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SUPPLY CHAIN COMPLEXITY: THE PARANOMA EFFECT

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ABSTRACT

This research examines the concept of supply chain complexity and evaluates how effectively current supply chain management strategies deal with it, encompassing processes, resources, and data. Extensive research was conducted on managing supply chain complexity. Research indicates that supply chain management efforts assist companies in navigating the intricacies of their supply networks by managing interactions and reducing uncertainty. Regarding the management of supply chain complexity, the poll findings highlight the key abilities that should be prioritised. Furthermore, current approaches, methods, and technologies in supply chain management are effective in managing supply chain complexities. Further, it lays the groundwork for studies that will focus on supply chain complexity management in the future.

Keywords: Supply chain complexity, Complexity management

Introduction

Businesses worldwide are facing a multitude of challenges as a result of global complexity. These include fierce competition, changing consumer demands, more deregulation, the global financial crisis, natural disasters such as those that hit Japan and Thailand in 2011, unpredictable power dynamics on an international level, and the rapid expansion of emerging markets (Gunasekaran et al., 2014; Park et al., 2013). While adapting to global business practices means learning and practicing new methods, it also brings up difficulties and uncertainty (Gunasekaran et al., 2014; Vahlne et al., 2011). Managers and researchers need a deeper understanding of the complexity of supply chains than what is provided by existing theoretical frameworks to address the entire global supply chain, starting from suppliers and ending with consumers (Gunasekaran et al., 2014; Grogaard, 2012).

Interconnected supply networks, where various businesses are linked together to form a chain, are crucial in today's competitive market. Management needs to focus on the entire supply chain

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rather than just individual firms. In the interconnected world of business today, operating as an isolated enterprise is increasingly challenging. According to Gunasekaran et al. (2014), Wildemann (2000), and Pfohl et al. (2000), SCC for management therefore rose dramatically. Multiple factors, including the diversity of business processes and the number of interacting parties like suppliers and consumers, suggest that supply chain complexity (SCC) is becoming more complicated, even though it is mostly influenced by internal and external forces (Milgate 2001). To identify the difficulties encountered by 50 prominent UK firms, KPMG conducted a research in 2011. The most obvious consequence of interconnected supply chains is the additional uncertainty they bring to operations within the network. Additionally, many supply chains are not adaptable enough to meet the needs of modern businesses. Thirdly, sustainability measures lead to changes in operating models. These essential components share a common trait: Supply networks are experiencing increasing complexity, leading to challenges and issues.

Statement of the Problem

Recently, the idea of a supply chain, which is a network that connects physical entities to deliver products and services to customers, has become widely accepted. People are becoming more attentive due to negative experiences with product availability and pricing, realizing that these problems originate from supply chain issues. Globalization has long influenced trade and businesses, expanding the scope and complexity of commercial activities. As a result, maintaining and managing interruptions in supply networks have become more challenging. Recent conflicts, prominent logistical disasters, and the ongoing pandemic have underscored the vulnerability of global supply networks. Supply chain management procedures are challenged by evolving customer preferences and demands. To retain and grow their customer base and revenue, businesses catering to end users and upstream entities are prioritizing the digitization and modernization of their supply chains. Operational organizations continually strive to enhance their supplier networks, revealing challenges in aligning future supply chain expectations. Everyone can agree that businesses want to be more responsive to changing consumer preferences, agile enough to weather unexpected storms, and in sync with their suppliers and consumers. Having said that, they do share some operational goals. A way to illustrate this is by examining the similarities between process industry supply networks and e-commerce. Both process industry supply networks and e-commerce encounter difficulties in achieving the required scale and level of integration in supply chain operations.

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2.0 Literature Review

Theoretical Framework

Institutional Theory

Institutional theory explains why organisations follow certain procedures (Hirsch, 1975). As Deephouse (1996) puts it, the goal of institutional theory is to determine what factors lead to isomorphism. Isomorphism refers to how organisations imitate each other or grow in similar ways under similar constraints, as proposed by Dimaggio and Powell (1983). The authors propose three distinct methods that might result in organisational isomorphism: coercive isomorphism, normative isomorphism, and mimetic isomorphism.

Coercive isomorphism refers to the influence or pressure exerted by powerful organisations or individuals on which the company relies (Dimaggio and Powell, 1983). For example, this type of coercion can come from governments, laws, or other organizations, such as headquarters pressuring subsidiaries (Rivera, 2004). Ball and Craig (2010) explain that normative isomorphism is influenced by requests from social groups like consumers, the media, and non-governmental organizations. The final concept, known as "mimetic isomorphism" (Dimaggio & Powell, 1983), occurs when a company imitates another by copying its actions. This is when one company tries to pass itself off as another by mimicking its actions. Companies often mimic the tactics used by their most successful rivals in the same market (Aerts et al. 2006).

This study examines Research Question 1 (RQ1) through the lens of institutional theory. Specifically, we want to know if there are any coercive, normative, or mimetic pressures in the country where the firm is based that affect the adoption of sustainable supplier development practices or any other organisational practice.

Transaction Cost Theory (TCT)

Williamson (1975) and Barringer & Harrison (2000) have highlighted Transaction Cost Theory's (TCT) ability to explain business linkages. If a business and its suppliers want to cut down on transaction costs, they should choose an exchange modality that Transaction Cost Theory (TCT) recommends (Williamson, 1975). In economics, transaction costs are defined as outlays that arise from a trade (Wilson, 1975, 1985, 1996; Simpson and Power, 2005 define). Both the upfront investment in relationship management and the hidden costs of dealing with the inevitable transaction risks that come with doing business with other companies add up to the total transaction costs. Examples of direct expenditures include the transaction cost and the cost to formalise the contract managing the connection. Transaction hazards, which could cause issues with trade, are two of Transaction Cost Theory's (TCT) basic assumptions about human conduct (Williamson, 1981). Initially, there is an assumption of limited rationality. The term

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"bounded rationality" refers to the limitations on human decision-making imposed by intelligence, memory, and language (Simon, 1957). The second assumption is related to the lack of honesty in transactions, including self-interest with deception (Williamson, 1975, p. 9). To reduce transaction risks caused by opportunistic activity in an existing relationship, Carter and Rogers (2008) argue that costly monitoring and oversight actions are necessary.

These kinds of observational tasks are known as supplier evaluation procedures when applied to the field of supplier development. Since the supplier will be subject to scrutiny and control, their opportunistic conduct will either diminish or cease as a result of the purchasing organisation using these techniques. This work partially addresses Research Question 2 (RQ2) by using Transaction Cost Theory (TCT). In order to prove the connection between sustainable performance and supplier evaluation approaches, we shall use it.

Resource Based View (RBV)

The RBV has become more popular as a tool for understanding cooperation in the supply chain (Cao & Zhang, 2011). According to this theory, one reason for differences in performance is how effectively a company utilizes its resources. These resources encompass everything a firm controls, such as assets, capabilities, organizational processes, and knowledge (Barney, 1991, p.101). According to the RBV, related companies may gain an edge in the market by investing in relation-specific assets that are expensive, unique, non-replaceable, and difficult to replicate (Barney, 1991). Investing in assets specific to the relationship results in increased cooperation between a purchasing organization and its suppliers, as discussed in supplier development literature. Besides developing these valuable assets, research on RBV indicates that supply chain collaboration enables companies to concentrate on their core strengths, leading to enhancements in their competitive position through factors like learning effects, economies of scale, and enhanced firm-specific skills (Park et al., 2004).

In this article, we will use the RBV to answer RQs 1 and 2. In relation to RQ1, the RBV will help us examine how external integration or internal factors influence the execution of sustainable supplier development strategies. We will utilize the RBV to discuss how collaborative efforts influence the performance related to RQ2.

Relational View

Dyer and Singh (1998) explain that firm networks and dyads, connections between buyers and suppliers, are used to understand relational rents. Dyer and Singh (1998) define a relational rent as an extra profit made together in a partnership that neither firm could make alone, only possible through the unique contributions of the alliance partners (p. 662). Cao and Zhang (2011) introduced the term "relational rents" to explain the advantages of partnerships. These include mutual investment in success, establishing information exchange norms, benefiting from complementary resources, and effective governance. Such partnerships are prevalent in

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transactions between buyers and suppliers due to their mutual investment and resource-sharing practices. A key aspect of the relational approach is that organizations can achieve shared goals through cooperation that would be unattainable individually. Collaboration between purchasing companies and suppliers on a supplier development plan establishes the connection in studies on sustainable supplier development methods. Here, we apply a relational perspective to address RQ3. Specifically, the effects of sustainable supplier development initiatives will be understood via the lens of the relational perspective.

Supply Chain Complexity (SCC)

The need for a large number of supply chain partners arises from increased globalisation, shorter product life cycles, and faster technology innovation in manufacturing and services. Collaboration in supply chains might take place in person or online, further complicating matters and making the chain harder to oversee. Efficient management and a plan to mitigate risks are necessary due to the complexity of the contemporary supply chain network. Effective management of a supply chain requires expertise in understanding the network's interconnected parts and minimizing complexity.

The field of supply chain management (SCM) is the result of the gradual merging of operations management (OM), sourcing, and logistics during the last 20 years. Companies, from a supply chain management (SCM) perspective, need to manage and monitor the physical and information flows, along with the linkages with downstream and upstream partners. Simply managing individual regions is no longer sufficient in supply chain operations. From a supply chain management (SCM) perspective, companies need to expand their design and management responsibilities. Due to shorter product life cycles, greater product diversity and customisation, and more geographically distributed supply chain partners, these operations have become more difficult.

The perception of a supply chain as a complex system contributes to the inherent difficulty of supply chain management tasks. This research defines SCC by drawing on systems science literature, characterizing the distinctively complex features of supply chains. Academics and business experts have only just started to talk about the downsides of this growing complexity, despite the fact that the need for enterprises to broaden and deepen their supply chain operations has been heavily discussed (Swafford et al., 2006). (Hoole). Beyond the concept of SCC, empirical studies examine the effects of several sources of complexity, such as those upstream in the supply chain with suppliers, internally in the manufacturing facility, and downstream from the plant to the consumer. The findings can help identify the types and origins of complexity that significantly impact a company's operations. Several sectors and areas throughout the world may benefit from these findings. Furthermore, the findings align with previous lean production research that identified specific sources of complexity as the primary causes of poor productivity

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outcomes. In addition to outlining critical goals, the report aids decision-making for supply chain managers.

Supply Chain Drivers

Internal complexity can be attributed to flaws in organisational structure and managerial decisions. It can be found at collaboration interfaces and at every point in the supply chain. Management decisions, such as technology choices, product development, sourcing, and collaboration, significantly influence the range and types of supply chain activities (Bode et al., 2015; Serdarasan, 2013; Seuring, 2004). In their study, Flynn and Flynn (1999) categorised internal manufacturing difficulty into two main types: detail complexity and dynamic complexity. Factors such as the number of product suppliers, the types of enterprises involved, and the production processes employed can all have an impact. Research has shown that an extensive range of products can lead to increased retailing expenses and longer manufacturing lead times (Thonemann & Bradley, 2002). Complexity of details can have a negative impact on performance, and this can be influenced by the number of individual parts. Using common materials and adopting shared product platforms can help streamline internal production processes and meet a wide range of market requirements (Fawcett, Fawcett, Watson, & Magnan, 2012). Unforeseeable fluctuations in demand and significant market dynamics can lead to external supply chain challenges (Fawcett et al. 2012).

This leads to a wide range of customer inquiries regarding quantity, diversity, timeliness, and excellence. Given the limited experience and proficiency of supply chain partners, it becomes quite challenging for them to meet such a wide range of requirements. They expand their network of partners and broaden their supply chain to address this issue. Furthermore, maintaining a well-coordinated supply chain requires regular communication with clients to adapt to evolving demands. These demands may involve adjustments in product specifications, quantities, or delivery schedules (Kembro, Selviaridis, & Näslund, 2014). As the number of interfaces and systems that need to be managed increases, the regulated business connections and processes also tend to grow. According to a study conducted by Vachon et al. in 2004, the rise in complexity caused by the increase negatively impacts the efficiency of the supply chain for all parties involved. It is important to note that SCM should incorporate complexity management, as highlighted by previous studies (Childerhouse et al., 2004; Gunasekaran et al., 2014). According to Bozarth et al. (2009), external supply chain complexity (SCC) refers to the level of dynamic complexity and intricacy caused by the external supply chain, including both upstream and downstream factors.

Examples of potential downstream SCC drivers include demand volatility and variation, customer volume, and product life cycle length. Factors such as the number of suppliers, their performance, and the impact of global sourcing can contribute to upstream SCC. Just as the number of suppliers increases, so does the flow of information and materials, along with the

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connections that need to be maintained. This indicates that the complexity of the details also grows accordingly. The complexity upstream is further enhanced by the global distribution of suppliers. Given the impact of globalisation, manufacturers are faced with various challenging issues concerning import/export, currency fluctuations, and cultural differences. These factors contribute to a higher level of dynamic complexity (Cho et al., 2001). This case study delves into further causes of internal and external SCC and appropriately broadens the existing hypothesis based on the findings of the literature. One of the key factors contributing to the external SCC in this research is the large customer base spread across various regions, each with their own specific needs. Delivery dates, packaging, and product specifications are some of the requirements that need to be considered. Providers must be flexible in terms of variety, quantity, quality, and timing due to the constantly changing demand. When customer demands cannot be met by existing suppliers, new external partners are brought into the supply chain (Wilding, 1998). Due to the effects of globalisation, the shipment schedules are influenced by suppliers located in various parts of the world. Complexity tends to rise as the number of supply chain participants and business processes increases, leading to a decline in supply chain performance (Fisher et al., 1999; Vachon and Klassen, 2002). Managers are aware that the level of complexity can increase significantly when additional variables come into play. The logistics manager asserts that maintaining the appropriate inventory of parts in the warehouse has become challenging due to the continuously growing variety of available products. Unwanted stock can significantly increase inventory costs and negatively affect business profitability. While this phenomenon is not delved into further in this context, it is described in the literature as a distinct category of complexity types (Bozarth et al., 2009). The management in this case study faces a significant challenge due to the unpredictable nature of demand. One of the key factors is the decreasing length of economic cycles, which directly affects a company's profitability through factors such as increased inventory expenses and excess capacity. "During times of crisis, such as in 2009 and the current economic downturn, it becomes crucial for us to respond with agility and speed in terms of personnel and technical capacities," the CEO stated, highlighting the importance of managing internal complexity. We are driven by this dynamic to efficiently carry out our processes and foster closer collaboration with our business partners. Dealing with an increasing amount of data and ensuring its accurate distribution will undoubtedly add to the intricacy of the supply chain."

Types of Supply Chain Complexity

Any attribute that promotes SCC is referred to as an SCC catalyst (Serdarasan 2013). As a result, this term is employed to delineate the genesis of SCC for the duration of this investigation. It could assume an assortment of forms. Static complexity pertains to the layout and interconnections of supply chain subsystems, encompassing enterprises, activities, and procedures (Serdarasan, 2013). The dynamic complexity of a system is a consequence of both its environment and operational behaviour. The third category is decision-making complexity, which involves factors related to making choices within the supply chain (Serdarasan, 2013).

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Despite the challenges involved, empirical evidence suggests that supply chain performance can be enhanced through the reduction of supply chain complexity (SCC) (Gunasekaran et al., 2014; van der Vorst et al., 2002). Consequently, complexity management must be incorporated into supply chain management. Developing and implementing strategies to manage supply chain complexity becomes feasible upon examining and comprehending the factors that drive SCC.

Bozarth et al. (2009) make a differentiation between detailed and dynamic SCC. Detail complexity refers to a specific quantity of products or providers, while dynamic complexity is the unpredictability or uncertainty in how a system responds to inputs, influenced by the interconnections of its components. The complexity of the manufacturing sector is primarily analyzed based on this distinction (Calinescu et al., 1998). Sivadasan et al. founded the differentiation between structural complexity and operational complexity in their works (1999, 2002a). The concept of "structural" or "static" complexity pertains to the degree of intricacy exhibited by a product during its conception, development, and promotion.

Operational (dynamic) complexity in supply chains is associated with the unpredictability of information and material transfers within and between organisations, originating from both internal and external sources (Frizelle & Woodcock, 1995; Calinescu et al., 2000). The literature categorizes SCC into internal and external complexity (Isik, 2011; Bozarth et al., 2009), technological and flow complexity (Kaynak, 2005), and organizational, environmental, and output complexity (Zhou, 2002; Bozarth et al., 2009). The origins of internal and external complexity drivers are the subject of discussion (Childerhouse & Towill, 2004; Blecker et al., 2005). In contrast, external complexity drivers are influenced by circumstances beyond the jurisdiction of the organisation, such as legislative changes or market developments. Internal drivers, conversely, stem from internal processes and are comparatively manageable (Serdarasan, 2013). The scope of this study is external and internal supply chain participants due to the wide range of activities and interactions that take place among them. Despite the fact that Seradasan (2013) describes a number of effective SCC management techniques, research on the subject remains scarce in the machine building industry, particularly from the standpoint of an OEM. From the perspective of the original equipment manufacturer, this research seeks to identify common sources of complexity and propose solutions based on industry standards. The outcome serves as the cornerstone for constructing an SCM system.

Internal Manufacturing Complexity

In a manufacturing plant, internal manufacturing complexity encompasses the levels of complexity in processes, planning, control, and product systems, both static and dynamic. The complexity of manufacturing operations can be influenced by the number and types of items, manufacturing processes used, and the consistency of production schedules over time (Flynn & Flynn, 1999). The level of detail complexity in the production environment rises in direct correlation with the quantity of supported products and components, as illustrated in our previous

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definitions. Experts and practitioners have noted that the continuous increase in products has long-term negative effects on manufacturing performance (Salvador et al., 2002). A key principle of Efficient Consumer Response (ECR) and Collaborative Planning Forecasting and Replenishment (CPFR) involves controlling the increase in products by maintaining a suitable product range and avoiding unnecessary new product introductions (VICS, 2004). Once you identify the "optimal" number of items for cost-effective selection, the higher costs of maintaining these products offset the increased profits. Researchers in this field have mainly focused on understanding the impact of growing product numbers on lead times for replenishment and setup costs (Yano & Dobson, 1998). Nevertheless, further research is essential to grasp fully the implications of these findings on the efficiency of the overall supply chain.

Upstream Complexity

The term 'upstream complexity' refers to the intricacies and details involved in the early stages of the supply chain in a manufacturing plant. Managing supplier connections, ensuring timely deliveries, and handling global sourcing can all make upstream operations more complex. Analyzing each challenge separately reveals that adding suppliers makes the details more intricate due to the increased connections, physical flows, and information flows to manage. Moreover, the efficiency of supplier lead time can significantly impact the complexity of upstream operations, akin to how customer differences and demand fluctuations influence downstream complexity. Manufacturers may find it necessary to adopt more comprehensive planning and material management systems that account for extended supplier lead times and unpredictable delays (Vollmann et al., 2005).

System Complexity

Complexity has been extensively studied in various fields, including philosophy, physics, engineering, and management (Choi et al., 2001). Despite the attention it has received, there are numerous criteria used to determine the nature of a complex system. The definitional work in the field of organisational theory has been widely utilised, as demonstrated by its inclusion in various studies and publications (e.g., Stacey, 1996; Stacey et al., 2000). Furthermore, this work has proven valuable in the analysis, prediction, and control of complex and unpredictable systems, as shown by its impact on studies like Stewart (2002). Building on the systems-theoretic research outlined in Holland (1995), Choi et al. (2001) introduced a framework for studying supply chains as "complex adaptive systems." Recent works by Surana et al. (2005) and Pathak et al. (2007) have expanded the theory-building work by applying complex adaptive system (CAS) concepts to supply chain management (SCM). One of the books presents analytical frameworks for studying supply chain management and performance improvement using CAS principles. In contrast, the other book offers a comprehensive review of CAS theory development and application in various fields. Before introducing our definition of supply chain

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complexity, which forms the basis for our conceptual model and empirical testing, we first explore several existing definitions.

Complexity Management in the Supply Chain

Mergers and acquisitions, strategic alliances, outsourcing, new technology, product and service launches, geographic and temporal expansion, and third-party integration are all ways in which supply chain organisations stay competitive. Introducing mergers and acquisitions, strategic alliances, outsourcing, new technology, product and service launches, geographic and temporal expansion, and third-party integration to a supply chain makes it more complicated. Globalisation, customisation, outsourcing, innovation, and adaptability are crucial for SCC's expansion. Before addressing SCC, distinguishing between necessary and unnecessary complexity is essential. Research by Frizzelle & Efstathiou (2002), Apostolatos et al. (2004), and Kearney (2004) indicates that although customers and markets are prepared to pay for complexity that provides value, complexity that is not essential increases costs and does not help the organisation or supply chain. To address complexity effectively, it is essential to understand its nature before devising solutions. The majority of literature focuses on complexity reduction and management initiatives. The standard method for dealing with complexity is to control the essential complexity while reducing or eliminating the extraneous complexity. The third approach to coping with complexity over the long run is prevention (Kaluza et al., 2006). In order to circumvent SCC, Towill (1999) proposes a set of twelve guidelines for the efficient transfer of goods and data throughout a supply chain. Childerhouse and Towill (2003) emphasised the need of supply chain integration, synchrony, transparency, and the deployment of powerful decision-support tools in their suggestions.

The following is Wildemann's (2000) ranking of the relative significance of complexity reduction, complexity management, and prevention. Complexity reduction is a short-term approach that aims to standardise, modularize, and eliminate items and processes in order to decrease existing variation. The creation of SCC measurement techniques and processes is the long-term objective of the complexity management strategy, which aims to manage the required complexity. Complexity prevention is an overarching approach that changes the organisational structure and/or supply chain architecture to avoid excessive complexity (Waldemann, 2000). Importing complexity at a cost, exporting complexity to other organisations, devoting resources for absorbing complexity, and exercising care to minimise the rise of complexity are the four policy categories suggested by Sivadasan et al. (2002b; 2004) for addressing operational complexity. In exporting complexity, the intricacy of a corporation is transferred to its suppliers and customers. But it serves no use in addressing SCC and doesn't mesh with the all-encompassing concept of SCM. One may make the case that implementing a fee for imported complexity serves as a safeguard. These two, charging for and exporting, are externally focused, in contrast to the other two, absorbing and avoiding, which are internally focused. According to Sivadasan et al. (2002b; 2004), a company's capacity to handle and prevent complexity is

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determined by its resources, which include inventory, capacity, time, IT systems, and decision-making procedures.

Two approaches to dealing with static complexity are complexity reduction and complexity management, according to Perona and Miragliotta (2004). They take a look at how reducing complexity and managing complexity work hand in hand to make systems run more smoothly. A supply chain or firm is the system being studied and has a basic level of complexity according to the normative complexity model proposed by Perona and Miragliotta (2004). Given the starting complexity, the system uses complexity reduction levers to bring the basic complexity down to a real complexity level. Afterwards, it makes use of complexity management techniques to reduce the effect of real complexity on system efficiency. The additional level of complexity that affects how well a system is seen to work is known as perceived complexity. Researchers found that keeping complexity to a minimum improved both efficiency and efficacy. Using the research of Perona and Miragliotta (2004), we may better grasp the logical relationships between supply chain performance, complexity, managing complexity, and reducing complexity.

PRTM's research shows that supply chain performance improves when complexity management strategies are implemented. The results underscore the vital role of corporate leaders in effectively managing complexity. According to Hoole (2006), crucial abilities include developing goods that simplify planning, procurement, production, and distribution, reducing product offerings, and assessing complexity using metrics. The four process elements of the SCOR (Supply Chain Operations Reference-model)—plan, source, make, and deliver—and the supply chain performance levers—organization, relationships, configuration, management practices, and information systems—form the basis of Hoole's (2004, 2005) complexity reduction matrix. The cells work to reduce complexity by actions such as reducing suppliers, outsourcing, collaborating, and using supply chain management technology and tools. Consistent with the findings of the PRTM research, the A.T. Kearney Report (2004) outlines five reactive measures to handle complexity: standardisation, supplier/customer reduction, elimination of non-value-added processes and activities, information sharing, and accommodation. The first three procedures may be considered attempts at simplifying things, but the latter two procedures are known as complexity management. By following this procedure, you can effectively manage and avoid supply chain complexity. First, wherever feasible, remove or decrease excessive complexity in order to manage the fundamental complexity of the system and avoid introducing further (unnecessary) complexity. Improved performance and happier customers would result from quicker responses, cheaper prices, and better quality brought about by a deeper understanding of the supply chain's intrinsic complexity and the correct measures to manage, reduce, and prevent it. Understanding how current supply chain management (SCM) approaches aid in complexity management is crucial for comprehending business operations. In what follows, we'll take a look at the SCM efforts and see how they may help with SCC.

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Findings

According to Chandra and Kumar (2001), Supply chain integration and coordination can be achieved by synchronizing processes and data. Effective synchronisation enables supply chain players to engage in real-time interactions. It is crucial to have instant communication regarding the impact of any modifications to data, strategies, or processes throughout the supply chain in order to achieve synchronisation. Automating and standardizing processes and data are crucial to achieve supply chain integration and coordination. When operations are automated, participants in the supply chain can communicate with one another more efficiently and effectively. It is crucial for information systems to adhere to established corporate data exchange standards, both within an organisation and when collaborating with supply chain partners, in order to streamline and automate tasks. Data exchange strategies are often included in business process definitions. Data and process standardisation is a crucial aspect of electronic integration, ensuring consistency and efficiency. Supply chain partners must agree on the data exchange protocol, format, structure, and semantics of the business data they share. This is crucial for their computer systems to effectively understand and process the data, supporting efforts towards data standardisation. Standardising processes involves pre-defining and coordinating tasks to enhance data transmission. Consortiums have been established by distributors, manufacturers, and system integrators to develop and standardise e-business protocols. In addition, according to the research conducted by Child et al. (1991) and Wildemann (2000), the practice of standardising various elements such as materials, components, interfaces, packaging, processes, tools, rules, and more is widely recognised as an effective method for simplifying operations.

Visibility is essential for establishing an electronic supply chain. Having the capability to monitor activities and processes in real time across a supply chain allows supply chain participants to offer more accurate estimates and receive timely notifications about any major deviations from plans. In response, the parties may take steps to mitigate the impact of supply chain uncertainty. Enhancements in lead times, delivery reliability, and inventory reductions are driven by the supply chain's ability to track orders, inventory, and shipments (Enslow 2006). To enhance visibility, supply chain partners must make the required technological investments. Now, let's discuss the impact of information sharing on supply chain operations. Studies have shown that using information technology and sharing information can enhance the efficiency of material and information flows in the supply chain (Cachon and Fisher, 2000; Sahin and Robinson, 2002; Zhou and Benton, 2007). In simple terms, sharing information facilitates supply chain activities like integration, coordination, and visibility, leading to easier SCC administration. Modern information technology enables seamless information sharing across a supply chain.

Successfully achieving a fully integrated supply chain with manageable complexity necessitates efficient coordination of information and physical interactions among chain partners. For a well-functioning supply chain, it's crucial to streamline, automate, and harmonise business activities and processes while also achieving complete visibility from start to finish. Implementing robust

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decision systems and removing unnecessary processes are vital parts of successful complexity management programmes.

Conclusion

Studies in the literature have shown that effectively managing complexity can greatly improve the performance of the supply chain, according to various research studies. Many businesses analyse the impact of complexity on supply chain performance and proactively work to mitigate any negative consequences. This study explores three key areas of supply chain complexity management: supply chain enabling technology, supply chain management tools, and fundamental SCM activities. According to this article, supply chain management solutions help companies minimise or even eliminate supply chain complexity. Managing supply chain complexity can be achieved through the implementation of SCM operations, which involve enhancing visibility, standardising procedures, and sharing information. Similar to the role of a financial advisor, supply chain management (SCM) solutions offer a structured approach to managing supply chain processes, optimising decision-making, and reducing unnecessary choices. SCM solutions also encourage the adoption of a common language, which helps to reduce complexity. Supply chain enabling technologies help to minimise uncertainty by providing visibility, utilising advanced forecasting and planning methods, and ensuring accurate predictions. Technologies that streamline supply chains also enable seamless communication throughout the entire chain, eliminating the complexities that arise from interacting with customers and suppliers. The findings also highlight the effectiveness of supply chain enabling technologies when combined with other SCM initiatives, helping businesses effectively navigate the intricacies of their supply chains. Understanding and assessing the relationships between supply chain complexity management initiatives and supply chain management projects can be challenging due to their ambiguous and subjective nature.

The literature review identifies existing gaps in supply chain complexity management that can inform future studies on supply chain complexity management (SCC) management. Understanding the distinction between essential and superfluous complexity is crucial. It is essential to have a common understanding of supply chain terms and practices for clear communication and conflict resolution. A unified framework for assessing and managing complexity would significantly help organizations in effectively managing supply chain complexity (SCC) while balancing internal, external, and interface variations.

To manage complexity effectively, firms need to prioritize clear communication, understand the fundamental system rules, balance internal, interface, and environmental factors, and eliminate non-value-adding tasks. By utilizing these capabilities, businesses can effectively manage supply chain variety by removing non-value-adding activities and maintaining a balanced variety. Businesses can also enhance interactions by promoting communication, understanding cause-and-effect relationships, and establishing a shared language. Additionally, they can tackle

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uncertainty by measuring complexity and comprehending rules and regularities. Lastly, they can navigate dynamism by utilising a framework to understand cause-and-effect relationships, enabling them to effectively address supply chain challenges.

Recommendations

i. In order to maintain synchronisation, real-time data transfers throughout the supply chain should reflect any changes made to plans, procedures, or data. Automation and process and data standardisation are needed to accomplish this.

ii. Supply chain participants can interact with each other more quickly and error-free when operations are automated.

iii. Initiatives for data standardisation have to be made in order to facilitate quicker supply chain communication.

iv. Supply chain enabling technology should be made available so that businesses can manage the complexity of their supply chains and assist other SCM projects.

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