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Article *in* The International Journal of Industrial Engineering: Theory, Applications and Practice · October 2021

DOI: 10.23055/ijietap.2021.28.1.5605

2 authors:

Saliha Karadayi-Usta
Istinye University

Seyda SerdarAsan
Istanbul Technical University

International Journal of Industrial Engineering, 28(1), 52-74, 2021

DEFINING AND MODELING RISKS IN SERVICE SUPPLY CHAINS

Saliha Karadayi-Usta[1] and Seyda SerdarAsan[2,*]

[1]Department of Industrial Engineering
Fenerbahçe University
Istanbul, Turkey

[2]Department of Industrial Engineering
Istanbul Technical University
Istanbul, Turkey
[*]Corresponding author's e-mail: serdars@itu.edu.tr

Risk management in supply chains is of growing importance and has been studied extensively in manufacturing supply chains. However, risk in service supply chains (SSCs) is largely neglected. Since SSCs are not immune to disruptions, there is a need to study and understand supply chain risks from a service perspective. This paper sets out to identify, define and examine risks in SSCs. Using a systematic literature review, the paper explicitly defines seven risk types associated with SSCs: financial, relationship, demand, operational, service delivery, Information technology (IT), and external risks. To gain a deeper understanding of these risks and their consequences, a structural model of the relationships among them was developed using ISM and MICMAC. This study helps us to identify and understand all the risks that need to be assessed in SSCs, which in turn would lead to enhanced risk management and business sustainability.

Keywords: service supply chain; service supply chain risks; systematic literature review; interpretive structural modeling; MICMAC

(Received on May 17, 2019; Accepted on June 14, 2021)

1. INTRODUCTION

Over recent decades, the relative importance of service components in a product offering and the importance of the service sector increased steadily. This reveals a fundamental shift in the industrial structure from manufacturing to services, especially in industrialized economies. Within the supply chain management literature, although the majority of existing research focuses on manufacturing, there is a steadily growing number of research on service supply chains.

A service supply chain (SSC) is a network of suppliers, service providers, customers, and other supporting business units that take part in the acquiring of the resources required to deliver the services; the transformation of these resources into services; and the delivery of these services to customers (Baltacioglu et al., 2007). SSC business processes are customer relationship management, demand management, capacity and resources management, supplier relationship management, service delivery management, order process management, cash flow management, information flow management, and service performance management (Ellram et al., 2004; Baltacioglu et al., 2007).

The literature on SSCs mainly focuses on developing conceptual frameworks (Liu et al., 2017; Ramish et al., 2017; Ellram et al., 2004; Baltacioglu et al., 2007), performance measurement (Rezaei Pandari and Azar, 2017; Cho et al., 2012; Sengupta et al., 2006), operational models (Liu et al., 2018; Helo et al., 2018; Yuen & Van, 2017; Wang et al., 2015) and the amplification phenomenon in services (Behzad et al., 2011; Akkermans & Vos, 2003). Recent studies in the SSC literature emphasize sustainable platform management (Lin et al., 2021), understanding the sentiment of big data (Cao et al., 2021), sustainability evaluations in SSCs (Nagariya et al., 2021), information technology, and service performance management capabilities of SSCs (Lenuwat & Boon-itt, 2021; Amonkar et al., 2021), decision optimization in SSCs (Wang et al., 2021), and partner selection (Li et al., 2021). However, within this growing research, very little attention was given to the SSC risks and how to manage them.

Natural or man-made disruptions to a supply chain have a negative impact on its performance (Hendricks & Singhal, 2005; Wilson, 2007; Gaonkar & Viswanadham, 2007; Wagner & Bode, 2008). Understanding and dealing with the impact of disruptions to a supply chain have been studied under supply chain risk management. Supply chain risk management and can be defined as the identification, assessment, and management of risks in the supply chain (Lee et al., 2010). Risk within a supply chain management context can be viewed as any chance of danger, damage, loss, injury, or any other undesired consequences (Harland et al., 2003). In other words, we speak of supply chain risk, when the negative consequences of an unexpected event outweigh the positive consequences. Numerous sources in a supply chain environment could lead to undesired consequences, such as environmental, supplier, demand, and operational risks (Jüttner et al., 2003; Mentzer & Manuj, 2008; Wagner & Bode, 2009; Sodhi & Tang, 2012; Hollman et al., 1991; Nordin et al., 2011).

Risk management in supply chains has been studied extensively in the context of manufacturing supply chains (Bak, 2018). Unfortunately, within this growing research, very little attention was given to the SSC risks and how to manage them. To express this in numbers, the Scopus database returned over 7000 documents to a basic search of (KEY (“supply chain” AND (risk OR interruption OR disruption)), whereas and the query of (KEY (“service supply chain” AND (risk OR interruption OR disruption)) provided only 45 document results (Date: May 6th, 2021). The difference in numbers can be attributed to the inherent characteristics of services and SSCs. As the economy shifts from manufacturing to services, it is important to understand whether the concepts in manufacturing supply chains are applicable to service supply chains as well. Services differ from goods in that they are intangible, heterogeneous, inseparable in production and consumption, and perishable. These characteristics of services together with the nested network structure of SSCs -where value is co-created by the customer together with physical goods suppliers and service suppliers-highlight the need for further studying the supply chain issues from the perspective of services.

With the increasing competition, changing customer preferences, globalization, outsourcing, and the need for flexibility and agility, risks in a supply chain are growing as well. Consequently, the need to manage these risks becomes a necessity. It is critical to a supply chain’s success to understand the risks that impact the supply chain flows and apply a risk management approach to deal with them. Naturally, SSCs are not immune to disruptions. Victorino et al. (2018) investigated the service operations via a systematic literature review and listed key service research themes. In a companion paper, the service operations research ideas are further discussed comprehensively (Field et al., 2018). One of the key themes discussed in these studies is service failures in service supply networks, emphasizing the need for an understanding of different types of risks and their consequences, which supports the motivation of this study. Hence, there is a need to examine and understand supply chain risks from a service perspective and develop a conceptual view of SSC risk so that all parties in the supply chain can use a shared vocabulary. Such a shared vocabulary would be beneficial in finding ways to manage different types of supply chain risks (Sodhi & Tang, 2012). Furthermore, categorizing risks would assist with risk management and enable us to develop ways to manage each particular risk type while considering their interdependencies.

Managing SSC risks are of vital importance, which has been negatively highlighted by the COVID-19 pandemic, especially in the airline (Belhadi et al., 2021), travel/transportation (Murano et al., 2021), tourism (Wu et al., 2021), restaurant (Yost & Cheng, 2021), entertainment (Liang et al., 2021; Mittal & Sinha, 2021; Eze et al., 2021), sports (Schellhorn et al., 2021), and rental industries (Baker et al., 2020). Recently, risk level determination (Sun et al., 2021), risk diffusion mechanism (Zhang et al., 2020), risk mitigation (Karadayi-Usta, 2020), risk management (Getele et al., 2019) concepts have been discussed in SSCs literature. A systematic literature review on the SSCs (Choudhury et al., 2020) states that the robustness of ideas underpinning SSC research has not been fully analyzed by the academic community yet, and emphasizes SSC risk management in future research agendas.

The existing studies dealing with SSC risks apply case analysis (Ma et al., 2020; Galanakis et al., 2021), scenario analysis (Choi, 2021; Zhang et al., 2020), stochastic modeling (Wang et al., 2021), and dynamic games (Zhou & Ju, 2015; Hu & Li, 2020; Qu et al., 2020; Wang et al., 2019). A few recent studies use structural analysis to study risks in a specific service environment, such as conference tourism (Karadayi-Usta, 2020), banking (Naser SadrAbadi et al., 2020), food service (Yadav et al., 2021), and telecom industry (Chen et al., 2021).

This paper aims to identify the risks associated with SSCs by a systematic literature review and explicitly define the types of risks in SSCs. The results of the systematic review prepare the ground for further research in this field. The review also reveals that there are interactions between these risks, which are further analyzed using Interpretive Structural Modeling (ISM) and MICMAC (Matrix-based Multiplication Applied to a Classification). ISM (Warfield, 1974) is an effective and efficient method to represent the interrelationships among various risks as a hierarchy, and MICMAC (Godet, 1994) enables us to examine the risks based on their direct and indirect relationships. To validate the theoretical findings, examples of risk events in services and the relationships between them have been further investigated via the case of an ERP consulting company. The experiences of the case company show great similarities with the generic structural model resulting from ISM and MICMAC. Overall, the study provides clear definitions of the SSC risk categories and develops a structural model that indicates the nature and consequences of these risks. The study results help us identify and understand all the risks that have to be assessed in SSCs, which leads to improved risk management and ultimately to better SSC performance.

2. SYSTEMATIC LITERATURE REVIEW

This research applies a systematic review of the literature to identify the risks associated with SSCs. Systematic reviews adopt a replicable, scientific and pre-planned process that aims to minimize bias through exhaustive searches of all relevant studies and by using explicit, reproducible criteria in the selection and review process (Cook et al., 1997; Briner & Denyer, 2012). This study followed the review process presented in Okoli and Schabram (2010), which is modified to meet the needs of this research. Table 1 presents the main steps of the review process.

The review aims to determine risks related to SSCs by examining the current literature. Since there are no extensive studies on SSC risks; a stepwise systematic literature review was implemented with the following research questions:

- What is the scope of SSCs? Which industries are under study?
- Which risk areas are mentioned in studies related to supply chains in these industries?
- What are the risk types/categories with respect to SSCs?

Table 1. The Main Steps of the Review Process

#	Steps	Stages
1	Background and rationale for the review	Planning
2	Defining research questions	
3	Defining search criteria (review protocol)	
4	Searching the literature	Conducting
5	Selecting studies	
6	Extracting data	
7	Analyzing data and synthesis	Reporting
8	Presenting the findings	
9	Interpreting results and drawing conclusions	

The background research led us to focus our search for academic literature in the Scopus database covering the indexed publishers such as Elsevier, Emerald, IEEE, Springer, Sage, Taylor & Francis, Wiley-Blackwell. Peer-reviewed journal articles, conference proceedings, and book chapters published from 1999 to the present day were included in the review process since studies on SSCs appear mainly after 1999. The citations in the identified studies were also traced to find additional ones, which were not directly accessible through our search in the periodical databases. Only the studies published in the English language were considered in the search process.

In the first phase of our review, we searched for the SSC studies in the literature. The search term was "service supply chain" in "title, abstract, keywords" (Query terms: TITLE-ABS-KEY ("service supply chain")). The initial search process in the Scopus database returned a total of 882 articles, conference proceedings, and book chapters (Date: May 06, 2021). After reviewing the abstracts of each manuscript, we excluded the studies that are out of our focus, such as the ones mentioning "supply chain services" that cover various services utilized along the supply chain, since our focus is on supply chains in the service sector. After eliminating the irrelevant and duplicate (e.g., studies published both as a conference proceeding and an article) records, 832 remained and were reviewed in more detail. For each study eligible to be included in this paper, the data provided in Table 2 were extracted (A list of reviewed articles is available from the authors upon request). The distribution of the studies according to the publishing year presents an increase in the number of studies on SSCs over time, hence indicating a growing interest in this topic.

Table 2. Data Extraction Fields (Step 6 of the Review Process)

Field	Concern
Year of publication	Extracting general details of the study
Journal	Extracting general details of the study
Industry-first phase review	Determining service industries with a supply chain
Risk areas-second phase review	Determining risk areas in service supply chains

After the first phase of the data extraction, the specific service industries discussed within the concept of SSCs were identified. The Pareto chart given in Figure 1 was constructed to identify the most frequently studied service industries. These are logistics, IT, transportation, healthcare, telecommunications, and tourism services. The keywords used to mention the specific industries were also recorded for the next phase of the review. Consequently, the next phase of the systematic literature review focuses on the supply chains of these industries.

In order to investigate the impact of global lockdown on SSC studies, the papers before 2020 and after 2020 were further analyzed separately. Accordingly, the number of papers in transportation (airlines, cruise, etc.) and tourism services decreased, while the ones in healthcare/medical/pharmaceutical, logistics/shipping, e-commerce/online shopping, IT/digital platform and cloud services, food retail services increased. Additionally, studies related to ecosystem services, lean/green practices, responsible consumption, and sustainability perception have been published more during the pandemic period.

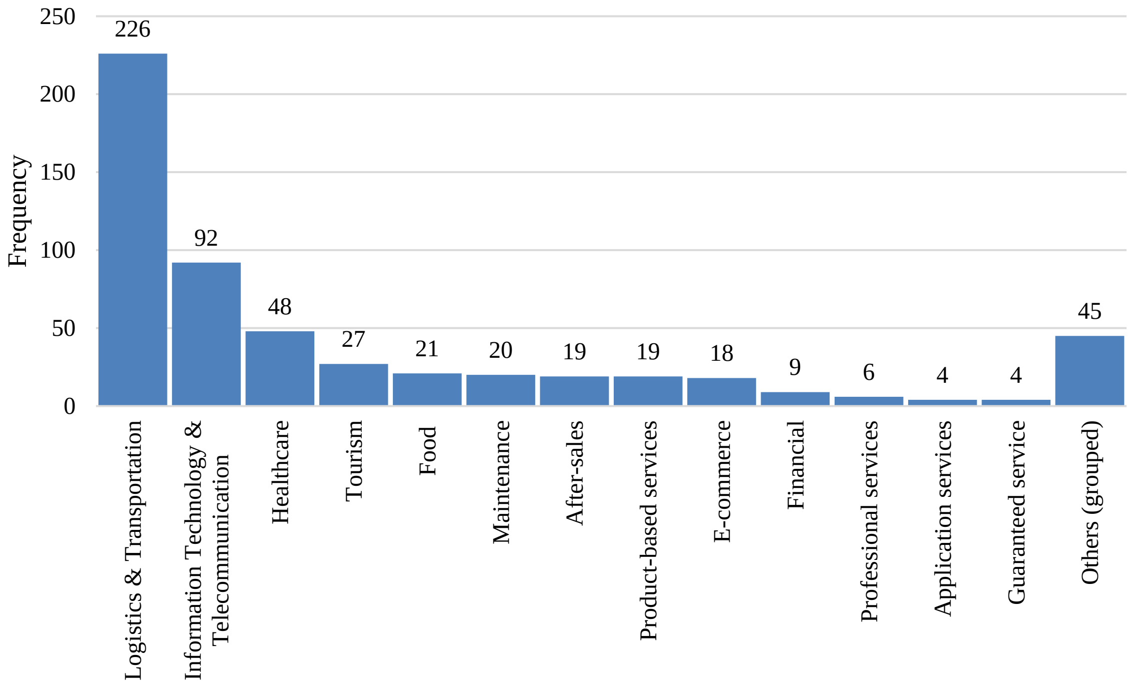


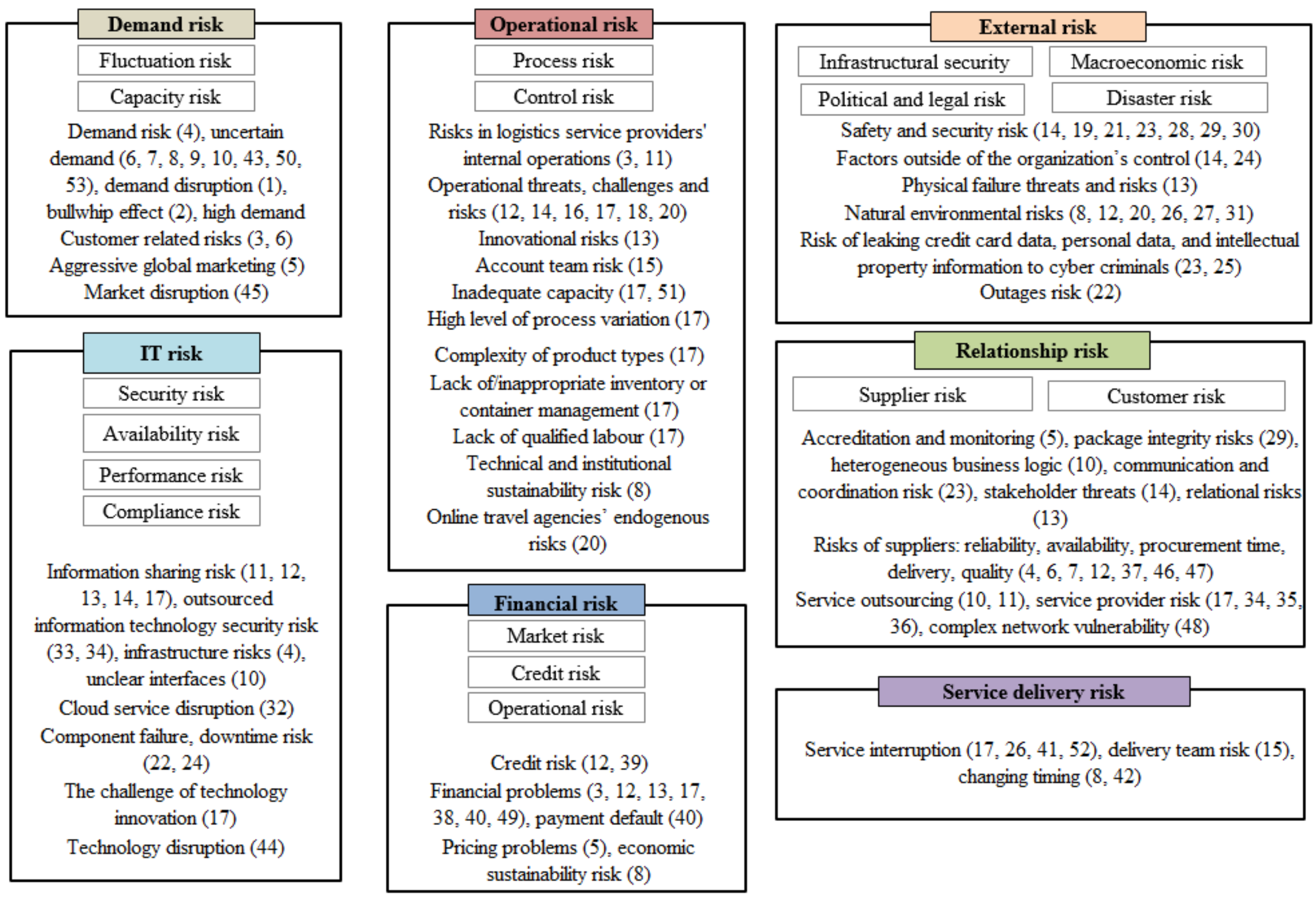
Figure 1. Pareto Chart of Service Industries that are Studied in Relation to Supply Chains

In the second phase of the review process, we conducted a new search by adding the industry names to the search terms so that we can determine their specific risk areas. For example, for tourism SSC risks, we used the search words ("tourism" OR "hotel" OR "travel agency") AND "supply chain" AND ("risk" OR "interruption" OR "disruption") in "title, abstract, keywords". A similar search logic was used for all the industries. The industry-specific search query terms are provided in Table 3. After reviewing the retrieved studies, we extracted the risk areas studied in SSCs.

Table 3. Search Query Terms Related to the Service Industries

Service industry	**Search terms**
Logistics and Transportation	Delivery, logistics, transportation, container shipping, maritime service, port service, shipping services, airline service.
Information Technology and Telecommunication	Cloud computing service, cloud service, communications technologies, digital services, information and communication technologies, information service, information technology, software service, web service, mobile service, mobile telecommunication systems, telecom, telecommunications, e-commerce services, online shopping services.
Healthcare	Healthcare service, home-care service, medical service
Tourism	Hotel service, tourism service, travel agency service

The extracted risk areas were analyzed following an affinity diagramming procedure. The affinity diagram is useful when we need to organize and present the nature of a relatively complicated system that is described in a large number of opinions and/or ideas. It allows us to sort the ideas into categories with common features so that we can understand the basic structure. The affinity principle of association and clustering is a useful step before discovering, visualizing, and communicating the high-level relationships that define the nature of the system we are dealing with (Brassard, 1989). As a result of the affinity diagramming session with experts, the risk areas are categorized into seven risk types: Financial, relationship, demand, operational, service delivery, IT, and external risks. As the reader may observe, they have similarities with the commonly studied supply chain risk types in a manufacturing environment –supply, demand, process, and corporate level risks (Sodhi & Tang, 2012)- except for the service delivery risk, which is a concept unique to service systems. The affinity diagram including the seven risk types and examples of associated risks extracted from the literature review is given in Figure 2. These risk types can be generalized for all SSCs. Next, a formal definition is provided for each SSC risk type.



1	Liu et al., 2016 a	14	Jereb et al., 2013	27	Faghih-Roohi et al., 2016	40	Chen et al., 2018
2	Tang and Li, 2011	15	Prasad and Shankar, 2018	28	Fuller, 2009	41	Wei and Ling, 2013
3	Govindan and Chaudhuri, 2016	16	Herrera and Janczewski, 2015	29	Lutostansky et al., 2016	42	Wang and Zhang, 2010
4	Baharmand et al., 2017	17	Li et al., 2016	30	Juang and Lin, 2005	43	Wang et al., 2021
5	Mendoza, 2014	18	Moen, 2012	31	Anjomshoae et al., 2016	44	Galanakis et al., 2021
6	Farughi and Mostafayi, 2017	19	Kimmins, 2011	32	Lu et al., 2016	45	Choi, 2021
7	Biao et al., 2014	20	Qin and Zhang, 2013	33	Deane et al., 2010	46	Ren et al., 2020
8	Valinejad and Rahmani, 2018	21	Liu et al., 2016 b	34	Espino-Rodriguez et al., 2012	47	Qu et al., 2020
9	Thierry et al., 2011	22	Cao and Wei, 2017	35	Selviaridis and Norrman, 2014	48	Ma et al., 2020
10	Agrell et al., 2004	23	Tang and Zimmerman, 2013	36	Chen, 2011	49	Zhang et al., 2020
11	Choi et al., 2016	24	Axelrod, 2010	37	Zamora Aguas et al., 2013	50	Hu and Li, 2020
12	Li et al., 2015	25	Laurits, 2013	38	Lu and Wang, 2011	51	Rajani and Heggde, 2020
13	Cavinato, 2004	26	Azad and Davoudpour, 2014	39	Nique and Smertnik, 20116	52	Hoseinpour and Ahmadi-Javid, 2019
						53	Wang et al., 2019

Figure 2. Affinity Diagram of the Defined Service Supply Chain Risk Types

Financial risk is associated with financial transactions, such as ‘sales and purchasing, investments and loans, and other business activities’ (Horcher, 2005). Drawing an analogy to the three sources of financial risks (i.e., operational, credit, and market risks), we consider financial risks in SSCs to arise through (1) operational risks on the provider side resulting from disruptions and failures in the service delivery process, (2) credit risks related to demand uncertainty on the customer side and supply uncertainty on the supplier side and (3) market risks referring to uncertainties in market prices and regulatory issues.

Relationship risks involve all significant risks that are driven by relationships with other entities within the supply chain network. These risks are external to the organization but internal to the supply chain network (Martin & Helen, 2004). Supplier risk relates to potential or actual disturbances to the flow of service, its by-products, and information coming from upstream of the service provider company (Martin & Helen, 2004). Thus, they are the risks associated with a service provider’s suppliers, or supplier’s suppliers being unable to deliver the services or the materials required to deliver the service provider’s value proposition as promised to its customers. In this paper, the main focus is on the supply side risks. On the other hand, there are also risks driven by the relationships with the customer downstream the provider company, associated with either the operational and/or service delivery failures on the provider’s side or the customer’s noncooperative behavior during the service delivery.

Demand risk is observed when demand for a product or service is experienced, which was not anticipated and provisioned for throughout its supply chain (Cranfield-SoM, 2003). Demand risk mainly arises from unpredictable fluctuations in demand or inaccurate forecasting, and the chain’s inability to adjust service delivery capacity accordingly. Three common characteristics of the services being intangible, inseparable, and perishable lead to most services not being able to be stored in inventory for later use, so the imbalance between customer demand and service delivery capacity has a significant impact on supply chain performance in services.

Operational risks are observed due to the failure to deliver the desired quality and quantity at the right time (Kumar et al., 2010). These risks are internal to the organization and include process and control risks (Martin & Helen, 2004). Process risk is related to the variability of operational processes. Hopp and Spearman (2000) define two key sources of variability: The first one is the process variability that originates from random differences in operators, machines, and material, setups, or operator unavailability. The second one is flow variability, the impact of which depends on the utilization. Since one common aspect of services is the high degree of human involvement in delivery, inflexibility of service delivery capacity, which affects both flow and process variability, becomes an important issue associated with operational risks. Control risk arises from the application or misapplication of the procedures, rules, and systems that govern the execution of the processes. Control risk relates to planning, whereas process risk relates to execution (Cranfield-SoM, 2003). Operational risks are associated largely with the design and standards gap and service performance gaps defined in the gaps model of service quality (Parasuraman et al., 1985).

The service delivery process is unique to services and differs from the delivery of products in that it requires the involvement of the service customer in co-creating value (Ostrom et al., 2010). The value of service results from service customers’ evaluation of the service experience (Sandström et al., 2008). Accordingly, borrowing from Harland et al. (2003), service delivery risk can be defined as any chance of danger, damage, liability, loss, injury, or any other undesired consequences during the service experience. This risk arises at the service interface and can be induced either by the service provider, the customer, and/or the other parties involved in the service delivery process and may impact any or all of the parties involved. Service delivery risks are closely related to the characteristics of the services being intangible, heterogeneous, inseparable, and perishable.

Information technology risk covers all kinds of risks IT creates for an organization. It can be classified as security, availability, performance, and compliance risks (Symantec, 2007). Security risk is related to unauthorized people gaining access to information; availability risk arises when information or applications are not accessible due to system failure or natural disaster, or recovering from such interruptions; performance risk is due to underperformance or inflexibility in systems, applications, or resources that delays implementing required task and changes; compliance risk arises through not meeting the regulatory, IT or business policy requirements when providing information (Symantec, 2007; Westerman & Hunter, 2009). Most of the current literature on IT risk supply chain focuses solely on security risks. As the involvement of IT is increasing in service businesses, which are in higher need of information from customers and information processing capabilities (Bowen & Ford, 2002), the significance of IT risk becomes more pronounced. Overall the IT risk in an SSC is a product of the frequency of occurrence of any IT related risks, their impact on the organization, and the consequences for the supply chain.

External risk is what is defined as an environmental risk by Sodhi et al. (2012) and involve infrastructural security, macroeconomic, political, and legal risks as well as disasters (van Wyk & Baerwaldt, 2005; Manuj & Mentzer, 2008) arising in the supply chain’s global environment and is out of direct control (Manuj et al., 2014). Natural or man-made disasters such as earthquakes, floods, hurricanes, pandemics, chemical spills, explosions, wars, and terrorist attacks disrupt the supply chain performance in an unanticipated manner (van Wyk & Baerwaldt, 2005; Manuj & Mentzer, 2008; Sodhi & Tang, 2012; Li et al., 2021). Many risk events associated with external risks eventually lead to supply or demand risks (Manuj et al., 2014).

Additionally, the studies that were part of the second phase of the review were categorized according to the service industry and risk types as defined in this study. This classification enables researchers to make inferences about which risk types are studied previously or not yet studied in the current literature. As seen in Table 4, service delivery risks are generally neglected in the studies. In each industry, there is at least one specific risk type that gets more attention. For example, logistics and transportation studies focus on operational, relationship, and external risks, whereas healthcare studies focus on relationship and demand risk. These implications lay the ground for further research in this field, discussed in the further research section.

The COVID-19 outbreak has affected the SSCs risk findings. The relationship (supplier) risk increased in logistics and IT services during the pandemics period. Also, the financial and demand risks in the logistics and transportation industry increased during the pandemic period.

Table 4. A Summary of Risk Types Studied in Surveyed Industries

	Logistics and Transportation	Information Technology and Telecommunication	Healthcare	Tourism
Financial Risks	% 13	% 4	% 15	% 22
Relationship Risks	% 20	% 15	% 29	% 22
Demand Risks	% 9	% 11	% 21	% 11
Operational Risks	% 21	% 15	% 7	% 22
Service Delivery Risks	% 5	% 11	% 7	None
IT Risks	% 13	% 15	% 7	% 11
External Risks	% 20	% 30	% 15	% 11

Along with the identification of SSC risk types, the review process revealed that these risks often arise simultaneously or in succession. This led us to a new research question, “Is there any relationship between the risk types?” addressed in the following section.

3. ANALYSIS OF RELATIONSHIPS BETWEEN RISKS

The relationships among the risks defined above are analyzed using ISM and MICMAC methods. Both structural modeling tools are useful –evidenced by numerous successful applications – when making decisions and clarifying the system’s structure for systems involving humans and technology. In the recent literature, these two tools are used complementarily (see Agi and Nishant (2017), Bohtan et al. (2017), Gopal and Thakkar (2016), Dubey et al. (2017), Raut et al. (2017) to emphasize the structure of the relationships between elements, which is essential to an understanding of the system under study.

ISM is a method of representing relations among elements of a system as multilevel digraphs, which are then used to produce interpretive structural models representing organized knowledge (Warfield, 1974). The methodology uses variable graphs, directs the relationships, and generates hierarchical models. In the application of ISM, initially, an issue and its elements are identified. Next, the contextual relations between the elements are determined according to the judgments made by the participants. A structural self-interaction matrix (SSIM) is developed based on the pairwise comparison of the elements. Next, the SSIM is transformed into an adjacency matrix, and its transitivity is investigated. Transitivity is the main assumption for conceptual relationships of ISM methodology. For instance, if there is a relationship between elements A and B, and there is a relationship between elements B and C, there must be a relationship between elements A and C. After the transitivity adjustments, the reachability matrix is obtained. The reachability matrix can also be obtained by raising the initial matrix (built by adding the identity matrix to the adjacency matrix) to successive powers until no new links are formed (Malone, 1975). Next, the elements are partitioned and rearranged, followed by drawing of the hierarchically reordered digraph. The resulting graph is transformed into an interpretive structural model, and the final structure is displayed following amendments.

The MICMAC method is a structural analysis tool, where the importance of an element is measured not only by its direct interrelationships but also by its many indirect interrelationships (Godet, 1994). The implementation steps of the method start with listing the elements and continue with describing the relationship between elements, analysis of relationships, and end with the chart analysis and interpretation of the results. In order to describe the relationships between elements, experts are asked to provide subjective estimates of the direct relationships among the elements, usually in the form of a matrix of impact values. To develop a structure (or hierarchy) for the elements, a system of multiplication of matrices is applied to the direct relationship matrix, so that the whole network of interrelationships (both direct and indirect) is taken into account. The result of this procedure enables us to associate each element with an influence and a dependence indicator that is plotted on the independence dependence chart. The chart has five regions and helps the results to be interpreted (Godet, 1994):

- "Influential elements have high influence but low dependence values". They have the power to influence the state of the rest of the system.
- "Dependent elements have high dependence but low influence values". They are the results and can be used to monitor the performance of the system.
- "Key elements have both high influence and high dependence values". They are critical elements and unstable in nature since they highly impact the stability of the system.
- "Excluded elements have both low influence and low dependence values". They are relatively unconnected to the system, thus can be ignored in the analysis.
- "Neuter elements are moderately influential and/or dependent elements". Their role in the system is hard to interpret in advance.

In this study, the elements (i.e. SSC risk areas) have been identified based on the systematic literature review. To identify the contextual relationship among the SSC risks, five experts from academia with research interests in the area of supply chain management and three field experts with experience in the area of supply chain management in the service sector were consulted. The experts were provided with definitions and examples of the risk areas. When analyzing the criteria, a contextual relationship of "affects" was chosen for model construction. An example of the question form is "Do financial risks directly affect relationship risks?", where the experts were asked to give a yes or no response. The experts were asked to evaluate the contextual relationships among the risk areas individually. In order to obtain a single judgment of the eight experts for the risk relationships and to ensure that the resulting data reflects the majority view (Warfield, 2006), the individual responses were counted and the majority vote was used (a tie vote corresponds to a "no") as an input for the SSIM.

After deciding on the risk areas and the contextual relationship between each risk area, the SSIM is generated (see Table 5) using the following four symbols for relationship definition:

- V: Risk type *i* affects *j*.
- A: Risk type *j* affects *i*.
- X: Risk types *i* and *j* affect each other.
- O: No relationship between *i* and *j* risk types.

Table 5. Structural Self-Interaction Matrix

	(R7)	(R6)	(R5)	(R4)	(R3)	(R2)
Financial risks (R1)	A	A	A	X	X	X
Relationship (supplier) risks (R2)	A	A	A	X	X	--
Demand risks (R3)	A	A	V	V	--	--
Service delivery risks (R4)	A	A	X	--	--	--
Operational risks (R5)	A	A	--	--	--	--
Information technology risks (R6)	A	--	--	--	--	--
External risks (R7)	--	--	--	--	--	--

The SSIM is transformed into the adjacency matrix (a binary matrix), by substituting V, A, X, O by 1 and 0 following the substitution rules:

- If the entry (*i, j*) in the SSIM is V, then the entry (*i, j*) in the reachability matrix becomes 1 and the entry (*j, i*) becomes 0
- If the entry (*i, j*) in the SSIM is A, then the entry (*i, j*) in the reachability matrix becomes 0 and the entry (*j, i*) becomes 1
- If the entry (*i, j*) in the SSIM is X, then the entry (*i, j*) in the reachability matrix becomes 1 and the entry (*j, i*) becomes 1
- If the entry (*i, j*) in the SSIM is O, then the entry (*i, j*) in the reachability matrix becomes 0 and the entry (*j, i*) becomes 0

The contextual relationships among the risks provided in the adjacency matrix are represented by the digraph in Figure 3. The initial matrix, given in Table 6, was built by adding the adjacency matrix and the identity matrix. Next, any transitive links that may exist between different elements were investigated, and the entries in Table 7 marked with * were updated accordingly in the reachability matrix.

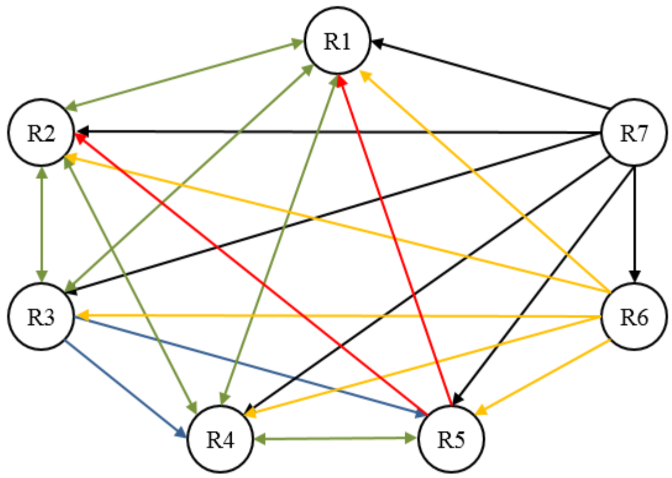


Figure 3. Initial Directed Graph

Table 6. Initial Matrix

	(R1)	(R2)	(R3)	(R4)	(R5)	(R6)	(R7)
Financial risks (R1)	1	1	1	1	0	0	0
Relationship (supplier) risks (R2)	1	1	1	1	0	0	0
Demand risks (R3)	1	1	1	1	1	0	0
Service delivery risks (R4)	1	1	0	1	1	0	0
Operational risks (R5)	1	1	0	1	1	0	0
Information technology risks (R6)	1	1	1	1	1	1	0
External risks (R7)	1	1	1	1	1	1	1

Table 7. Reachability Matrix

	(R1)	(R2)	(R3)	(R4)	(R5)	(R6)	(R7)
Financial risks (R1)	1	1	1	1	1*	0	0
Relationship (supplier) risks (R2)	1	1	1	1	1*	0	0
Demand risks (R3)	1	1	1	1	1	0	0
Service delivery risks (R4)	1	1	1*	1	1	0	0
Operational risks (R5)	1	1	1*	1	1	0	0
Information technology risks (R6)	1	1	1	1	1	1	0
External risks (R7)	1	1	1	1	1	1	1

The reachability matrix (see Table 7) is partitioned by assessing the reachability and antecedent sets for each risk. Reachability set of element *i* contains the element itself and the other elements that it may impact, that is all the elements whose columns have an entry of 1 in row *i* in the reachability matrix. The antecedent set contains the element *i* itself and the other elements that can impact it. In other words, all the elements whose rows have an entry of 1 in column *i*. After this assessment process, the intersection set is determined that consists of elements common to both the reachability set and the antecedent set. If the reachability set and the intersection set of an element are the same, then that element is considered to be in Level I. The first level indicates the top position in the ISM hierarchy. The Level I elements are removed from consideration, and this process is iterated until the level of each element is determined. The reachability matrix is partitioned into three levels, as presented in Table 8.

Table 8. Partitioning for the Reachability Matrix

	Reachability Set	Antecedent Set	Intersection	Level
Financial risks (R1)	1, 2, 3, 4, 5	1, 2, 3, 4, 5, 6, 7	1, 2, 3, 4, 5	I
Relationship (supplier) risks (R2)	1, 2, 3, 4, 5	1, 2, 3, 4, 5, 6, 7	1, 2, 3, 4, 5	I
Demand risks (R3)	1, 2, 3, 4, 5	1, 2, 3, 4, 5, 6, 7	1, 2, 3, 4, 5	I
Service delivery risks (R4)	1, 2, 3, 4, 5	1, 2, 3, 4, 5, 6, 7	1, 2, 3, 4, 5	I
Operational risks (R5)	1, 2, 3, 4, 5	1, 2, 3, 4, 5, 6, 7	1, 2, 3, 4, 5	I
Information technology risks (R6)	1, 2, 3, 4, 5, 6	6, 7	6	II
External risks (R7)	1, 2, 3, 4, 5, 6, 7	7	7	III

Finally, the final interpretive structural model is constructed based on the final reachability matrix and the partitioning. The visual model is shown in Figure 4.

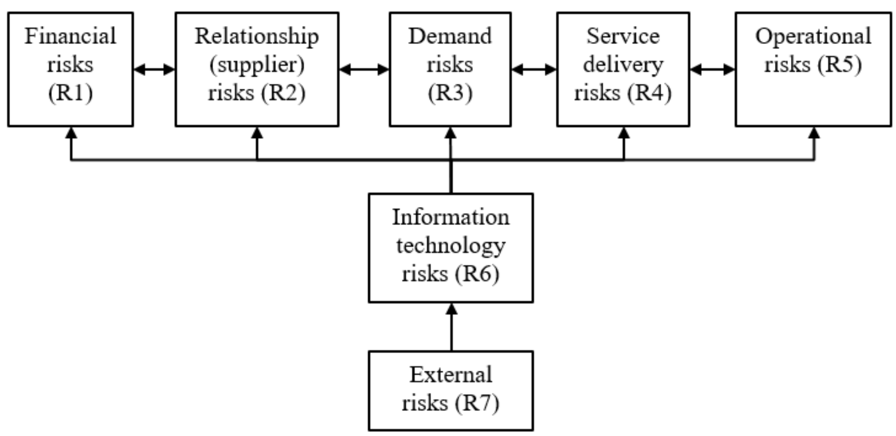


Figure 4. Final Interpretive Structural Model

According to the final model, financial, relationship, demand, service delivery, and operational risks are at the same level and interact with each other. Any negative event may lead to an undesired consequence for these five risk types. Information technology risks are at the second level of the model and may affect the first level risks directly but do not have a direct impact on the external risks. The external risks are at the third level of the model and affect all SSC risk types.

The MICMAC method is used to study the network of interrelationships based on the influence and dependence values of risks. The matrix of indirect influences (MII) is the matrix that has resulted by incorporating all the transitivities from the matrix of direct influences, which is the adjacency matrix in ISM. The sums of rows and columns of MII provide the indirect influences and dependencies, as shown in Table 9. A comparison of element rankings by direct and indirect influences, given in Figure 5, reveals that, when the indirect relationships are considered, the influence ranking of financial risks (R1) and supplier risks (R2) move up. In other words, they become more influential in time.

Table 9. Influence and Dependency Levels of Risks according to MICMAC

	Influence	Dependency
Financial risks (R1)	31	66
Relationship (supplier) risks (R2)	31	66
Demand risks (R3)	38	42
Service delivery risks (R4)	29	66
Operational risks (R5)	29	34
Information technology risks (R6)	50	0
External risks (R7)	66	0

Direct Influences

Rank	Variable
1	External risks (R7)
2	Information technology risks (R6)
3	Demand risks (R3)
4	Operational risks (R5)
5	Service delivery risks (R4)
6	Relationship (supplier) risks (R2)
7	Financial risks (R1)

Indirect Influences

Rank	Variable
1	External risks (R7)
2	Information technology risks (R6)
3	Demand risks (R3)
4	Relationship (supplier) risks (R2)
5	Financial risks (R1)
6	Service delivery risks (R4)
7	Operational risks (R5)

Figure 5. Comparison of Ranking of Risks by Direct and Indirect Influences

The indirect influence–dependence chart in Figure 6 presents the risk variables on an influence dependence plane with the influence on the X-axis and the dependence on the Y-axis. The factors are plotted on the plane according to the strength of their influence and dependence on the MII. Each risk is assigned to one of the five different regions, determined according to the middle values. The neuter region is specified within ± %10 of the mid-value. The MICMAC results locate the risks mainly into two regions: influential and dependent (except for operational risks), which is in line with the ISM results. External (R7) and IT risks (R6) are influential, whereas financial risks (R1), supplier risks (R2), demand risks (R3), service delivery risks (R4) are dependent, and operational risks (R5) are neuter. Therefore, when an SSC encounters external and/or IT-related risks, it is highly likely that a risk related to the rest of the risk areas emerge.

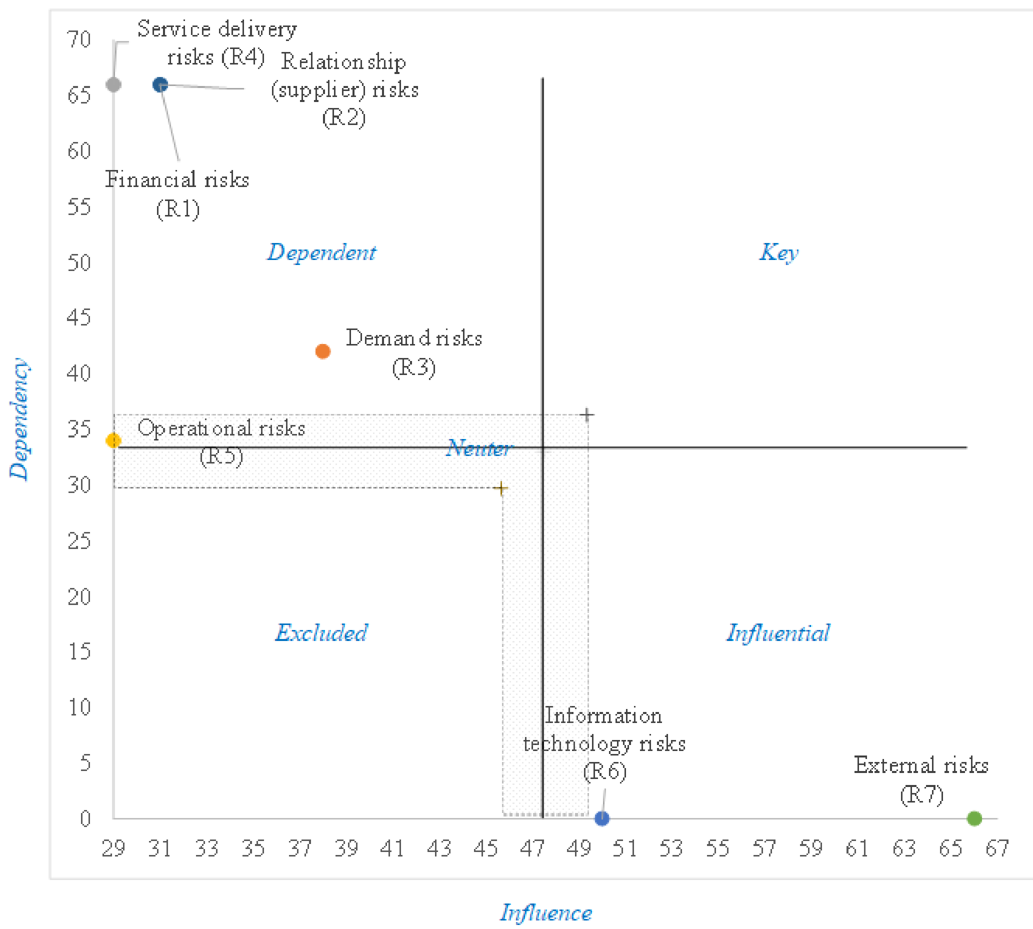


Figure 6. Projection of MICMAC Results on the Influence–Dependence Chart

ISM and MICMAC results provide a hierarchical and dependency-based model of risk relations as well as the main structure of risk dependencies. The findings show us that the risk areas are highly interrelated. To validate the theoretical findings, examples of risk events in services and the relationships between them have been further investigated via the case of an ERP consulting company.

4. CASE EXAMPLE

A company providing ERP consultancy services, hereinafter referred to as ACom, assisted our research with their SSC experiences. ACom is a Microsoft Dynamics partner and a software solution provider located in Turkey. Within the scope of our research, an ACom representative provided evidence to support the relationships between risk types based on their business experiences and evaluated our structural risk model.

As stated by the ACom representative, an external risk leading to service delivery disruptions is caused by heavy snowfall/rainfall. Especially in remote consultancy service delivery, it leads to data exchange interruption since the internet and electricity services are disrupted due to bad weather conditions. For example, because of a flood disaster in 2009, Vodafone, a telecommunication services provider, couldn't carry on its business for days ("Sel Felaketi", 2009), which caused disruptions in ACom's operations and services provided by Vodafone's infrastructure. This is an example of an external risk event leading to supplier risk and eventually to operational and service delivery risks. Another such external risk event influencing ACom's operations took place in 2012 due to an electric breakdown. During the electricity service failure, even subway lines could not provide transportation service for hours ("Elektrik Kesilince", 2012). ACom's employees had to sit stranded in a coffee shop for hours during this wide-scale power cut, preventing them from delivering the promised service performance. Similarly, the on-site visits for consultancy services are delayed or canceled as a result of traffic congestion caused by bad weather conditions. Since the company provides on-site consultancy services to its customers, any disruption in transportation has a negative impact on its operational and service delivery processes.

Unexpected events such as the coup attempt in 2016 and revote in 2015 (external risks) resulted in ACom's customers avoiding new investments and therefore creating credit and market risks. Similarly, any negative statement of the politicians leading to fluctuations in exchange rates brings a new wave of avoiding investments or disruption in import/export operations on the customer side. Thus, undesired incidents associated with external risks resulted in financial risks in the SSC.

An example of IT security risk leading to service delivery risk was faced when ACom failed to provide a complete access control system (control risk), allowing unauthorized users to access privileged customer data (security risk) and causing serious problems with the customer (service delivery risk). The customer wanted to end the business relations with ACom (financial risk), regarding the case as a lack of responsibility and accountability since the payrolls were accessible by a warehouse employee due to wrong permissions.

ACom every so often encounters problems in receiving the full contracted amount on time. Postponement of payment by the customer represents credit risk exposure to ACom. To illustrate, after one of ACom's projects had reached a specific milestone, they had a payment problem with their customer. To prevent further financial risks, ACom decided to suspend the project. When they restarted the project, ACom was faced with technical and employee-based process risks mainly due to having forgotten the project details over time. Going through the same steps for a second time was time and resource-consuming, which would not be paid for since the initial contracted amount was still valid. This is an example of financial risks leading to operational risks faced by ACom.

An upward demand fluctuation affects ACom's workload, which may turn into an operational risk due to the mental fatigue of employees. For instance, the company's customers request more services in winter compared to the other seasons. Mental overload and increasing error potential due to inadequate breaks cause operational risks. On the other hand, in case of a decrease in demand, ACom is affected financially due to the low level of workload. Therefore, demand risks may give rise to operational or financial risks in the SSCs.

Another fluctuation in demand is observed at the end of a fiscal year/month and VAT return time since the accounting modules are used more than usual, and the ERP consultancy service demand increases accordingly. That is, the demand risk can give rise to operational risks in the form of a workload increase. As a precaution, ACom attempted to employ new people in this high-demand period. However, this turned out to be counterproductive since it required spending time and money to train these new employees, creating even more workload for existing employees and a costly process leading to financial, operational risks. Similar risks arise when customers demand extensive changes to the applications during the implementation phase, which was not planned initially. This creates an unplanned workload causing operational and service delivery risks as well as problems with the finances since the customers are not willing to pay more than the contracted amount.

Different kinds of risks are encountered when the scope, scale, and requirements of a project are not well defined. Analyzing the customer needs properly and obtaining the correct information from the customer are basic requirements to run a successful project. ACom representative states that they frequently face difficulties with the customers in the concept building and initiation stage. Any failure in the initiation phase of a project leads to operational failure, service delivery disruptions, and financial, operational risks. The common causes leading to such risks are communication problems and resistance to change. Successful service delivery requires good communication and collaboration between the consultant and the customer so that the project can run as planned. The consultants make suggestions regarding the customer business processes owing to their previous experiences. However, customers are not generally willing to change their existing processes. Common customer behavior is resisting change and suggestions. This resistance generates service delivery risks and operational risks. In addition, the relationship risk may arise due to communication issues. The ACom representative stated that they encounter lots of communication-related negativities resulting in misconceptualization of the project, unhealthy relationships with their customers, and eventually operational and financial risks.

Operational problems in finding the right solutions at the right time to cover the specific needs of the customer often cause financial credit risks and relationship risks. For instance, when ACom couldn't provide their customer on time with a customized software solution to be integrated with their accounting module, which was necessary to meet the regulatory requirements, the government obliged the customer to pay the penalty. The reflection of this undesired event to ACom was a reduction in the contracted full amount and the loss of further business with the customer. A similar problem was experienced when one of their customers couldn't ship an order at the right time because of a service delivery failure on ACom's part. As a result, the relationship between the customer and its customer was damaged, and in turn, it caused a relationship problem between ACom and its customer.

A usual concern for ACom is the process variability-based operational risks owing to the implementation of the same software applications to serve the particular needs of very diverse customers such as toy manufacturers and electrical panel producers. Especially newly-recruited employees have difficulty in devising solutions to meet different customer processes, resulting in similar financial and relationship risks.

Additionally, the ACom representative indicated that the COVID-19 outbreak had affected the company in many ways across various departments and at different unexpected times. During the pandemic period, they have encountered all types of SSC risks defined in this study. At the first stage of the pandemics, the customer demand fluctuated as a consequence of this external risk. Some projects accelerated, while some ended dramatically, leading to relationship risks. Also, service delivery, operational and financial problems emerged during the pandemics period. The weak internet infrastructure of the country, home-office working conditions, infected employees hindered the business.

Figure 7 provides the risk map of ACom, which is very similar to the structural model derived from the generic risk evaluations of experts. In other words, the experiences of ACom match with the SSC risk definitions and provide a similar structure to the results of the ISM and MICMAC analysis. The ISM provides a workable hierarchy in the form of a digraph that shows the connections between risk types and their relationships, and the MICMAC method helps to categorize the risks, which would be beneficial in risk identification and then in risk assessment. The generic model was also representative of the situations the case company has experienced.

5. CONCLUSIONS AND FURTHER RESEARCH

An SSC is a network of organizations that take part in the acquisition of necessary resources, the transformation of these resources into services, and the delivery of the promised services. Its management involves the management of resources, processes, information, and service performance throughout the whole supply chain (Ellram et al., 2004). Just like any other supply chain, disruptions to an SSC have a negative impact on its performance. Understanding and dealing with the impact of disruptions requires a risk management approach.

This paper attempts to identify and define SSC risk types for the first time in the literature, based on a systematic literature review. The review sets out to examine the scope of the SSC, the industries under study, the risk areas mentioned in these industries, and risk types with respect to SSCs. To determine the risk areas faced in the SSCs, we searched the SSC studies in the literature via the Scopus database. Since there is no known previous research addressing this issue directly, the risk studies related to the service sector have been reviewed to identify the associated risk types. Hence, in the first phase of the data extraction, the specific service industries that are discussed within the concept of SSCs were identified, the most frequent ones being logistics, IT, healthcare, and tourism services. In the next phase of the review process, multiple queries were executed using industry-related search terms to determine the specific risk areas mentioned in each industry. After reviewing the retrieved studies, the risk areas studied in the context of SSCs were extracted. The elicited risks are then categorized using affinity diagramming. The review and the analysis reveal the common risk areas in SSCs and point out seven risk types: Financial, relationship, demand, operational, service delivery, IT, and external risks. A formal definition is given for each SSC risk type. The definitions serve as a shared vocabulary for all parties in the SSC, which would be beneficial in dealing with supply chain risks.

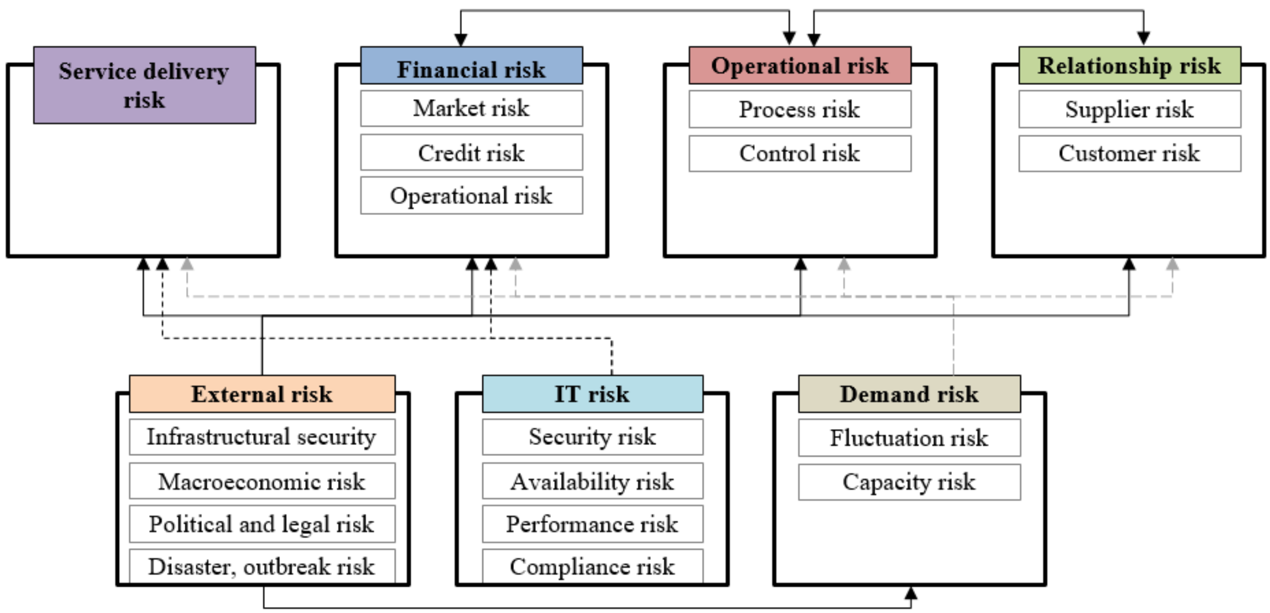


Figure 7. Risk Map of ACom

Based on the implications of the systematic literature review, we have identified some of the underrated issues in the literature:

- External risks were addressed in studies in IT and telecommunications, and logistics industries. As presented in our case example, IT services are directly affected by severe weather conditions due to their negative impact on IT infrastructures. However, while healthcare and tourism services are highly vulnerable to external risks, there are only a few examples and hence a need for further research. Thus, it is safe to suggest that the impact of natural disasters, political and macroeconomic risks (e.g., exchange rate fluctuations) on the performance of SSCs are open research issues.
- Operational risks should be studied in detail in accordance with the nature of the service product both in the planning and execution phases.
- All services are delivered via a network of relationships. Since the concept of ‘service supply chain’ is relatively new, it is not surprising that the studies mentioning relationship risks in SSCs are limited and need to be further explored.
- Although financial risks are a well-studied subject in the literature, in the context of SSCs it is a lesser studied topic. Especially considering the growth of the small and medium-sized enterprises in the service sector and their vulnerability to financial risks, this area merits considerable further research.
- Managing demand risk in SSCs is equally important, if not more, to managing it for goods supply chains. This is mainly since pure service output, as well as the unused service capacity, cannot be inventoried. However, there is a lack of research on this risk type in the published literature. For instance, in our case example, the demand risks are perceived to be critical to the business and its supply chain.
- Service delivery risks, which are specific to services, were not dwelt upon in the reviewed literature. Taking into account the extensive and growing literature on service experience, this research area is yet to be explored further.

The paper also investigates the interrelationships between the defined risk types using ISM and MICMAC. Pairwise analysis of risk interdependencies by a group of experts with experience in services provides a better understanding of the overall risk structure. Results of the ISM and MICMAC deliver a hierarchical and dependency-based model of risk relations as well as the main structure of risk dependencies. The findings show us that the risk types are highly interrelated. The ISM result indicates that external risks trigger the IT risks, and they directly affect the remaining financial, relationship, demand, service delivery, and operational risks. The MICMAC analysis result classifies external and IT risks as influential and all the others as dependent variables. While ISM provides the structural hierarchy of interrelationships between risk types, MICMAC helps us to describe the system based on the influence and dependence values of the risk types. The integrated ISM-MICMAC approach provides academicians and practitioners with a macro picture of the risks in SSCs.

To support and validate the theoretical findings, examples of risk events in services and the relationships between them have been further investigated via the case of an ERP consultancy services provider. Since IT and telecommunication services were listed as the second frequently studied the industry, the case offers a representative example of the risks faced in SSCs and their consequences. An analysis of the company’s experiences reveals that external, IT, and demand risks trigger the service delivery, financial, operational, and relationship risks. Demand risk can be either an influential or a dependent variable depending on the service industry and branch of activities.

Defining and categorizing risks would assist with risk management and enable us to develop ways to manage each particular risk type while considering their interdependencies. The provided structural model increases the awareness of decision-makers while providing them with a better understanding of the interdependency among different SSC risks and their consequences. In practice, this would be beneficial in risk identification and then in risk assessment, which in turn would facilitate the decisions about risk mitigation strategies.

Future research may consider weighing the risks defined in this study by applying various multi-criteria decision-making techniques in the literature that can be used to solve complex issues such as DEMATEL, cognitive mapping, Analytic Hierarchy Process, or Analytic Network Process. Another approach would be expressing the relationships between risks as fuzzy relationships. Additionally, although the risk definitions made in this study involve sub-categories, the expert evaluations of interactions between risk types were made at a higher level. This criticism represents both a limitation of the study and a direction for future research. Thus, a further study may consider analyzing the sub-categories as well as expanding them. Another future research may be focusing on a particular SSC and studying the structure of industry-specific risks in a more detailed way. Moreover, all relationships derived from the ISM could be formalized as propositions, and future research may test the validity of the propositions via statistical methods such as structural equation modeling.

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