

TEDARİK ZİNCİRİ RİSKLERİ: LİTERATÜR TARAMASI VE YENİ BİR SINIFLANDIRMA

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ÖZET

Risklerin belirlenmesi dirençli ve sürdürülebilir tedarik zincirleri oluşturmak ve proaktif risk yönetimi stratejileri geliştirmek için ilk adımdır. Tedarik zincirleri farklı form, olasılık ve etkiye sahip sayısız risk içermektedir. Tedarik zinciri riskleri çok boyutlu bir yapıya sahiptir ve talep ve tedarik değişkenliği, zayıf performansla sahip tedarikçiler, fiyat dalgalanmaları, dinamik tüketici pazarları, küresel ekonomik belirsizlikler ve hatta iş kazaları, siber saldırılar ve doğal afetler gibi beklenmedik olaylardan kaynaklanabilmektedirler. Tedarik zinciri riskleri iş kesintileri, finansal kayıplar, olumsuz şirket imajı ile insan sağlığına ve hayatına gelebilecek zararlara yol açabilmektedirler. Bu makalenin amacı tedarik zinciri ağlarındaki riskler ve kaynakları üzerine bir literatür taraması sunmak ve tedarik zinciri riskleri için kapsamlı bir sınıflandırma geliştirmektir. Önerilen sınıflandırma risk yönetimi çalışmaları için bir başlangıç noktası oluşturmaktadır ve uygulayıcılara riskleri belirlemede yardımcı olacaktır.

Anahtar Kelimeler Tedarik Zinciri Riski, Risk Sınıflandırması, Bozulma

SUPPLY CHAIN RISKS: LITERATURE REVIEW AND A NEW CATEGORIZATION

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ABSTRACT

Identification of risks is the first step to build a resilient and sustainable supply chain and develop proactive risk management strategies. Supply chains contain numerous risks with different forms, probabilities and impacts. Supply chain risks have a multi-dimensional nature and can result from a wide variety of sources including demand and supply variability, poor performing suppliers, price fluctuations, dynamic consumer markets, global economic uncertainty, and even unexpected events such as work accidents, cyber-attacks and natural disasters. Supply chain risks may cause business interruptions, financial losses, a negative corporate image and, damages to human health and safety. The purpose of this paper is to present a literature review on the risks and their sources in supply chain networks and develop a comprehensive categorization for supply chain risks. The proposed categorization provides a starting point for risk management and may assist practitioners in identifying risks.

Key Words: *Supply Chain Risk, Risk Categorization, Disruption*

1. INTRODUCTION TO SUPPLY CHAIN RISK

In today's dynamic and global market, Supply Chain (SC) networks have become more complex, dynamic and interconnected. The recent changes in the nature of SCs and increased dependency among firms increase the vulnerability of companies to unforeseen disruptions and cause companies to lose their adequacy to absorb these disruptions [1]. The factors causing SC risks, their relationship and possible consequences are very complex. The effects of a possible disruptive event may propagate quickly to the entire SC. All business processes and decisions are prone to uncertainty and risk surrounding them inherently. Companies should manage risk as well as efficiency and cost for sustainability and competitiveness. Supply Chain Risk (SCR) is a growing challenge in today's world. Supply Chain Risk Management (SCRM) gained attention especially in the late 1990s with the occurrence of major risk events and the evolution of sustainability concerns [2,3]. Some events occurred in the past highlighted the weaknesses of SCs for risk events and also broadened the definition of SCR.

Basically we can define SC risk as the potential (or probability of) occurrence of a failure, harm, damage or loss from unforeseen events [4,5]. There are some important terms that are often used synonymously instead of the triggering events of risks; uncertainty, disturbance, disruption, disaster, hazard, or crisis [6]. Understanding risks is the first step to build a resilient and sustainable SC and develop proactive risk management strategies [7]. SCR may result from a number of different events that are controllable/influencable or outside the control of the organization. SCRs have a multi-dimensional nature and can result from a wide variety of sources including demand and supply variability, poor performing suppliers, price fluctuations, dynamic consumer markets, global economic uncertainty, transportation of dangerous

products and even unexpected events such as work accidents, cyber-attacks, natural disasters and terrorism [7]. SC disruptions and vulnerabilities have a significant effect on SC's performance and sustainability. SC disruptions may result in various quantitative and qualitative consequences such as disruptions of SC operations, financial losses, a negative corporate image and, damages to human health and safety etc. [8-10]. Criticality of a risk event is generally measured by its probability, impact and detectability [10].

Supply Chain Management (SCM) literature is rich of studies that examine SCRs and provide models for SCRM [11-13]. Many researchers have tried to list SCRs [1,14], but the majority of the existing studies are based on case studies, empirical studies or specific contexts. Despite the increasing awareness on risks, conceptual frameworks on SCRs and risk management are insufficient [15]. There is a need for an extensive classification of SCRs incorporating social, organizational, regulatory, legal, deliberate, ethical, environmental and industry specific risks as well as traditional risks. This study contributes to this research gap by introducing a general comprehensive and multi-dimensional categorization for the uncertainties and risks in SCs.

There are hundreds of articles in SCRM literature. Since it is not possible to review all relevant articles in this study, this review is intended to develop a comprehensive categorization of SCRs and focused on the papers that contribute to develop the new classification scheme. The sources of risks are identified based on extant literature and, are refined or combined under determined headings. The main objectives through this study are listed in the following: i) explore the potential sources and root causes of risks in SC networks by reviewing the academic literature, ii) develop a comprehensive categorization for the sources of risks in the SC context in order to construct a holistic understanding and generalizability about SCRs; iii) investigate the research trends and

emerging risk areas. The proposed risk categorization may be used as a guide for providing insights for risk sources in SCs and their relationship, and support the risk identification step by strengthening the understanding of SCR.

The remainder of this paper is organized as follows: Section 2.1 gives an overview of the literature review. Section 2.2 introduces some of the SCR types from the literature. Section 2.3 presents literature review findings and the new categorization of SCRs. Finally Section 3 concludes the paper.

2. LITERATURE REVIEW

2.1. An Overview of Literature Survey

A literature review is conducted to identify different risks in SCs and provide a comprehensive understanding for SCR. This study aims to determine the most mentioned and studied risks in the reviewed articles and also develop a new categorization for SC risks. The searches are conducted via Science Direct, Emerald and IEEE online databases. “Supply chain risk” and “supply chain risk management” keywords are used for searching the titles, keywords and abstracts of articles. 284 journal articles on the SCR topic between 1998-2016 years are collected and screened. The aim of the study is to develop a comprehensive list of SCRs, hence the most relevant articles were filtered by considering the contribution of the article to the new SCR categorization. Also some references of the collected papers are reviewed. Finally, 65 articles were reviewed between 2000-2016 years and from 32 different journals. Figure 1 represents the number of reviewed articles according to year.

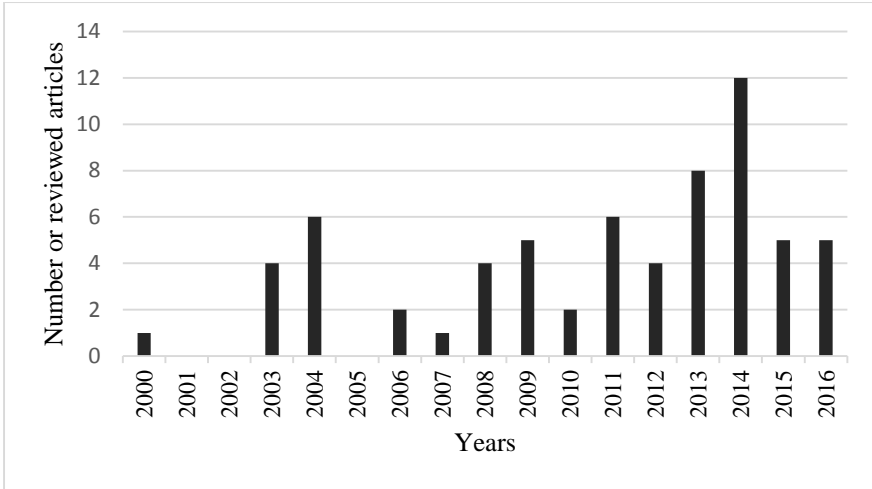


Figure 1. Number of reviewed articles according to year

Table 1 represents the most common keywords existing in the reviewed articles and their frequency. Most of the existing articles use different keywords, but risk management and SCM are the most common keywords in the reviewed articles.

Table 1. Most common keywords in the reviewed articles

Keywords	Frequency	Keywords	Frequency
Risk Management	27	Supply Chain Risk(s)	5
Supply Chain Management	23	Supply disruptions/risks	4
Supply Chain(s)	9	Supply Chain disruptions	4
Supply Chain Risk Management	8	Resilience	3
Risk	8	Sustainability	3
Uncertainty	6	Disruption(s)	3

Although many studies tried to list and classify SCRs, there is a need for a more comprehensive and a systematic categorization for risks. Therefore this study focused on determining possible sources of uncertainties in SCs and the risks emanating from them and developing a new categorization in order to generate a general overview of SCRs. The encountered risks and their root sources in the reviewed articles are recorded in an excel table. These risk sources are then combined and categorized under different risk categories.

2.2. Literature Review on Different Supply Chain Risks

Understanding risks and vulnerabilities is the first step to build a resilient and sustainable SC. There is an extant literature on SC

risks. Risks also take a great attention by organizations. There are a variety of online articles (in forums, consultancy firms ‘web pages etc.) and business reports about risks and their sources. The categorization of SCR is necessary in order to apply specialized strategies and methods to deal with each group of risks [15]. There is a vast amount of classifications for SCR based on different approaches both in the literature and the practical business life. Some of the existing classification approaches for SCR are given in Table 2. There are also various more exhaustive classifications in the literature [16-19].

Table 2. Risk classifications based on different perspectives

Perspective	Risk Classification	Reference
Origin	<ul style="list-style-type: none"> • Endogenous uncertainty • Exogenous uncertainty (Discrete events and continuous risks) 	Trkman and McCormack, 2009
Frequency	<ul style="list-style-type: none"> • Frequent risks • Infrequent (rare) risks 	Oke and Gopalakrishnan, 2009; Bradley, 2014
Cause	<ul style="list-style-type: none"> • Natural • Man-made disasters 	Sawik, 2013
Measure	<ul style="list-style-type: none"> • Quantitative risks • Qualitative risks 	Manuj and Mentzer, 2008
Duration	<ul style="list-style-type: none"> • Short-term risks 	Chopra and Sodhi,

	<ul style="list-style-type: none"> • Long-term risks 	2004 [54]
Controllability	<ul style="list-style-type: none"> • Controllable • Somewhat controllable • Uncontrollable 	Byrne, 2007 [53]
Source	<ul style="list-style-type: none"> • Environmental risks • Supply chain-related risks • Organisational risks 	Jüttner et al., 2003 [55]
Disrupted/ threatened field	<ul style="list-style-type: none"> • Material flow risk • Financial flow risk • Information flow risk 	Tang and Musa, 2011
Source	<ul style="list-style-type: none"> • Social risks • Legal risks • Political risks • Economic risks • Technical risks • Environmental risks 	Maclean-Bristol, 2008 [56]

SCRs may be classified based on various aspects such as frequency, impact, source and triggering factors. Basically, SCRs are classified as internal and external risks [5,20]. Internal SCRs arise from business operations within an organization and have a higher likelihood to occur than external risks [14]. External risks are generally seen rarely and most of them cannot be controlled by the focal firm or other members of the SC network [21]. These

risks may result from economical, sociopolitical, technological, natural or geographical reasons [14]. Similarly, [22] separated the sources of uncertainty as endogenous uncertainty and exogenous uncertainty. The sources of endogenous risks are embedded in the SC and include operational risk, financial risk, collaboration risk, strategic risk, information risk and market and technology turbulences [21, 22]. Market and technology turbulences that are usually neglected are analyzed under endogenous uncertainty. Political risk, regulatory risk, natural disaster risk and foreign exchange rate risk are examples to common exogenous risks [21]. Trkman and McCormack (2009) also divided exogenous uncertainty into two categories; discrete events (e.g. natural disasters, terrorist attacks, strikes) and continuous risks (e.g. inflation rate, raw material prices) [22]. Manuj and Mentzer (2008) classified SCRs as quantitative and qualitative. While quantitative risks refer to risk factors that are measured by objective numerical metrics, qualitative risks include factors such as reliability and precision of materials in the SC [9].

With respect to their frequency and impact, SCRs can typically be divided into two general categories: frequent (high likelihood, low impact) risks and rare (low-likelihood, high-impact) risks [10, 23]. SC disruptions may result from frequent risk events such as machine breakdowns or rare events such as natural disasters, strikes, wars and terror events. According to their empirical findings, Oke and Gopalakrishnan (2009) added an additional category to this classification; medium likelihood, moderate/medium impact risks (such as regulation risk). Managers generally overlook rare risk events, but they may cause to unsettling results and should be considered along with frequent risks (Bradley, 2014). Bradley (2014) compared frequent versus rare, catastrophic disruptions in SCs and considered the following difficulties of rare risks in his risk management framework; i) Some of them are unforeseen; ii) Probability estimates of these

disruptions and their impacts are imprecise; iii) Comprehensive data collection is impossible. Er Kara and Oktay Firat (2015) made a literature review to introduce the most-cited real life SCR events in the literature [3].

Similarly, risks in the supply chain can be classified as quantitative or qualitative. Quantitative risks include stock-outs (lost sales), overstocking, obsolescence, customer discounts, and/or inadequate availability of components and materials in the supply chain. Qualitative risks include lack of accuracy, reliability, and precision of the components and materials in the supply chain. Both qualitative and quantitative risks may create the need for atomistic or holistic evaluations of supply chains.

Manufacturers and service providers have to adapt themselves to varying customer needs and respond to changes in demand rapidly to survive in the competitive environment. Uncertain demand may lead to capacity shortage and capacity excess risks [24]. There exist many studies considering demand uncertainty [25-27]. Supply-demand imbalance is a major risk factor especially for the industries in which capacity is very expensive such as automotive sector [24]. Supply risk is more complex than demand side risk and it is one of the most studied risks in the literature since the late 1980s [8, 11, 28, 29]. Ambulkar et al. [30] asked 199 respondents to list a disruption that they have faced in the past year as a part of their questionnaire and, 62 of the reported disruptions were supply glitches, 42 were logistics/delivery glitches, 44 were in-house plant glitches and 51 were reported as natural hazards, regulatory issues, or political issues. Supply risk is an umbrella term that includes the factors affecting the inbound flow of goods or services; e.g. failure of suppliers, late deliveries, quality problems, financial instability of suppliers [8]. Supplier risk also includes the risks in the sub-tier level. Traditional SCM approaches generally regard this issue and

there are very few studies that consider the risk beyond the first tier [21].

Nowadays outsourcing and off-shore sourcing are popular trends for SCs. Companies may use manufacturers at low-cost and/or low-wage countries such as China or India and distributors in various locations to reach customers [31]. Outsourcing and offshore sourcing leads to additional dependencies between companies and cause more complex and susceptible supply networks [14]. Off-shore sourcing includes a great number of exogenous risk factors due to exchange rate, cross-national partnerships, political issues and cultural factors and hence it is more risky than domestic outsourcing [31, 32].

Recent technological developments and globalization of IT technologies bring new risks including cyber risk, system risk and technology adoption risk. Boyson [33] illustrated some examples of risks disrupting IT systems including cyber-attacks, unauthorized access, counterfeit products and sales, "report-back mechanisms" embedded to hard drives, malwares and viruses, fraud by employees, software integrity threats and regulatory risks.

Nowadays, the advances in computing and communication systems have resulted in increased collaboration between enterprises in the SC network in order to cope with increased competitiveness. However, data sharing has the potential to create risk in SC collaboration. Le et al. [34] examined the risk caused by sensitive knowledge leakage in retail SC collaboration and applied association rule hiding to remove a set of association rules to avoid risks before sharing the data. Tang and Musa [12] investigated the developments in SCRM literature and classified risks based on material, cash and information flows. The results of their literature survey show that there is a research gap for analyzing information flow risks. Transaction risks and lack of trust among the trading partners are other risk factors that affect the efficiency and

effectiveness of SC operations and collaborative performance [35, 36].

Financial risks has taken increased attention since the global financial crisis in 2007 [37]. Especially exchange rate uncertainty is one of the most important concerns of global companies [37]. Most of the studies in SCM area focus on the efficiency of physical and information flows in SCs. Tsai [38] focused on SC cash flow risks and developed a model to measure these risks with respect to some time-related risk factors such as lead time. Volatile and uncertain purchase price of raw materials, semi-finished goods, parts and other commodities is another risk source that threatens the business sustainability and continuity. Fischl et al. [39] made a literature review by specifically focusing on price risk as a supply risk. Mulhall and Bryson focused on energy price risk because of the increases and high volatility of the prices in the sector [40].

Today one of the key drivers for economic success is intellectual property that covers legally-protected rights such as patents, copyrights, trademarks and trade secret [41]. Managing intellectual property related risks is a growing challenge for companies in all industries. Outsourcing and off-shoring manufacturing operations may increase the risk of intellectual property leakage [16, 29].

There are always unforeseen disruptions present in SCs such as natural disasters, extreme weather conditions, diseases, wars, and terror events. These disruptions cannot be estimated imprecisely and arise without a warning. Unlike frequent disruptions, these rare disruptions generally cause severe/unsettling negative results. In recent years catastrophic events has gained increased attention by researchers [42, 43]. All of these risk events have low probability but they may cause to severe consequences [3]. The number of studies that incorporate extreme/catastrophic events in their study is very limited [10, 44- 46].

Deliberate acts are another kind of vulnerability factor. Pettit et al. listed piracy, theft, terrorism/sabotage, labor disputes, industrial espionage, special interest groups and product liability under deliberate threats heading [18].

Today many researchers from different fields incorporate sustainability issues, corporate social responsibility and green management practices in their studies [13]. Hofmann et al. integrated sustainability issues and SCR [47]. Giannakis and Papadopoulos identified 30 sustainability-related SCRs across the three main dimensions of sustainability (environmental, economic and social) [48]. According to them, different from typical SCRs, sustainability-related SCRs consider additional issues such as the effects on the nature, compliance with laws and corporate reputation. Child labor, healthy and safe working environments, unnecessary packaging, bribery and patent infringements are some examples to sustainability-related risks given in their study [48]. Lintukangas et al. performed an empirical study to examine the linkages between green supply management practices and different supply risks: property rights, image, outsourcing, quality and price [29].

There are also risks that arise from non-physical failures such as; false strategic decisions, inter-organizational strife, relational risks, unsatisfying and stressful work environment of the employee, culture of the company and damage to the reputation of the company etc [12, 49].

2.3. Literature Review Findings and Proposed Categorization for Supply Chain Risks

There are various classifications in the SCR literature, however most of the studies focus on some selected risk factors or the risks of a single organization. There is a need for a more comprehensive categorization of risks. This study tried to develop a multi-dimensional SC risk categorization by compiling some of the

related studies in the SCRM literature. SC risks and uncertainties and, their sources that are mentioned and studied in the reviewed articles are recorded in an excel table. The table contains the following columns: risk category, sub-heading/source of the risk, references that contain this risk type and the frequency of this risk. Approximately 800 different risk sources were identified and they were used in determining the proposed risk categories and sub-headings. This table is provided to facilitate the identification of disruptive events in SCs.

Figure 2 gives a list of the most frequent SC risks and uncertainties that appeared in the reviewed articles. Although the uncertainties vary according to the process, company or sector, some of them are mentioned in most of the studies.

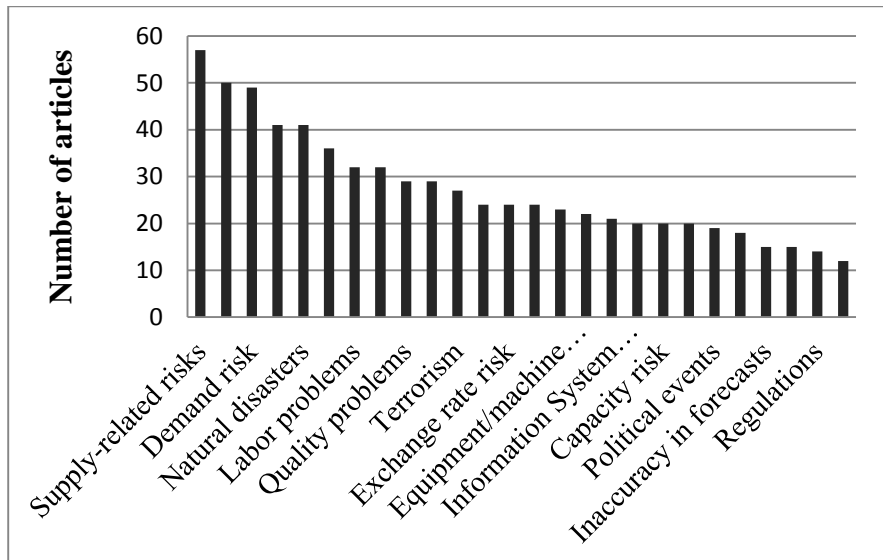


Figure 2. Main risk issues discussed in the reviewed articles

Most of the risks in Figure 2 are related and interconnected and some disruptions can be incorporated into more than one category. For example the failure of a machine that is used in the manufacturing of a part can be classified into both process and

technological risk categories. Also a disruption may cause other disruptions or even cause a ripple effect [15]. There are relations in both inter and intra- clusters. The sub-components of disruption sources may fluctuate by one or more. For example, an earthquake may affect only a supplier, or the entire suppliers, manufacturer and the customers.

There are numerous sources of risks in SCs, hence it is not possible to list all of the conceivable risks. We incorporated some of the related risk factors under a unique heading and developed a new categorization for SCRs based on their sources. Appendix A summarizes the main categories of SCRs and their sub-categories. The sources of uncertainties and risks in SCs are separated into 13 groups. Each risk category has its own triggering factors. Risks may arise from endogenous and exogenous sources. Endogenous sources contain the risks related with the firm, its suppliers and customers. Exogenous sources include economic, environmental, geopolitical, regulatory, regional and legal issues. The proposed categorization can be used as a guide to discover different types of disruptions. The table in Appendix A provides an integrated view of SCRs and their sources. These categories are not mutually exclusive. Some of the risks may be categorized in more than one class. Also SCR may arise as a combination of different risk types [9]. Some of the internal risks are specific to an individual sector or business function. Hence industry-related risks are added to the categorization.

Financial risks cover the risks associated with the monetary issues. Risks related with economic environment may be listed as; economic uncertainty, instability and volatility, weak economic climates, financial distress, and regional financial policy risks. Organizational risk category includes many types of risks at the strategic level. Management risk is related with corporate governance and management capabilities. Management risk sub-

category contains the following risks: i) strategic risks, ii) tactical risks, iii) policy risks, iv) operational decision risk, v) faulty planning and coordination procedures. Labor problems include human error, loss of workforce, employees' quality, poor working conditions and compensation, lack of motivation among employee, labor unrest, dispute, strike, lockout, picketing and lawsuit, union activities or industrial action, unfair wages, worker-management relationships, and occupational Health and Safety risks. Relational risks cover inter-organizational strife, lack of trust among the trading partners, cultural differences, insufficient interaction, cooperation, collaboration and communication, incompetent partners, unwillingness for information sharing, upstream and downstream invisibility and, availability and continuity of contact persons.

Supply risk is a multifaceted concept and associated with the threats to the availability of resources. Supply risk category includes various risks related with the shortage of resources, supplier failures, disruption/loss of a supplier, capacity and responsiveness of alternative suppliers etc. Manufacturing risks are associated with the threats and disruptions in the manufacturing processes. Operational risks cover process malfunction, complexity of process operations, poor operational utilization, breakdown of equipment/ machinery, equipment reliability and operational accidents. Production risks include production rate uncertainties, fluctuation of a production cycle, capacity risk and inadequate manufacturing or processing capability. Product related risks are related with product obsolescence, short product life cycles, new product development problems and product changes. Inventory risk includes two factors; inventory variability and inventory obsolescence, depreciation and deterioration.

Customer and market risks are the risks associated with losses of customers and market position. Demand risk is associated with uncertain demand and bullwhip effect. Market risk arise from

factors related with market characteristics and the focal company's position in the market: market volatility, loss of market share, market capacity constraints, competitive risk, time-to-market risk, market collapse, boycotts against a company's products, high uncertainty in new market entry and product introductions, customer service disruption, and financial strengths of customers. Quality problems include poor customer satisfaction, product safety failure and product recall issues.

Logistics and transportation risk category covers the risks related with the storage, packaging and delivery of goods. Transportation route risk sub-category include long distances, geographic risks, uncertain traffic conditions, blocked routes, border delays, port stoppage and cessation of airplane flights.

Technological risks arise from engineering, technological processes and technological development. Information systems failures are malfunction and instability of the system, system implementation and management problems, software integrity threats, Information Technology failures, Information System security and privacy risk, cyber-attacks, information flow risk, and fraud by employees. Information risk is associated with information inaccuracy, information distortion, information sharing problems, information outsourcing risk and lack of information transparency. Communication problems arise from unstable and inefficient communication networks and infrastructure, and difference in communication standards. Changes in technology refers to breakthrough scientific invention, quick technological advances, technology incompatibility and technological innovation in the industry.

Environmental risk category covers natural hazards and factors that threat environmental sustainability. Natural disasters can be listed as follows: earthquake, extreme weather and climatic conditions, volcanic eruption, wildfire, pandemics, outbreaks, and increased exposure to weeds and insect pests. Geopolitical risks are events

that directly and indirectly cause economic losses for the SC. This risk category includes government actions, geopolitical events and socio-economic factors linked to the business location or market. Regulatory, legal and bureaucratic risks arise from changes in laws, regulations and bureaucratic processes. Deliberate acts range from intellectual property theft to discrimination. Deliberate acts may cause to serious disruptions to an organization's activities. Industry-specific risks relate to the risks associated with a certain-industry. There are also some risks that are related with the structure of the supply network.

3. DISCUSSION AND CONCLUSION

SCR is a strategic issue that should be considered in the decision making processes of the companies. It is a multi-dimensional concept that covers a variety of triggering factors. A better understanding of the nature of SCR (and their relationships) increases the effectiveness of risk management actions and allocation of resources to these actions. The main purpose of this study is to explore the potential sources and triggering events of SCRs by reviewing the SCR literature and providing a comprehensive categorization for SCRs. 65 articles in the SCR literature between 2000 and 2016 years are reviewed. According to the literature review, the following results have been concluded:

- i) Various classifications exist for SCR in the literature, but most of the authors classified SCRs based on the sources and triggering factors [15, 16, 48].
- ii) Studies generally focus on frequent and low-impact risks but ignore low-frequent high-impact risks. Unavailability of sufficient data about rare risk events makes it very difficult to estimate the probability and impact of these events. Therefore, despite the awareness of rare risks, the number of studies that incorporate these risks in their SCR models is few.

- iii) Supply risk is the most studied risk in the SCRM literature [12, 22].
- iv) Past disruptive events highlighted the importance of considering the risks in other stakeholders including sub-tier supply networks [3]. Most of the studies in the literature focus on dyadic risk management and there is a need for studies that incorporate the risks in sub-tier supply networks.
- v) Outsourcing is a popular risk that has been studied in a lot of publications. Especially, the tendency of outsourcing to low cost countries increased this type of risk.
- vi) The supplier selection is a complex and stochastic optimization problem. A lot of studies in the literature studied on solving this problem under disruption risks [50,51]. The suppliers' risk and the turbulence of their environment should be considered in selecting and managing suppliers. Supplier selection in offshore sourcing is also much riskier than in domestic sourcing because there are exogenous risk factors influencing off-shore sourcing.
- vii) Interconnectedness in global SC networks can cause small and local events to grow and result in significant disruptions. Therefore collaboration and transparency across SC actors is very important. Collaboration and information sharing between SC members increase the visibility of risks. However they may also lead to new risks such as intellectual property risk, possibility of collaborators becoming competitors, and data security risk [35, 52].
- viii) Many researchers focus on risks associated with material flows. Another risk sources such as information flow risks should be considered in SCM decisions.
- ix) The developments in the computer science and information technologies increase the efficiency of SCM. However technology also brings new risks including IT system

failures, security risks, cyber risks and technology adoption risks.

- x) Risk attitude of companies have a great effect on SCRM decisions and the perception of SCR. Hence it should be considered in analyzing the risks in SCs.
- xi) Some researchers considered sustainability related risks in SCs [29, 47, 48,]. Besides traditional risks, sustainability-related risks incorporate additional environmental, social and economic issues including the effects of SC operations on the environment, sustainable use of natural resources, energy efficiency, human rights and corporate social responsibility.
- xii) Risk types are interconnected and should not be assessed in isolation from other risk events. However the number of studies that focus on the interrelationships between risks is very few. Researchers should consider this issue more especially to increase the efficiency of risk identification and monitoring steps.

Companies need to understand the holistic picture of the risk areas in their SCs to select and apply effective risk management strategies. Hence, this study combines a variety of significant risks under a comprehensive SCR categorization by reviewing the literature. The proposed SCR categorization has a great potential to provide a detailed and multidimensional insight to managers and academicians in the SCM area. Additionally, it may be used as a guide for managers to prioritize risks.

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APPENDIX A. PROPOSED CATEGORIZATION FOR SUPPLY CHAIN RISKS

<i>Financial Risks</i>	
<ul style="list-style-type: none"> • Risks related with economic environment • Cost/price risk • Liquidity and cash flow risks • Exchange rate risk • Financial crisis and recession • Volatility in energy prices • Changes in the GDP 	<ul style="list-style-type: none"> • Stochastic interest rate • Varying inflation rate • Funding risk • Trade credit risk • Tax risk • Varying tariffs and import fees • Uncertain yield
<i>Organizational Risks</i>	
<ul style="list-style-type: none"> • Management risk • Assets and infrastructure impairment risks • Intellectual property risk • Labor problems • Bankruptcy 	<ul style="list-style-type: none"> • Relational risks • Increasing bargaining power of suppliers and customers • Safety hazards • Corporate responsibility failures • International business risks
<i>Supply Risks</i>	
<ul style="list-style-type: none"> • Uncertain supply • Supply-demand imbalance • Supply disruptions • Supply quality problems • Supplier delivery problems • Supplier capability risk • Supplier capacity risk • Supplier dependency • Inadequate sourcing flexibility 	<ul style="list-style-type: none"> • Supply market risk • New supply network configurations • Poor communication and coordination with suppliers • Problems with supplier trust, loyalty, relations, reliability • Risks of sharing production information with suppliers • Risks in the sub-tier supply network
<i>Manufacturing Risks</i>	
<ul style="list-style-type: none"> • Operational risks • Production risks • Product-related risks 	<ul style="list-style-type: none"> • Inventory risk • Quality problems • Lead time uncertainty

<i>Customer and Market Risks</i>	
<ul style="list-style-type: none"> • Demand risk • Market risk • Quality problems in products and services • Financial strength of customers 	<ul style="list-style-type: none"> • Customer relations • Reputation, brand and image risk of the company • Order entry system failures
<i>Logistics and transportation risks</i>	
<ul style="list-style-type: none"> • Transport infrastructure inefficiency or failures • Transportation flexibility • Delivery disruptions and failures • Transportation route risks 	<ul style="list-style-type: none"> • Weather and climatic conditions • Poor packaging • Delivery of hazardous materials • Transportation labor related issues
<i>Technological Risks</i>	
<ul style="list-style-type: none"> • Information systems failures • Information risk • Communication problems 	<ul style="list-style-type: none"> • Changes in technology • Energy shortage and power outage
<i>Environmental Risks</i>	
<ul style="list-style-type: none"> • Natural disasters • Incompliance to environmental standards and regulations • Risks related to energy consumption 	<ul style="list-style-type: none"> • Waste management and environmental pollution • Deterioration of ecosystems • Accidental incidents
<i>Geopolitical Risks</i>	
<ul style="list-style-type: none"> • Political instability and unrest • Socio-demographic factors • Government policy uncertainty 	<ul style="list-style-type: none"> • Export/import restrictions • Terrorism • War • Coup

<ul style="list-style-type: none"> • Socio-economic risks • Trade restrictions
<p><i>Regulatory, legal and bureaucratic risks</i></p>
<p><i>Deliberate Acts</i></p>
<ul style="list-style-type: none"> • Theft, hijacking and vandalism • Sabotage • Ethical risk • Frauds and patent infringements • Counterfeiting • Child and forced labor • Exploitative policies • Lack of contract or insurance • Security breach • Spying and espionage • People-smuggling • Discrimination • Bribery • Criminal activity • Piracy
<p><i>Industry-specific risks</i></p>
<ul style="list-style-type: none"> • Industry capacity limits • Resource limits • Labor availability problems • Fierce competition in the sector • Industrial unrest • Technological innovations in the industry • Changes in industry regulations • Industrial accidents
<p><i>Risks related with the structure of the supply chain</i></p>
<ul style="list-style-type: none"> • Scale and extent of supply network • Geographical dispersion of the SC • Supply chain capacity risks • False designs on SC structure and operations