

Risks in Service-Oriented Manufacturing Supply Chains: Current Insights and Implications

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Abstract

This research presents an analysis of the risks associated with the service-oriented manufacturing supply chain based on the contingency theory. It aims to offer a comprehensive overview of the existing information by identifying and categorising diverse hazards into three primary tiers of risk determinants. The present research utilises a generic Risk Breakdown Structure (RBS) as a foundation but focuses on a particular industrial context to examine and validate hazards identified in the existing literature. Leveraging the Fuzzy Delphi-Analytic Hierarchy Process (AHP) technique, information was gathered from 50 local construction specialists, including government representatives, consultants, contractors, and clients. We propose formulating a comprehensive definition for a service-oriented manufacturing supply chain grounded on its fundamental significance within the contemporary economic landscape. Researchers and practitioners can consider a comprehensive list of seven risk categories: demand, supply, operations, information, finance, time (delays), and external sources (human-made or natural-related). These categories provide valuable insights into potential risks associated with various aspects of a given context. This study is one of the first research endeavours to provide the notion and attributes of the service-oriented manufacturing supply chain. The Fuzzy technique is employed to produce comprehensive and industry-specific Resource Breakdown Structures (RBSs) inside a singular investigation.

Keywords : service-oriented manufacturing supply chain, risk identification, systematic literature review, construction industry

I Introduction

In contemporary times, consumers exhibit a preference for targeted resolutions to their predicaments rather than tangible merchandise (Vargo and Lusch, 2008, Quang and Hara, 2019b). Hence, the supply chain has the capacity to provide these inherent benefits via the seamless integration of products, information, and financial flows to consumers. In order to achieve this objective, it is essential for a supply chain to establish a robust service-oriented framework, therefore enabling supply chain management to emerge as a valuable driver of competitive advantage (Flint et al., 2014a, Christopher and Ryals, 2014). The concept of a service-oriented manufacturing supply chain originated from the principles of service-dominant logic. This approach revolves around intangible

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elements such as collaborations, connections, networks, value generation, and value constellations within the supply chain (Vargo and Lusch, 2004a). To date, numerous scholars have posed inquiries pertaining to the service-oriented manufacturing supply chain in order to facilitate the transformation of business models and enhance the allocation of organisational resources. These inquiries encompass determining the current stage of the service-oriented manufacturing supply chain (Wittmann et al., 2014b), devising methods to gauge the level of service orientation, and evaluating its impact on business and supply chain performance (Karpen et al., 2015, Truong Quang and Hara, 2018). However, there is a lack of comprehensive understanding of the processes that drive the service-oriented manufacturing supply chain. This has led to a certain misunderstanding between the service supply chain and the service-oriented manufacturing supply chain.

Moreover, within the realm of international trade, supply chains are now encountering times of unpredictability, heightened levels of outsourcing and offshore endeavours, and advancements in information technology. As a result, the management of service-oriented manufacturing supply chains is becoming more susceptible to disruptions, hence exposing organisations to elevated levels of risk (Pettit et al., 2010, Kovács and Tatham, 2009). According to Quang and Hara (2019b), a contemporary supply chain encounters over 24 distinct sources of risk. Undoubtedly, there is a discernible upward trend in the occurrence of the aforementioned phenomenon during the ongoing COVID-19 pandemic, which may yield substantial and unfavourable repercussions for pursuing sustainable development goals (Craighead et al., 2020). Removing all risks is impossible; nevertheless, we may effectively manage and mitigate them to lessen their impact (Wagner and Bode, 2008). The first stage, out of the three stages of supply chain risk management, involves risk identification (Quang and Hara, 2019a), which serves as the foundational step in examining the risks present within the supply chain and their associated impacts and potential mitigation strategies (Wagner and Bode, 2008).

In their study, Fan and Stevenson (2018) advocated for the implementation of a more suitable method for risk categorisation. They proposed the development of a complete risk framework that incorporates hierarchies and interconnections. Despite the significance of risk identification within the service-oriented manufacturing supply chain, there exists a scarcity of empirical knowledge about the factors that determine these risks and their subsequent effects on supply chain performance. According to Ho et al. (2015), there is a significant focus on studying supply chain-related risks in manufacturing businesses, but the risks associated with service-oriented firms have received significantly less attention.

The primary objective of this research is to provide a clear and comprehensive definition of the service-oriented manufacturing supply chain. This will be achieved by thoroughly examining and analysing the existing knowledge in service science and supply chain theories as documented in relevant academic publications. Furthermore, this study aims to analyse different dimensions of risk within service-oriented manufacturing supply chain networks using contingency theory. Additionally, the data collected from regional construction experts will be validated using the Fuzzy Delphi-Analytic Hierarchy Process (AHP) technique. The subsequent sections of this article are

organised in the following manner. Section 2 of the paper delineates the defining characteristics of a service-oriented manufacturing supply chain. Subsequently, in section 3, contingency theory is applied to discern potential dangers within a generic service-oriented manufacturing supply chain. The Fuzzy Delphi-Analytic Hierarchy Process (AHP) technique is described in section 4, followed by the presentation and discussion of the important results in parts 5 and 6. The concluding portion of the report outlines potential avenues for future research and acknowledges the current study's limitations.

II Service-oriented manufacturing supply chain

In supply chain management, evaluating its competence often revolves around finding a balance between responsiveness and efficiency to gain a competitive advantage.

From a managerial standpoint, there exists a well-established body of knowledge in the field of supply chain management, which places significant emphasis on the role of resources or goods as the central element of a process. However, it is regrettable that this focus has led to an undesirable rise in inventory costs. Furthermore, the field of supply chain theory has made significant progress in its understanding of value, including both physical and intangible aspects (Lusch, 2011).

Technological advancements have empowered consumers with more agency in their purchasing decisions, enabling them to modify various aspects of the sales process or switch between different companies according to their preferences and convenience (Jiang et al., 2020). In order to achieve a cohesive and impactful outcome, there is a preference for a uniform service experience across all communication channels (Tokman and Beitelspacher, 2011, Jiang et al., 2020, He et al., 2021b, Jiang et al., 2021a, Jiang et al., 2021b). Therefore, it is essential for the supply chain to prioritise service in order to effectively compete with other entities (Wittmann et al., 2014a).

Quang and Hara (2019a) argued that there are shared characteristics between supply chain management and service science, suggesting that they may mutually support one other in two important aspects:

- Given that the supply chain serves as a crucial link inside organisations, it is essential to establish a robust foundation in order to effectively meet the expectations of consumers (Vural, 2017).
- Central to the unrelenting success of product/service design innovation (Tokman and Beitelspacher, 2011) and value creation (Maas et al., 2014) is customer feedback, which provides products/services to downstream partners and enables suppliers with real and exact demand information. Value co-creation is a prominent process when myriad parties cooperate to enhance the value of a product (Maas et al., 2014, Flint et al., 2014b, Tokman and Beitelspacher, 2011). In this context, the exchange of information is crucial in facilitating a dual function (Lusch, 2011).

Value co-creation is a suitable approach for the integration of the supply chain, resulting in the development of a novel model known as a service-oriented manufacturing supply chain.

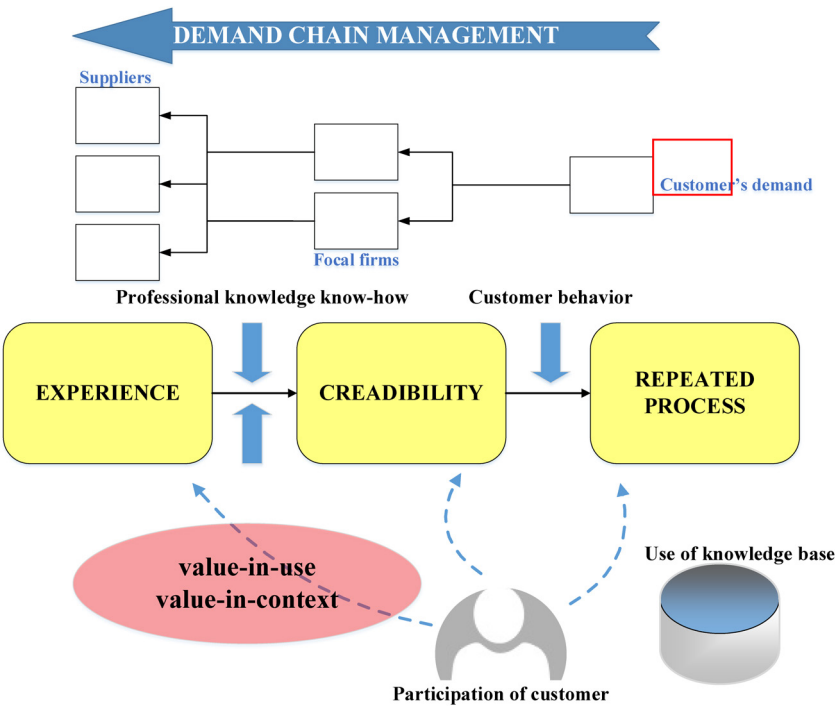


Figure 1 Characteristics of service-oriented manufacturing supply chain
Source: Adapted from the research proposal of the project "An Empirical Study on Services Value Chain based on the Experiential and Credibility Values"

Within the context of the service-oriented manufacturing supply chain, the focal point of attention and significance is the customers, who are given priority and play a crucial role in the process of value generation (Flint et al., 2014b, Vural, 2017). Value creation is not only the responsibility of suppliers; rather, it is achieved via mutually beneficial collaborative interactions between consumers and players throughout the supply chain (Maas et al., 2014, Wittmann et al., 2014a). The consumer plays a vital role within the network as both a value co-creator (Wittmann et al., 2014a) and a facilitator in the supply chain within the value constellation (Maas et al., 2014, Vural, 2017). This enables firms to use their assets and meet buying demands effectively (Tokman and Beitelspacher, 2011). The topic of discussion pertains to service-oriented manufacturing supply chains. The objective is to eradicate functional silos and enhance engagement with external stakeholders in order to create value propositions (Maas et al., 2014). Therefore, this supply chain is regarded as a service ecosystem (Flint et al., 2014b, Lusch, 2011), which includes but is not limited to:

‘A spatial and temporal structure that spontaneously perceives and responds to value is tightly coupled, suggesting economic and social actors interacting through institutions and technologies to copy services, exchange services and co-create value (Lusch, 2011).’

The conventional industrial supply chain has not undergone a significant transformation due to the incorporation of service-oriented practices. This is mostly because essential elements such

as facility design, inventory management, shipping policies, supply operations, and expenditures remain crucial in the overall functioning of the supply chain (Huang et al., 2020b, Jiang et al., 2020, He et al., 2021a, Jiang et al., 2021b). However, they propose and reveal prospective competitive advantages (Truong and Hara, 2018). The conventional supply chain places a strong emphasis on tangible elements such as products, assets, and inventory, whereas the service-oriented approach prioritises intangible aspects to a greater extent (Maas et al., 2014, Wittmann et al., 2014a, Huang et al., 2020a, Jiang et al., 2021b).

In order to provide a comprehensive understanding of the service-oriented manufacturing supply chain, we proceed to delineate its key characteristics and components:

A service-oriented manufacturing supply chain is the beneficial collaborative interaction chain between customers and players in the supply chain, which aims to create a service ecosystem that includes service co-production, exchange service provision and co-creation to propose values that meet the demands of customers.

Upon the first examination, service-oriented manufacturing supply chains prioritise the quantifiable units of output while simultaneously highlighting the significance of the serviceability aspect of those outputs (Huang et al., 2020a, Jiang et al., 2020, He et al., 2021b, Jiang et al., 2021a, Jiang et al., 2021b). The service-oriented manufacturing supply chain prioritises the provision of customised services to consumers (Vural, 2017, Huang et al., 2020a, Jiang et al., 2020, He et al., 2021b, Jiang et al., 2021a), which is of utmost importance (Wittmann et al., 2014a).

III Risks in the service-oriented manufacturing supply chain

The contingency hypothesis posits that there exists a congruence between organisational structures and contingencies, which results in a favourable impact on performance. Therefore, optimal performance is achieved when the structural variable is aligned with the specific contingency (Donaldson, 2001). The risks associated with the supply chain are intricately tied to the specific environment, exhibit variations, and are influenced by the practices used. According to Wagner and Bode (2008), the identification of supply chain risk sources is crucial as they serve as significant contextual factors that might originate both internally and externally to the supply chain. These risk sources impact not only the supply chain itself but also the firms that are involved in the operation of the supply chain network. In line with the findings of Quang and Hara (2019b), it is important for supply networks to align their architecture with the contextual elements, including both physical and social aspects, that influence the overall performance of the supply chain. The authors posited that the determination and categorisation of risks in a suitable manner is contingent upon the risk treatment attitude, which is a crucial aspect that may vary and rely on the supply chain strategy. One often used methodology in the field of supply chain risk management is to delineate the notion of strategy into two distinct components, namely “procedure” and “content.”

Numerous researchers have undertaken an examination of the methodology and/or substance involved in the identification of hazards within the confines of the supply chain (Cagliano et al., 2012). Ho et al. (2015) required that the inclusion of context is crucial in the identification of risks and demands and should be incorporated into the existing framework alongside content and procedures. Therefore, the notion of a "fit" strategy within this framework implies that the effectiveness of a strategy in generating profits or mitigating losses is shown by its alignment with the external and internal dynamics of the supply chain (Amit and Schoemaker, 1993, Porter, 1991, Wernerfelt and Karnani, 1987). Hence, the identification of risks in a service-oriented manufacturing supply chain encompasses both internal and external sources, constituting the first stage of risk assessment (Quang and Hara (2019b). External sources of risk refer to factors originating from the external environment that are outside the control of a supply chain. On the contrary, internal sources of risk provide a greater potential for effective management due to their in direct association with decision-making processes and operational activities inside the supply chain.

1 Internal risks

In the context of a service-oriented manufacturing supply chain, the initiation of the whole chain revolves around customer demand, with the primary objective of surpassing rivals in providing customer requirements. This strategic approach is sometimes referred to as demand chain management (Christopher and Ryals, 2014). Therefore, the first risk category mentioned in this essay is the demand risk. Factors such as demand unpredictability, bankruptcy, and market rivalry might influence the customer's capacity to initiate an order, thereby impacting the design and quantity specifications of the desired product (Manuj and Mentzer, 2008, Buzacott and Mandelbaum, 2008). Hence, companies are unable to effectively anticipate the genuine requirements of consumers and the market, resulting in product shortages or backlogs, influencing operational planning deficiencies, and generating bullwhip effects (Wagner and Bode, 2008, Thun and Hoenig, 2011). The presence of demand risks has the potential to escalate production costs and disrupt the effectiveness of random inventory systems. The worldwide supply chains have been significantly impacted by the COVID-19 pandemic. The rapid transmission of the virus and the accompanying stringent measures implemented by the government resulted in notable variations in demand for supply chain management (Arora and Grey, 2020), resulting in alterations to consumer behaviour, e.g. a notable rise in the preference for online shopping and home services (Ratten, 2020), exacerbating the problem to an unprecedented extent.

After estimating consumer wants, supply chain efforts are focused on the manufacturing and distribution processes to fulfil these requests. This entails aligning value-creating activities with the flow of products. The first stage of this workflow encompasses the input phase of the manufacturing process, whereby the functions of suppliers are emphasised. In this context, the supply chain encounters several supplier-related risks, such as supplier insolvency, price volatility, and instability in the quality and quantity of inputs, among others (Thun and Hoenig, 2011, Wagner and Bode, 2008, Manuj and Mentzer, 2008). This risk may result in disruptions in subsequent phases of

the service-oriented manufacturing supply chain, including the planning phase aimed at meeting customer demand in terms of quantity and quality. These disruptions may incur extra costs and time or perhaps endanger the customer and compromise their safety (Manuj and Mentzer, 2008). In essence, the aforementioned phenomenon may be described as a cascading sequence of events that originates at an earlier stage and subsequently impacts the whole of the downstream service-oriented manufacturing supply chain. During the global pandemic, firms had significant challenges in maintaining their operations and managing the escalating costs of various commodities, including medical and protective items, raw materials, and equipment. These disruptions in supply chains resulted in rapid and severe disruptions, necessitating enterprises to adapt swiftly to the changing circumstances. The ongoing pandemic has had a substantial influence on global trade, particularly in relation to crowded ports and the resulting container transportation challenges. Consequently, this has caused a scarcity of supplies for the downstream segment of the supply chain (Sharma et al., 2020).

The subsequent phase of the product flow entails the execution of operations inside the focus firm. The internal capacity of an organisation to generate products and services, as well as the quality, timeliness, and profitability of its production, may be significantly impacted by risks arising from unfavourable events. These risks include several factors, including alterations in design and technology, occurrences of accidents, and instances of labour conflicts (Truong and Hara, 2018, Manuj and Mentzer, 2008). Hence, organisations are unable to ascertain the most efficient order amounts, manufacturing volumes, safety stock levels, and other inventory rules that have a substantial impact on the functioning of supply chain activities. The operational operations in industrial facilities are significantly affected by the scarcity of manpower, restricted working hours, and the need to maintain physical distance. These impacts are exacerbated during the pandemic as a result of the social distancing regulations in place (Ratten, 2020).

The alignment of information throughout the service-oriented manufacturing supply chain is crucial for effectively coordinating and optimising the overall profitability of the supply chain. According to the findings of Kreye and van Donk (2021), it has been shown that information plays a crucial role as the binding agent that facilitates the integration of physical and financial movements within the supply chain. In the context of a service-oriented manufacturing supply chain, the exchange of information between consumers and other stakeholders within the chain serves to enhance enterprises' comprehension of customer expectations, align operational strategies, and bolster the overall responsiveness and adaptability of the supply chain (Truong Quang and Hara, 2018, Dominguez et al., 2021, Li et al., 2017). Failures to communicate within the project team and the intricate nature of the information infrastructure can give rise to significant issues. These issues may include excessive investment in inventory, subpar customer service, revenue loss, inaccurate capacity planning, ineffective shipping, and failure to meet production schedules (Chopra and Sodhi, 2012, Manuj and Mentzer, 2008). During the height of the Covid-19 pandemic, there was a distortion of information, resulting in alterations in consumer behaviour. These changes included heightened levels of stockpiling, excessive demand, and panic purchasing, all of which had

significant implications on supply chain capabilities (Ranjit et al., 2021, Ratten, 2020).

The field of finance plays a pivotal role in facilitating and supporting the many operations within the supply network. Therefore, the potential hazards associated with financial flows, such as inflation, interest rates, and currency fluctuations, can diminish the supply chain's advantages (Manuj and Mentzer, 2008). These risks may lead to price variations in supply operations, labour conflicts, demand shifts, and supply chain interruptions (Truong Quang and Hara, 2018). An illustrative instance is the impact of a significant inflation rate on prices, resulting in consumer dissatisfaction and the attribution of responsibility to producers for the escalation of selling prices. Consequently, this phenomenon induces a change in demand dynamics (Eyster et al., 2014). Companies use a strategy of mitigating price rises by establishing long-term contractual agreements with suppliers to stabilise the costs of commodities and so transfer the financial burden to the suppliers. Inflation is a hindrance to planning efforts (Melo et al., 1996) since it engenders uncertainty among organisations about cost implications. Also, as an inevitable outcome of the elevated inflation rate, workers seeking increased remuneration from their employers have a likelihood of giving rise to labour conflicts. Concerning interest rates, How et al. (2005) argued that financial institutions employ higher interest rates on business loans, resulting in a reduction in customers' purchasing power for goods and services, thereby increasing the risk of demand. In addition, the variability of exchange rates has a crucial shape in both output and price growth, particularly for multinational companies and foreign counterparts (Kandil and Mirzaie, 2005). The financial implications of pandemic avoidance measures, such as lockdowns and social distancing, have impacted the supply chain's financial aspects. This eventually gave rise to a shift in consumer preferences as individuals faced constraints on their financial power (Craighead et al., 2020, Ratten, 2020).

The utmost dynamic risk pertains to time risk, explicitly encompassing potential postponements in supply chain activities. The inability to meet predetermined intervals can expand to multiple risks associated with operational activities and demand fluctuations and eventually influence the performance of the supply chain. As stated by Manavazhi and Adhikari (2002), the presence of postpones in the process of purchasing materials and equipment is predominantly responsible for cost-escalated tensions, resulting in an extra 0.5 % of the overall project budget. Sambasivan and Soon (2007) also argued that the presence of time-based risks in projects can contribute to dissatisfaction among all stakeholders. Notably, a potential consequence of information delays is a disruption of communication among project team members and within the supply chain, while tardiness in the delivery of products has the potential to result in the partner's insolvency. Truong Quang and Hara (2018) determined that the primary cause of disputes is the delay in payment. For example, the Covid-19 pandemic has resulted in significant delays due to the implementation of lockdown measures.

2 External risk

The supply chain is prone to various external risks that may profoundly influence its operations. These risks encompass natural disasters such as earthquakes and tsunamis, armed conflict

and terrorism, fire accidents, legal issues, financial and political unrest, socio-cultural tensions, and epidemics. These risks have been extensively investigated by researchers and highlighted their comprehensive impact on all activities within the supply chain network (Truong Quang and Hara, 2018, Thun and Hoenig, 2011, Manuj and Mentzer, 2008, Fan et al., 2017, Li et al., 2017). The COVID-19 pandemic has garnered considerable scholarly and practical concern as a severe global crisis. It has culminated in a substantial economic shock, leading to negative per capita GDP growth in more than 200 countries (Craighead et al., 2020). Moreover, the enactment of non-pharmaceutical interventions, such as social distancing measures and nationwide lockdowns, has had an unfavourable effect on business operations and financial distress, particularly within the service industry (Ratten (2020).

Therefore, a comprehensive representation of a generic Risk Breakdown Structure (RBS) can be found in Table 1, illustrating three distinct levels of prevailing factors influencing risks for a service-oriented manufacturing supply chain.

Table 1 Risk Breakdown Structure frame for service-oriented manufacturing supply chain risks

Level 1	Level 2	Level 3	Authors
Internal	Demand	• Customer reliance • Customer reliance • Elevated demand for services • Inadequate or absent customer relationship management mechanism • Customer insolvency • Order fulfillment flaws	(Craighead et al., 2020, Buzacott and Mandelbaum, 2008, Thun and Hoenig, 2011, Christopher and Ryals, 2014, Manuj and Mentzer, 2008, Wagner and Bode, 2008, Ratten, 2020)
	Supply	• Supplier expediency and dependency • Supplier responsiveness • Failure to offer competitive pricing • Supply shortages • Price volatility • Port capacity and congestion • Rigidity of suppliers • Single sourcing for crucial and prolonged cycle time items • Supplier's inability to provide drawings, datasheets, etc. • Abrupt supplier default • Incapacity to manage fluctuations in volume demand • Insurance concerns • Deficient quality over requirements • Carriers' fragmentation	(Sharma et al., 2020, Thun and Hoenig, 2011, Manuj and Mentzer, 2008, Wagner and Bode, 2008, Ratten, 2020)

Table 1 Continued

Level 1	Level 2	Level 3	Authors
Internal	Supply	• Damages during shipping • Transportation accidents • Transportation breakdowns • Port strikes • Custom clearance at ports • Elevated transportation costs • Storage constraints • Poorly designed transportation network • Inaccurate transportation mode choice • Incorrect packaging and labeling	
	Operations	• Operator absenteeism • Labour disputes/strikes • Employee accidents • Job dissatisfaction • Insufficient experience or training • Working conditions • Improper packaging and labelling • Production capabilities/capacity • Products quality and safety • Shorter lifetime products • Lack of maintenance • Process inconsistency • Production cycle time inconsistency • Improper warehousing handling/maintenance • Operational issues • Ambiguous inspection and acceptance procedures • Frequent product recalls • Inflexibility in layout for free flow of materials • Product obsolescence	(Kate, 2013, Manuj and Mentzer, 2008, Truong and Hara, 2018, Ratten, 2020)
	Information	• Disruption in information infrastructure • Comprehensive system integration or network connectivity • E-commerce • Internet insecurity	(Dominguez et al., 2021, Li et al., 2017, Kreye and van Donk, 2021, Truong Quang and Hara, 2018, Manuj and Mentzer, 2008, Ranjit et al., 2021, Chopra and Sodhi, 2012, Ratten, 2020)

Table 1 Continued

Level 1	Level 2	Level 3	Authors
Internal	Information	• Bullwhip effect or distorted information • Inappropriate selection communication/information sharing medium • Internal communication breakdown	(Eyster et al., 2014, Craighead et al., 2020, Truong Quang and Hara, 2018, Manuj and Mentzer, 2008, Kandil and Mirzaie, 2005, How et al., 2005, Ratten, 2020, Melo et al., 1996)
	Finance	• Exchange rate • Currency fluctuations • Interest rate • Wage rate variations • Customers purchasing power • Inflation • Stakeholders' engagement (request late changes, new stakeholders, etc.) • Credit risk	
External	Human	• External political constraints • Economic and political uncertainty • Social and cultural grievances • Conflicts & terrorism • Fire accidents	(Craighead et al., 2020, Fan et al., 2017, Li et al., 2017, Thun and Hoenig, 2011, Truong Quang and Hara, 2018, Manuj and Mentzer, 2008, Ratten, 2020)
	Natural	• Earthquakes • Tsunami • Flood • Hurricane • Epidemics	

IV Methodology

Given the existing discrepancies in the literature regarding supply chain risk management, we have followed the suggestions put forth by Akkermans et al. (2003) and sought the expertise of professionals in the field to gain valuable insights into the process of detecting risks in a service-oriented manufacturing supply chain. Regarding the experimental nature of this investigation, we implemented the mixed fuzzy Delphi-Analytic Hierarchy Process (AHP) approach, which has gained popularity in exploratory and theoretical research within the field of supply chain management in the last few decades (Le and Nguyen, 2023b). Precisely, the integration of fuzzy set theory into the Delphi-AHP method is advised due to its ability to address the limitations of the conventional approach in effectively managing the inherent uncertainty associated with human judgements (Le and Nguyen, 2023b, Bisht et al., 2022a, Kumar et al., 2019).

1 Questionnaire Development

A comprehensive review of existing literature was conducted, and insights were gathered from a pilot panel of experts in order to construct the questionnaire. A total of 77 significant items, derived from internal and external sources, are shown in Figure 6.

2 Data collection

Conforming with the study undertaken by Akkermans et al. (2003), our objective was to involve a minimum of 20 participants with expertise in the field. This approach was adopted to mitigate potential individual biases that could potentially distort the outcomes of our research. Established upon preceding studies (Simmons et al., 2020, Shadid, 2018, Akkermans et al., 2003), our study specifically concentrated on the engagement of construction professionals who possess expertise in the field. The primary objective of our research was to assess the practical implications of our findings to provide valuable insights for policymakers and practitioners operating within the construction industry.

Subsequently, the participant experts were queried concerning their perspective on the appropriate inclusion threshold for subsequent analyses, wherein items deemed to be of importance above this threshold would be included. Specifically, they were requested to vote on whether this threshold should be set at a minimum of 5 on a five-point scale ranging from 1 (indicating insignificance) to 9 (indicating utmost significance). It was found that a unanimous consensus was reached among all participants, as they concurred with the concept of setting the inclusion threshold at a minimum of 5. Then, each specialist gave anonymous assessments regarding each item's significance.

With raw expert opinions, we calculated the interquartile range, i.e., the difference between the first quartile (25th percentile) and the third quartile (75th percentile), and the coefficient of variation, i.e., the standard deviation divided by the sample mean. According to the review of von der Gracht (2012), consensus is attained when the interquartile range (IQR) does not exceed 1 unit on a 5-unit scale and the coefficient of variation is less than 0.5 (or 50%).

In the following round, it is requisite to conduct a follow-up survey for items that exhibit an interquartile range (IQR) or coefficient of variation that surpasses the aforementioned thresholds. Based on the aggregate mean values for each item, it is uncertain whether the participants will alter their initial opinions. Following two iterations, it was observed that all the items successfully fulfilled the consensus criteria.

Among the initial set of 55 experts, a mere five individuals could not participate in the subsequent round.

The data that was gathered was subsequently examined using the fuzzy Delphi-AHP methodology, which will be further explained in the subsequent subsection, to pinpoint the key factors and their corresponding weights of importance. Afterwards, the analysis findings were displayed to the experts to gather their feedback and ascertain their endorsement.

Table 2 concisely summarises the participants' experience and professional positions.

Table 2 Overview of participant experts' backgrounds and their construction companies

Position	Percentage	Department	Percentage		
(Deputy/vice) director	15	30.00%	Board of directors	13	26.00%
Head of department	9	18.00%	Project management	17	34.00%
(Deputy/vice) head of department	2	4.00%	Design	13	26.00%
Specialist	24	48.00%	Others	7	14.00%
Total	50	100.00%	Total	50	100.00%

Entity type	Percentage	Number of employees	Percentage		
100% private-owned	23	46.00%	<50	39	78.00%
100% state-owned	27	54.00%	50–200	9	18.00%
Total	50	100.00%	201–500	1	2.00%
			>500	1	2.00%
			Total	50	100.00%

Years experience	Percentage	Operation scope*	Percentage		
5–10 years	14	28.00%	Design	19	38.00%
10–20 years	20	40.00%	Construction execution	5	10.00%
From 20–30 years	13	26.00%	Project management	18	36.00%
30–40 years	1	2.00%	Land-use planning	1	2.00%
Over 40 years	2	4.00%	Investment and others	7	14.00%
Total	50	100.00%	Total	50	100.00%

* A firm can operate in more than one field.

3 Data analysis process

In the beginning, the expert opinions regarding the items preserved from the previous Delphi round were subjected to fuzzification as in Table 3 below:

Table 3 Fuzzy triangular numbers of each importance level

Linguistic expressions	Fuzzy number (l, m, u)
9: Absolutely important	(9, 9, 9)
7: Strongly important	(6, 7, 8)
5: Fairly important	(4, 5, 6)
3: Weakly important	(2, 3, 4)
1: Unimportant	(1, 1, 1)

(Adapted from Hatefi & Tamošaitienė, 2018; Wind & Saaty, 1980; Zhang et al., 2023)

Following Bisht et al. (2022b), the fuzzified significance of item i is aggregated as follows:

$$l_i = \sqrt[J]{\prod_{j=1}^J l_{ij}}, \quad m_i = \sqrt[J]{\prod_{j=1}^J m_{ij}}, \quad u_i = \sqrt[J]{\prod_{j=1}^J u_{ij}},$$

where (l_{ij}, m_{ij}, u_{ij}) indicates the fuzzified opinion of expert j on item i .

The process of defuzzification involves aggregating the fuzzified importance of item i and subse-

quently converting it into a crisp value:

$$\lambda_i = \frac{l_i + m_i + u_i}{3}$$

In accordance with the agreed-upon inclusion threshold among the participant experts, if $\lambda_i < 5$ (fairly important), then item i is excluded from subsequent analyses.

Given the items retained from the previous step, a fuzzy pairwise matrix of relative importance $\tilde{M}_{(n \times n)}$ was constructed as follows:

In matrix $\tilde{M}$, $\tilde{M}_{xy}$ indicates the relative importance of item x over item y .

$$\tilde{M}_{xy} = \left(\frac{l_x}{u_y}, \frac{m_x}{m_y}, \frac{u_x}{l_y} \right),$$

where (l_x, m_x, u_x) and (l_y, m_y, u_y) indicate the aggregation of the fuzzified importance of item x and item y , respectively.

Aligning with prior research (Singh et al., 2018, Le and Nguyen, 2023a, Geng et al., 2022), our fuzzy AHP to determine the importance and weight of each item was undertaken as follows:

Step 1: Computing $\tilde{S}_x = (S_{xl}, S_{xm}, S_{xu})$ value for each row x of the matrix by:

$$\tilde{S}_x = \sum_{y=1}^n M_{xy} \times \left[\sum_{x=1}^n \sum_{y=1}^n M_{xy} \right]^{-1} \quad \forall x = 1, 2, \dots, n$$

Step 2. Determining the degree of possibility of $\tilde{S}_x \geq \tilde{S}_y$ and $x \neq y$. Given $\tilde{S}_x = (S_{xl}, S_{xm}, S_{xu})$ and $\tilde{S}_y = (S_{yl}, S_{ym}, S_{yu})$, then:

$$\left[\begin{array}{l} V(\tilde{S}_x \geq \tilde{S}_y) = 1, \quad \text{if } S_{xm} \geq S_{ym} \\ V(\tilde{S}_x \geq \tilde{S}_y) = 0, \quad \text{if } S_{xu} \leq S_{yl} \\ \left\{ \begin{array}{l} V(\tilde{S}_x \geq \tilde{S}_y) = hgt(S_x \cap S_y), \text{ otherwise} \\ hgt(\tilde{S}_x \cap \tilde{S}_y) = \frac{S_{xu} - S_{yl}}{(S_{xu} - S_{yl}) + (S_{ym} - S_{xm})} \end{array} \right. \end{array} \right.$$

Step 3. Calculating the weight of each item:

$$W'(x) = \min_{y \neq x} \{ V(\tilde{S}_x \geq \tilde{S}_y) \}$$

$$W' = [W'(1), W'(2), \dots, W'(n)]$$

Step 4. Obtaining the normalized weight vector by applying:

$$W_x = \frac{W'(x)}{\sum_{y=1}^n W'(y)}$$

Upon completion of the four steps aforementioned, the consistency ratio $CR = CI/RI$ was used to evaluate the consistency of our fuzzy AHP result. While the random index (RI) can be found in Donegan and Dodd (1991), the consistency index (CI) can be calculated as follows:

$$\left\{ \begin{array}{l} \Gamma = MW, \\ \gamma = \Gamma \odot \left(\frac{1}{\bar{W}} \right), \\ CI = \frac{\bar{\gamma} - n}{n - 1}, \end{array} \right.$$

where W is the weight vector taken from step 4.4 while M is the de-fuzzified matrix of $\tilde{M}$ and $\odot$ is the elementwise multiplication.

Once the CR surpasses the threshold of 0.100, it becomes necessary to initiate a repetition of the entire process due to the absence of sufficient consistency among the assessments among the participants. The fuzzy Analytic Hierarchy Process (AHP) results demonstrated consistency among the evaluations our group of expert respondents provided, as indicated by a consistency ratio (CR) of 0.026, below the threshold of 0.100.

The aforementioned findings were presented to the participants who possessed expertise in the relevant fields to ascertain the attainment of a comprehensive consensus.

V Key Findings

Our study used combined fuzzy Delphi-AHP to identify the sources of risks found in the construction-service supply chains, which are presented and summarised in Table 4.

The table shows the hierarchy of risks according to their perceived importance in the opinions of experts, which were elicited from both a questionnaire and a decision-making task through the application of the fuzzy Delphi-Analytic Hierarchy Process (AHP) methodology. There are seven major categories of risk sources, which are external, financial, information, time, supply, demand, and operational risks.

The risk that was identified as the most impactful is 'Natural Catastrophes' (0.938). Examples of this risk include events such as natural disasters, which can leave devastating impacts on the operation of supply chains. Following natural catastrophes is the related category of 'Epidemics' (0.879). The fact that these two risks occupy the top spots of importance shows how the recent COVID-19 pandemic might have shifted expert concerns to phenomena that may have extensive impacts on not only the supply chain but also society as a whole.

The third and fourth ranks belong to "Currency Fluctuations" and "Information Infrastructure Breakdown", with average importance scores of 0.845 and 0.840, respectively. These show that the experts placed much emphasis on the stable performance of financial environments and information technology systems as contributors to a responsive and efficient supply chain.

Risks related to the time and information categories, such as "Delays in Distribution Activities", "External Legal Issues", and "Communication Breakdown", come next, which shows concerns for timely distribution, legal compliance, and effective communication as ways of preventing supply chain disruptions.

Next come the issues related to suppliers and customers, the bankruptcy of whom are risk factors that occupy the eighth and ninth positions, respectively. This shows the experts' awareness of the reliance of a supply chain on the stable performance of its partners. These were followed by "Customer Fragmentation", which also emphasises how market dynamics can influence demand continuity.

Various other factors were also mentioned, such as "Delayed Payment", "Distorted Information",

Table 4 Combined fuzzy Delphi-AHP results for the risk sources in construction service-oriented manufacturing supply chain

Risk source	Type of risk	Average importance	Importance weight	Rank
Natural catastrophes	External risk	0.938	0.044	1
Epidemics	External risk	0.879	0.042	2
Currency fluctuations	Financial risk	0.845	0.040	3
Information infrastructure breakdown	Information risk	0.84	0.040	4
Delays in distribution activities	Time risk	0.801	0.038	5
External legal issues	External risk	0.799	0.038	6
Communication breakdown	Information risk	0.796	0.038	7
Supplier bankruptcy	Supply risk	0.794	0.038	8
Customer bankruptcy	Demand risk	0.792	0.038	9
Customer fragmentation	Demand risk	0.785	0.037	10
Delayed payment	Time risk	0.771	0.037	11
Distorted information	Information risk	0.77	0.036	12
Delays in supply activities	Time risk	0.761	0.036	13
Interest rate level	Financial risk	0.753	0.036	14
Design changes	Operational risk	0.752	0.036	15
Price fluctuations	Supply risk	0.741	0.035	16
Inflation	Financial risk	0.738	0.035	17
Delays in operations activities	Time risk	0.733	0.035	18
Information delays	Time risk	0.731	0.035	19
Technological changes	Operational risk	0.73	0.035	20
Economic downturns	External risk	0.73	0.035	21
Political instability	External risk	0.72	0.034	22
Accidents	Operational risk	0.715	0.034	23
Unstable quantity of inputs	Supply risk	0.69	0.033	24
Demand variability	Demand risk	0.653	0.031	25
Labour disputes	Operational risk	0.636	0.030	26
Unstable quality of inputs	Supply risk	0.618	0.029	27
High competition in the market	Demand risk	0.588	0.028	28

“Design Changes”, “Technological Changes”, “Accidents”, “Labour Disputes”, “and “Unstable Quality of Inputs”, which are all factors that can disrupt the supply chain. In voicing concerns over these risks, the experts implicitly agree that adaptability, process stability, and quality assurance are important safeguards.

Finally, being lower ranked than all the above-mentioned risks in perceived importance, “High Competition in the Market” nonetheless still highlights how market dynamics and competitive pressure, all belonging to the demand category, might exert a certain influence on the healthy performance of the supply chain.

VI Discussion

Using the Fuzzy Delphi-Analytic Hierarchy Process (AHP), this study has analysed the elicited opinions of 50 regional construction experts in Vietnam in order to provide a better illustration of the characteristics of the service-oriented manufacturing supply chain and the risks that it is most vulnerable to. These risks are identified and related to the contingency theory and the RBS theory, which represent the forefront of the current knowledge on risk and their categorisation. One notable aspect of the innovation of this study is its usage of an updated model of the service-oriented manufacturing supply chain. According to this model, value is not created solely from the providers but also at other pre-sales and post-sales junctions of the customer service experience, creating a constellation of “in-use” and “in-context” values that are created by all participants in the supply chain. Although this model has been well-developed in the marketing discipline since 2004, researchers have yet to pay critical attention to it, as seen through the limited number of relevant papers (Vargo and Lusch, 2004b). This paper also seeks to provide an exemplary case study of the usage of this model and asks that future research in Operations and Supply Chain Management utilises it more, considering its novel emphasis on value creation and customer satisfaction.

Another point of innovation of this study lies in its categorisation of risk sources. Recent studies often only focus on one type of risk, or they provide categorisation schemes that lack specificity, e.g. not showing exactly what risks belong to a category (e.g., Matook et al. (2009). Furthermore, Fan and Stevenson (2018) highlight how researchers have only stopped considering the two steps of risk identification (listing and categorising) without venturing to discover the relationships between the categories. One exception is Truong Quang and Hara (2018), who put risks into five critical categories, which are demand, supply, operation, information, and finance. Our findings confirm theirs and, in addition, also identify two new sources of risk, time risk and external risk, which are related to human society (economic, legal, political) and nature (disasters and epidemics).

The motivation behind introducing these new risk factors comes from the delays, information distortion, and other disruptions observed during the COVID-19 pandemic. This introduction is apt as the results show that not only are these new risks but they are also perceived to be of the utmost priority according to the experts questioned. For example, the panic generated by the pandemic caused widespread misinformation, which resulted in collective stockpiling, shocking the supply and disarranging production plans and schedules (Ratten, 2020). Measures such as lockdowns and social distancing also affect the financial circumstances of businesses and customers, leading to halted demand due to decreased buying power (Ratten, 2020). Businesses also cut costs to mitigate their losses, which further impact the operation of the supply chain, reducing business efficiency and customer order fulfilment (Ratten, 2020). It is suggested that the government should develop a reliable information channel and inject cashflows to help businesses survive the pandemic.

Our findings also demonstrate that risks for the service-oriented manufacturing supply chain tend to be more complex, originating from a spontaneous mixture of internal and external factors. If not identified correctly, firms may introduce solutions that are ineffective (Cagliano et al., 2012).

The COVID-19 pandemic is a good example of how devastating the effects of these external risks can be on all aspects of business (Craighead et al., 2020, Ratten, 2020), which in turn disrupt the performance of supply chains worldwide. This damage is also augmented by a globalised market, which gives room for disruptions from one end to cascade to other ends.

Regarding the research methods, we have used a combination of the contingency theory and the Fuzzy Delphi-Analytic Hierarchy Process (AHP) methodology in order to develop a comprehensive and adaptable RBS that can be effectively utilised across many industries. Prior studies have mostly concentrated on more intricate methods of risk identification, such as the analytical hierarchy process (AHP) (Gaudenzi and Borghesi, 2006) and the value-focused process engineering methodology (Neiger et al., 2009). In contrast, Fan and Stevenson (2018) put forward the assertion that professionals in the field exhibit a preference for straightforward and well-established methodologies, such as the Ishikawa diagram, value stream mapping, and the cause-effect diagram (Chen et al., 2011). Hence, professionals and scholars may find this comprehensive justification relevant for effectively addressing risk management in the service-oriented manufacturing supply chain.

This study further establishes the groundwork for future investigations pertaining to risk management within service-oriented manufacturing supply chains. According to scholarly sources (e.g., Giannakis and Papadopoulos (2016), Majumdar et al. (2021)), it has been determined that a comprehensive risk management process consists of four distinct phases: risk identification, risk assessment, risk mitigation, and risk monitoring. Hence, our work posits additional avenues for future research pertaining to the evaluation, alleviation, and surveillance of risks.

In relation to the evaluation of risk, Xu et al. (2019) argued that there is currently a deficiency in a comprehensive framework that allows for a quantitative assessment of risk within service-oriented manufacturing supply chains while also considering the triple bottom line. The viewpoint expressed aligns with the findings of Marandi Alamdari et al. (2023), who assert that the adoption of green supply chain strategies promotes sustainability and environmental friendliness. However, there has been a limited amount of research conducted on the evaluation of hazards associated with green service-oriented manufacturing supply chains. Within the existing body of literature, researchers have employed various methodologies to evaluate the sustainability risk of supply chains across multiple industries, such as the integrated fuzzy TOPSIS-CRITIC approach (Rostamzadeh et al., 2018), fuzzy step-wise weight assessment ratio analysis (SWARA) and fuzzy complex proportional assessment of alternatives (COPRAS) (Ansari et al., 2020), best-worst method (Tavakoli Haji Abadi and Avakh Darestani, 2023), backpropagation neural networks (Jianying et al., 2021), dynamic Bayesian network (Sajid, 2021), fuzzy-weighted aggregated sum product assessment (F-WASPAS) method (Tavakoli Haji Abadi and Avakh Darestani, 2023), fuzzy analytical hierarchy process (FAHP) (Raihan et al., 2022), and failure mode and effect analysis (FMEA) (Sutrisno and Kumar, 2022). As previously stated, there is a dearth of studies on the evaluation of sustainability risks within service-oriented manufacturing supply chains. Subsequent investigations may use the aforementioned methodologies to appraise such risks.

Concerning mitigating and monitoring risks, Elmsalmi et al. (2021) affirmed a substantial body

of research focusing on supply chain risk management. However, their efforts do not extend beyond the step of risk assessment. One plausible explanation for this matter is the presence of several risk categories and intricate interdependencies among them, including disputes and divergent goals among the stakeholders engaged in the SC. According to Faisal et al. (2006), the primary factors that contribute to contributing to risk mitigation in this particular context are collaborative relationships and trust, along with exchanging information about risks among partners. Additional research (e.g., Chen et al. (2013), Yoon et al. (2018)) organisations might mitigate the effects of SC risks by engaging in collaborations across three key dimensions: supplier, internal, and customer collaborations. Researchers have employed various methods to mitigate and monitor risks in SCs. Examples include the integrated fuzzy TOPSIS-CRITIC approach (Rostamzadeh et al., 2018), the novel pathogenic TOPSIS-CRITIC model (Abdel-Basset and Mohamed, 2020), modelling sustainable risk mitigation strategies using a morphological analysis-based approach (Elmsalmi et al., 2021), mitigating SC risk by deploying resilience capabilities and resilience-enhancing features (Hsu et al., 2021), best-worst method (Kusi-Sarpong et al., 2021). This study proposes the development and validation of service-oriented risks. It further advises that future research should use the aforementioned methodologies to address and monitor risks that arise within the service-oriented manufacturing supply chain processes.

Numerous research studies have been conducted in the past to investigate the influence of SC risk on performance, such as Chen et al. (2013), Mishra et al. (2016), Nyamah et al. (2017), Wang (2018), Chen (2018), Quang and Hara (2019b), and Ali et al. (2023). However, within the realm of service-oriented manufacturing supply chains, there is a limited body of research a limited body of research sustainability risk on both performance outcomes and the adoption of sustainable practices. An example of a study conducted by Syed et al. (2019) focused on investigating the correlations among sustainability risks, SC integration, and the financial performance of firms. Furthermore, the study conducted by Chowdhury and Quaddus (2021) examined the potential impacts of supply chain sustainability on performance via the mitigation of sustainability risks, considering different degrees of sustainability governance. In their study, Vu et al. (2023) employed a sample of 254 garment companies to construct a comprehensive measurement scale for assessing supply chain sustainability risk. Additionally, they examined the efficacy of dynamic supply chain management techniques in minimising the influence of sustainability-related risks on various characteristics of firm performance. Despite the extensive research conducted on the subject, the available data pertaining to the impact of sustainable risk on performance in service-oriented industrial supply chains remains insufficient. Hence, future investigations may use the risk constructs utilised in our study to analyse the impact of sustainability risk on the performance of service-oriented manufacturing supply chains.

VII Concluding Remark

The present investigation has significant significance for scholars. This study is the first known

research endeavour to introduce the notion of the service-oriented manufacturing supply chain via the use of the Fuzzy Delphi-Analytic Hierarchy Process (AHP) methodology. The aim of this study is to develop comprehensive and industry-specific Resource Breakdown Structures (RBSs) within a single investigation. Based on the existing literature, it is thus recommended that more research be conducted to address the existing knowledge gaps pertaining to service-oriented manufacturing supply chains and the associated hazards, which are currently not well understood. This particular domain presents itself as a promising avenue for future research endeavours.

In addition to the theoretical implications for academics, it is advisable to consider many management consequences for enterprises. This study stands out as an early endeavour to comprehensively develop a universal Risk Breakdown Structure (RBS) applicable to many industries. Its purpose is to serve as a valuable resource for practitioners, aiding them in identifying potential risk sources. Furthermore, our empirical study highlights a sector-specific risk management strategy that may be beneficial for managers operating in the construction industry while navigating the challenges of doing business, particularly in times of turbulence.

Nevertheless, the research exhibits three inherent constraints. Despite the meticulousness of the empirical study, it is possible that unintentional mistakes may have been present in our analysis. Furthermore, it is essential to consider that the construction sector in a poor nation may lack efficiency when attempting to generalise the conclusions of this research.

Despite these limitations, the work proposes some intriguing directions for further research. The process of risk assessment involves many phases, with risk identification serving as the first phase. However, further steps in the process need more research and analysis. This study aims to generate interest and encourage further investigation into risk assessments within service-oriented manufacturing supply chains. Additionally, it is important to include different sectors in order to thoroughly investigate and develop industry-specific Risk Breakdown Structures (RBS). Ultimately, it is necessary to quantify the dynamic connection of the risks that have been discovered in order to establish a more complete risk structure that incorporates hierarchies and interactions.

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