretical discussion based on a literature review about these systems, compares their practices and strategies, similarities and complementarities and finally proposes future research. Findings of this study shows that one of the strategies like flexibility is more advanced on strategic issues such as pricing and flexible contracts in supply chain resilience theory than on slack theory. Other contributions are discussed for collaboration, social capital, margin of manoeuvre, agility and redundancy strategies.

KEYWORDS

Supply chain resilience, slack, strategies.

INTRODUCTION

Disruption in the supply chain is a phenomenon related to the interruption of the supply flow due to an unexpected event, usually having a high negative impact on the performance of organizations (Azadegan et al., 2021). Costs, revenues and deliveries can be harmed (Hendricks and Singhal, 2013; Ponomarov and Holcomb, 2009; Stecke and Kumar 2009; Ponis and Koronis, 2012), in addition to the possibility of losing market to the competition (Rezapour et al, 2016) or even collapse (Xu et al, 2014). With globalization, increased competitiveness, climate and environmental changes, as well as government and economic crises, supply chains have become more complex (Hendricks and Singhal, 2005; Pettit, Fiksel and Croxton, 2010) making disruptions frequent (Resilinc, 2018). At this point, in a recent study by McKinsey (2020) executives reported that they suffered on average a severe disruption in their supply chain every 3.7 years and that every decade, a decrease in annual profit of around 45% can be expected.

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Civil construction is a system with complex characteristics, which means that it is exposed to several social and organizational factors that can lead to instabilities, (Formoso et.al, 2021; Saurin, 2017) and, therefore, it is also subject to disruptions in the supply chain. It is therefore necessary to propose systems that are able to absorb variations and uncertainties, responding to the disturbances generated in order to minimize or even nullify the effects of these disturbances (Böhle et al 2016; Tukamuhabwa, 2015). Although little has been said about the disruption in the civil construction supply chain, showing that there is a knowledge gap that needs to be filled (Ekanayake et. al, 2021).

The phenomenon of supply chain resilience is a concept that precisely contemplates dealing with the challenges of disruption and has evolved in recent decades not only to propose ways to avoid or mitigate the effects of disruption, but to make it possible to learn from the process and in some cases allow progresses to a more efficient operational future state than the original (Shuai, Wang and Zao, 2011; Mandal, 2012; Pettit, Fiksel and Croxton, 2010, Melnyk et al. 2014). In recent years, studies in the area have identified the existence of a group of strategies that, when adopted help to mitigate the risks of disruption or to have faster and more effective responses to any disruption after it occurs, these strategies are classified into: Redundancy, Flexibility, Collaboration, Agility and Social Capital (Sawyer and Harrison, 2019; Polyviou, 2019; Pettit, et al. al 2019; Tukamuhabwa, 2015). The theme of supply chain resilience has gained space in the literature referring to several industrial sectors, however it has still been little discussed in civil construction (Ekanayake et al., 2020).

Recently, the concept of Slack was pointed out as an asset for resilience in complex systems, such as civil construction (Righi;Saurin, 2015). Bourgeois (1981) defines slack as a reserve of current or potential resources that allow an organization to successfully adapt to internal or external changes. Formoso et. al (2021) highlights that Slack has been used in the literature to describe a broad set of strategies to deal with complexity, Saurin; Werle (2017) corroborates this thought and highlights those slack strategies provide resources to adjust performance and maintain the “vital” functions of the operating system during expected and unexpected events. Fireman et al (2022) presented, from two pilot studies, a set of slack strategies applied in projects that went through a phase of disruption in the supply chain, however the study was more focused on investigating the strategies that were managed by planning and production control.

This paper aims to add clarity to the relationship of slack and supply chain resilience to answers the research question: “What are the strategies of slack and supply chain resilience theories that aim to avoid, mitigate or eliminate possible disruptions in the supply chain? Are there differences, similarities or complementarities between them?”. This study is based on theoretical discussions coming from a literature review of the main papers that address strategies used in each system, highlighting similarities and complementarities so that companies can choose and apply the ones that best suit for their business environment context. Although the authors recognize that there are limitations in the literature reviews, which may not have addressed all strategies or theoretical definitions of the concepts. Finally, from the perspective of theoretical discussion, the paper provide guidance on future research on topics for the civil construction sector.

RESEARCH METHOD

The search to foster the theoretical discussion of supply chain resilience strategies consisted of finding the main systematic reviews of the literature in the last ten years using the Web of Knowledge and Google Scholar databases, for the advanced search the search string was used 'supply chain resilien* AND literature review', from the reading of the abstracts 13 papers were selected for the complete reading. Common themes of ways to perform in supply chain

resilience appeared in these surveys: collaboration, flexibility, redundancy, agility and social capital. The authors then decided to explore each one of them, forming a base of 67 papers.

To verify what has been studied about supply chain resilience in the civil construction sector, the search string 'supply chain resilien* AND (civil construction OR construction industry)' was used, where only 28 relevant papers were found, indicating a possible line of research to be developed.

In the case of slack theories, the first search was carried out in the IGLC bases with the search string 'slack' resulting in 9 papers, of which 5 were selected after reading the abstract. To complement the search, the Web of Knowledge and Google Scholar databases were used again, with the strings 'slack AND (civil construction OR construction industry)', an extensive reading of the abstracts of 42 papers was made to select only 12 papers. Once again, themes common to the papers were found with regard to theoretical discussions of strategies to use slack: redundancy, flexibility and margin of manouvre.

As the two searches resulted in strategies to avoid disruption of the supply chain, so it was decided to investigate whether there are similarities, differences or complementarities between them and finally and propose a theoretical discussion.

LITERATURE REVIEW

SUPPLY CHAIN RESILIENCE

The concept of supply chain resilience has been studied with the aim of dealing with the challenges of disruption, where companies must avoid or respond quickly to disturbances and return to operational normality (Melnyk et al., 2014; Rice and Caniato , 2003) and even learn from the process and progress to an even better operational future state than the original (Shuai, Wang, and Zao, 2011; Mandal, 2012; Pettit, Fiksel, and Croxton, 2010, Melnyk et al. 2014) .

In the last two decades, studies have shed light on strategies to support supply chain resilience, whether reactive or proactive, depending on the application context (Tukamuhabwa, 2015). Sawyer; Harrison (2019); Polyviou (2019) and Pettit, et. al (2019) highlight the role of four main categories of strategy: Flexibility, Redundancy, Collaboration and Agility.

Redundancy

Redundancy is an element of the supply chain resilience strategy that involves the selective use of spare capacity and inventory to deal with supply shortages or demand variations (Parast and Shekarian, 2019). These spare capacity can be reserve stocks (Datta et. al, 2007; Pereira et. al, 2014); multiple supplier options in cases of low reliability (theme that can also be found in the flexibility strategy, but with regard to redundancy, it is related to having supplier options beyond the necessary demand and not just sharing capacity delivery between two or more suppliers, for a given demand) (Sheffi, 2001; Feng and Shi, 2012); reserve capacity of facilities, employees and modes of transport (Linnenluecke, 2017; Sheffi and Rice; 2005; Rezapour, Farahani and Pourakbar, 2016; Ponomarov and Holcomb, 2009).

Flexibility

Flexibility is a category that includes strategies that allow organizations to manage risks in the supply chain by adapting to changes in market demand or supply, causing resources to be reallocated quickly in turbulent scenarios and still maintaining performance in service levels (Tang and Tomlin, 2008; Stevenson et. al, 2008; Erol, Sauser and Mansuri, 2010; Christopher and Holweg 2011; Tukamuhabwa, 2015). Pereira et.al (2008) also points out that flexibility is a decision-making structure that allows responsiveness in the dynamics of environments.

Several strategies involving the concept of flexibilities are addressed in the literature, Tang and Tomlin (2008) list flexibility strategies in three dimensions: supply risks; process risks and

demand risks. Supply risks involve multiple-supplier strategies to reduce dependence on a limited number of suppliers and flexible contracts for eventual demand adjustments, which allow changes in quantity orders between suppliers or over time (Li et. al, 2020; Wu et. al, 2019), another example can be strategies contemplating multi-modal transport (Tang, 2006). Process risks consider the flexibility of manufacturing processes or resources, such as production route alternatives due to the multi-purpose machine or even the adoption of multifunctional workers (Sheffi and Rice, 2005; Ekanayeke et al, 2021; Tang and Tomlin, 2008). Demand risks, on the other hand, are related to the flexibility of postponing production (Datta et. al, 2007) and product pricing (Zhanhai and Zhipeng, 2019).

Collaboration

Collaboration can be defined as the ability to work efficiently with other stakeholders to achieve common benefits by sharing risks, resources, information and knowledge (Parast and Shekarian, 2019; Scholter and Schilder, 2015). The collaboration strategy can contribute to reducing uncertainties inherent in the supply chain, as well as ensuring recovery in the face of a disruptive event and providing speed and agility to decision-making due to consensus between the parties (Scholten et.al, 2014).

In recent studies Duong and Chong (2020) gathered 157 literatures in a systematic review to confirm the hypothesis of the positive impact of collaboration for the recovery and response to disruptions, several collaboration mechanisms were pointed out in the authors' review, including contractual and economic practices, practices joint planning and control, relationship management, information and technology sharing, governance practices, supply chain design, and assessment and feedback practices in the post-disruption period.

A well-known example of collaboration is the case at Toyota, when Aisin Seiki's, one of Toyota's main suppliers responsible for supplying proportioning valves used in the brake system of all vehicles, suffered a serious fire. Due to just-in-time (JIT) principles, only about two or three days' worth of inventory was available. Toyota group companies, together with some external companies, immediately set up alternative production factories. The result was a feat, it was expected that the production of Toyota vehicles would stop for weeks, in just two days the plants started producing again (Nishiguchi and Beaudet 1998).

However, like most of the studied strategies, trade-offs are expected even in supply chain collaboration, Choi; Krause (2006) alert to horizontal collaboration and the risk of collusion between the parties, Jüttner; Maklan (2011) point out that there may be risks of sharing confidential information, sometimes strategic for companies.

Agility

This strategy revolves around the concept of rapid response to unpredictable changes in demand or in the supply chain (Christopher and Peck, 2004) in order to adapt, give pace and speed in the recovery of risk events (Shekarian et.al, 2020; Tukamuhabwa, 2015; Jüttner and Maklan 2011, Erol et.al, 2010).

Recent studies address the issue of technology as an increase in resilience performance through increased agility, involving blockchain, network inventories and real-time analysis, big data analytics and monitoring tools to increase supply chain visibility (Li et. al, 2022). Visibility is a key concept in the agility construct that helps to quickly identify the status of the chain and possible vulnerabilities (Tukamuhabwa et.al, 2015; Jüttner and Maklan 2011), it is closely connected with visual management and Lean Construction practices for problem solving (Saurin et al, 2021).

Social Capital

Polyviou (2019) conducts a study to explore strategies that allow small and medium-sized companies to be resilient, the author argues that companies of this size often do not have enough

resources or power to use the strategies proposed so far, such as raising levels of safety stock, negotiate with multiple suppliers, and increase space, workforce, and equipment capacity. The analyzes of the study reveal other strategies in addition to those studied for large companies and that are linked to human resources, more specifically to social capital. In this point, Adler and Kwon (2002) define social capital as links or relationships between individuals or cohesive groups that seek the same goals.

The construct of social capital is formed by three dimensions: *structural capital*, *cognitive capital* and *relational capital* (Ghoshal, 1998). *Structural capital* is related to the links between actors in a given network and the patterns inherent to the links (Nahapiet and Ghoshal, 1998), examples of structural capital factors are the geographic proximity between decision makers and network size and hierarchy, in this case, the smaller the size of the network and the more horizontal the organization, the greater speed in decision-making, that is, it favors structural capital (Whittington et al., 2009; Inkpen and Tsang, 2005). *Cognitive capital* is related to the time of experience and knowledge of employees (Fischer and Pollock, 2004), and *relational capital* to team commitment, mutual respect and proximity in relationships (Nahapiet and Ghoshal, 1998).

SLACK

Slack is defined here as a reserve of resources that exceed or not the minimum necessary and that can be reallocated to support organizations to adjust performance in the face of expected and unexpected events (Fireman et al. 2022; Formoso et al. 2021; Saurin; Werle , 2017). It is possible to identify in the literature the existence of two dimensions of the slack concept, the first of which refers to which resources are being applied as slack (eg: time, equipment, projects, procedures, materials, etc.) while the second dimension is strategy-related how slack resources are being employed (Fireman et al., 2018). This paper seeks to address the second dimension, which brings the categories of strategies for the application of slack (Formoso, et al. 2021): Redundancy; Flexibility; Margins of Manoeuvre.

Redundancy

It is a category of strategy in which the resource is provided above the minimum amount necessary to perform a specific function (Nonaka, 1990), or when more than one resource performs the same function (Azadeh et al., 2016). As examples of this strategy are the redundant procedures for checking materials that must be sent to the project (Fireman et al., 2022); stock of materials (Formoso et al., 2021); and more than one foundation project considering different types of soil (Saurin et al., 2021).

In the literature on Slack, it is possible to identify four subcategories of redundancy (Formoso et al., 2021; Saurin and Werle 2017; Fireman et al.; 2022): (a) standby redundancy – strategy that deals with the adoption of resources that are not involved immediately in the running task; (b) active redundancy – when the applied resources are involved in the task; (c) redundant procedures that apply to specific cases of redundant procedures; (d) finally, the work-in-progress category, which adopts the strategy of using a backlog of available work areas (in the case of construction) or stock of semi-finished products.

Flexibility

Flexibility is seen in the literature on slack as a strategy related to the use of resources in diverse and adaptable ways (Formoso et al., 2021). At Toyota, workers' multifunctionality is naturally encouraged to absorb deviations in the production line (Shingo, 1989). Other examples of flexibility are multi-purpose equipment, flexible plant layout or even alternative sequence of production routes. The flexibility category is the most recent slack category presented in the literature (Formoso et al., 2021; Saurin, et al., 2021) which explains the low number of examples or the current lack of subcategories.

Margins of Manoeuvre

The third strategy, margin of manoeuvre, is considered a combination of the two previous strategies (Formoso et.al, 2021). It addresses the creation or maintenance of margins and additional resources that allow the system to continue to function despite unexpected demands (Saurin; Werle, 2017). Examples of this application can be seen in the study by Fireman et al (2022), which brings examples such as design changes to simplify connections in metallic parts in order to increase assembly speed; use of a reserve shift for production to correct line delays; contingency margins in the budget of suppliers. Stephens et al (2011) highlights the existence of three types of margins of manoeuvre: defensive – restrict actions of a unit or borrow margins from another unit; autonomous – local reorganization or adaptation of resources in cases of need; coordinated – creation of features that can be shared by two or more units.

DISCUSSION: SIMILARITIES AND COMPLEMENTS WITH SLACK STRATEGIES AND SUPPLY CHAIN RESILIENCE STRATEGIES

There are common points between the main strategies listed in the literature regarding slack and supply chain resilience, Table 1 represents strategies that are used for each concept. Of the six strategies presented, two themes studied are explicitly common to the slack and supply chain resilience literature: Redundancy and Flexibility. However, despite seeming to converge, apparently there are differences in the focus of action that will be commented further.

Table 1: Supply Chain Resilience and Slack Strategies

Strategies	Slack	Supply Chain Resilience
Redundancy	X	X
Flexibility	X	X
Collaboration		X
Agility		X
Social Capital		X
Margins of Manoeuvre	X	

Redundancy is a strategy that appears to have a greater degree of convergence between the two themes, it is mainly about maintaining a contingency of resources whether active or standby, as proposed by the slack literature. In the literature on supply chain resilience, although there are no clear subcategories, there are more popular examples such as capacity reserve, safety stock, backup facilities. There is a divergence regarding the role of procedural redundancy, a subcategory presents in the slack literature, but which is not identified in the supply chain resilience literature. In some situations, double-checking a critical process or supplier can be important to mitigate possible disruptions. Another important point is that the focus of slack literature has been on combating production uncertainties and not necessarily preventing a disruption in the supply chain. Examples of this are given in Saurin et. al (2021) utilizing foundation project redundancy or even reserve staff on important equipment. Fireman et. al (2018) and Saurin (2017) discuss the use of WIP (work-in-process) to have stocks of materials in different manufacturing stages, kit centers or distribution centers shared between construction trades can be examples of WIP to protect the flow production when there is instability in the production flow. These redundancy utilization strategies are more connected to production planning and control rather than supply chain resilience.

Flexibility: strategy that considers the adaptation of changes with existing resources in the company. At this point, supply chain resilience studies seem to be more advanced with regard to strategic issues to deal with supply chain demand variability and disruptions. For product pricing flexibility, for example, Tang and Tomlin (2008) cite the case of Dell, where the factory

of one of its main suppliers suffered from an earthquake that compromised the delivery of components for a certain line of computers, Dell's response outside of lowering prices on other computers that did not depend on that supplier's components and thus altering demand. Behzadi et al, (2017) proposes a mathematical modeling on the multiple-sourcing strategy in the agriculture sector and concludes that this is efficient to avoid financial losses, but does not have a good performance to avoid climatic risks of harvests. Li et.al (2020) study two types of flexible contracts for risk sharing, one with the possibility of changing quantities and another with capacity reserve, they conclude that when there is no coordination in the supply chain ie - when the decentralized system does not make profits equivalent to the centralized system, these contract models perform better than contracts with less flexibility. As for issues involving operational problems, they converge in slack and the literature of supply chain resilient, such as developing skills in teams, relocation of workers to higher priority jobs, creation of alternative layouts, flexibility in changing processes to meet critical change scenarios (Saurin et.al 2021; Fireman et. al, 2022). Once again, as in the case of the redundancy strategy, the flexibility strategies used in slack seem to be more focused on the concepts of production planning and control and not on supply chain resilience. On the other hand the literature of Slack presents procedures redundancy as a subcategories of redundancy, but it is not presented on supply chain literature. Figure 1 shows the subcategories of flexibility and redundancy in the slack and supply chain resilience literatures.

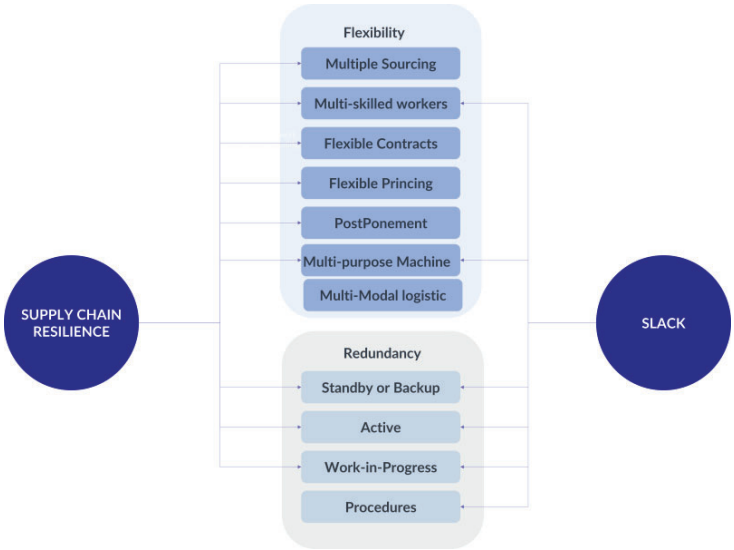

Figure 1: Redundancy and Flexibility Map

Collaboration and Margins of Manouver: It is possible to verify that there is a certain relationship between the two strategies, since the subcategories margins of manouver defensive or a coordinated it is possible to identify that there is an implicit model of collaboration, whether achieved through borrowing or sharing resources. However, the collaboration strategy has a greater focus on the supply chain external to the production environment (factory or, in the case of civil construction, the construction site), its networks of connections and development of trust, risk sharing, predictability of delivery, knowledge exchange, and postponement and resource sharing. A relevant theme for case studies involving the civil construction sector is the deepening of the trade-offs pointed out in the cited literature, to study the extent to which collaboration can be used, for example: is there any kind of conflict of interest when integrating a certain part of the supply chain? What company information can be shared with a certain network of suppliers that does not compromise the strategic advantages over the competition?

Agility: theme correlated with the use of visual management and indicators for the quick perception of problems related to suppliers, in order to detect possible threats in the chain. In the slack literature related to the civil construction sector, they point out themes that can be considered agility strategies inside other strategies, such as Saurin et al (2021) put examples of importance of daily meetings where employees detect problems to propose quick solutions and sometimes reallocated resources between teams, as defined in the flexibility strategy. Saurin and Werle (2017) still argue that visibility, a nomenclature used synonymously with agility, is a way of classifying resources.

Social Capital: strategy that enters the field of behavioral studies of human resources, there is also similarity in these resilience strategies in the supply chain with what is discussed in slack. In this point, the initial study related to slack on complex socio-technical systems presented by Saurin and Werle (2017) pointed out that discuss problem-solving techniques were classified as a category os slack strategy known as cognitive diversity. So, there is convergence with the strategy of Cognitive Capital pointed out by Polyviou et.al (2019), which aims to share knowledge of experienced employees for others. Means of measuring the performance of these strategies are still scarce in civil construction studies, as well as frameworks and case studies that shed light on how to develop these skills in human resources, with the scope to improve the effect of supply chain resilience.

CONCLUSIONS

The concept of slack is still not widespread in the civil construction sector, as well as strategies to improve aspects of supply chain resilience. Disruptions in the supply chain can be caused by external factors such as catastrophes and wars, although we must remember that these disruptions are also frequent in characteristics internal to the context of the business model, such as competition, new demands for products, relationship with the supplier network, among others. It is therefore inferred that there is a knowledge gap that needs to be taken advantage of to make companies more efficient in relation to supply chain resilience in the civil construction environment, and that they are able not only to pass unscathed through turbulent times, but that they are able to develop new ones. opportunities from them.

There are several similarities between the studies of slack strategies with supply chain resilience, theoretical definitions and discussions should be improved in order to facilitate the understanding of the topics, so companies can choose which methods and how much resources they should employ in the solutions theories without misunderstanding of concepts and duplication of applications. The present study demonstrated that there is a wide field of study on slack strategies related to flexibility, since in the resilient supply chain literature there are important subcategories that have not yet been addressed in slack studies as multiple sourcing, flexible contracts, flexible princing, postponement and multi-modal logistic. On the other hand the literature of Slack presents procedures redundancy as a subcategories of redundancy, but it is not presented on supply chain literature.

Another important point of the paper was to bring more clarity about the differences between the redundancy and flexibility strategies, which currently prove to be very close to the performance limit of each one. In this regard, it is possible to note that there is greater clarity in the supply chain literature on the difference between the two, since while the redundancy strategy seeks to work with an excess of capacity than necessary to respond to disruptions, the second has as its main objective to create capacities in existing resources to promote adjustments as demand changes occur (Xu, 2008; Datta et.al, 2007).

Finally, this study sought to confirm the importance of slack in the effects of resilience in companies, more specifically in supply chain resilience. It should also be noted that future research should study the trade-offs listed in this study to optimize their applications and choices in the desired context.

FUTURE RESEARCH

Below are some suggestions for possible future research:

- Case studies involving the application of resilience and slack strategies and lean construction mediating theses strategies.
- Performance measurement of strategies in different contexts.
- Frameworks for implementing supply chain resilience concepts adapted to the civil construction supply chain in different sectors: SMEs, infrastructure works, construction buildings, etc.

RESEARCH LIMITATIONS

Theoretical discussions are limited to current research and literature review, other concepts and discussions may not have been addressed.

Few case study examples are placed in the AEC industry, which may hinder the practical interpretation of supply chain resilience strategy concepts

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