REPUBLIC OF TURKEY

ADANA ALPARSLAN TÜRKEŞ SCIENCE AND TECHNOLOGY UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

DEPARTMENT OF INDUSTRIAL ENGINEERING

Analysis of Supply Chain Risks by Structural Equation Model and Fuzzy Analytical Hierarchy Process

RABİA SULTAN YILDIRIM

MASTER OF SCIENCE

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ADANA 2020

I hereby declare that all information in this thesis has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all information that is not original to this work.

[Signature]

Rabia Sultan YILDIRIM

ABSTRACT

Analysis of Supply Chain Risks by Structural Equation Model and Fuzzy Analytical Hierarchy Process

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Supply chain risk management activities attempt to eliminate or minimize the effects of risks that businesses face or may encounter within the scope of supply chain activities. The main aim of this study was to define, decide, and prioritize the supply chain risk factors. In the content of the study, firstly, supply chain risks from the literature were gathered and the obtained risks were grouped and combined. Afterward, a summary of the risk table to be considered in the study was created. Secondly, a questionnaire was created to evaluate the risks in the created risk table, and evaluations were received from 391 users. According to the collected results, the main risks were evaluated statistically with the help of the Structural Equation Model (SEM), and then sub-risks were prioritized by the Fuzzy Analytical Hierarchy Process (Fuzzy AHP) method according to the model results. With the help of the obtained results, action plan suggestions have been developed for individuals and/or businesses in the supply chain over prioritized risks. Pareto Analysis was used to determine the sub-risks hosted by the main risks and the sub-risks that will be included in the action plan. According to the results of the study, supply and demand risks were obtained as the most important main risks; procurement cost; frequency of material design changes, inaccurate demand forecasts, risks arising from supplier, risks arising from the costumer, transit time variability, short lead times and product's life cycle risks were identified as the most important sub-risks in the action plan.

Keywords: supply chain risk management, supply chain risks, structural equation model, fuzzy, analytical hierarchy process, Pareto analysis

ÖZET

Analysis of Supply Chain Risks by Structural Equation Model and Fuzzy Analytical Hierarchy Process

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Tedarik zinciri risk yönetimi faaliyetleri, işletmelerin tedarik zinciri faaliyetleri kapsamında karşılaştıkları veya karşılaşabilecekleri riskleri ortadan kaldırmaya veya en aza indirmeye çalışır. Bu çalışmanın temel amacı tedarik zinciri risk faktörlerini tanımlamak ve önceliklendirmektir. Çalışmanın içeriğinde ilk olarak literatürden tedarik zinciri riskleri elde edilmiş, daha sonra elde edilen riskler gruplandırılmış ve birleştirilmiş ve çalışmada dikkate alınacak bir özet risk tablosu oluşturulmuştur. İkinci olarak, oluşturulan risk tablosundaki riskleri değerlendirmek için bir anket oluşturulmuş ve 391 kullanıcıdan değerlendirmeler alınmıştır. Toplanan sonuçlara göre temel riskler, Yapısal Eşitlik Modeli (YEM) yardımıyla istatistiksel olarak değerlendirilmiş ve model sonuçlarına göre Bulanık Analitik Hiyerarşi Süreci (Bulanık AHP) yöntemi ile alt riskler önceliklendirilmiştir. Elde edilen sonuçların yardımıyla, tedarik zincirindeki bireyler ve / veya işletmeler için öncelikli riskler konusunda eylem planı önerileri geliştirilmiştir. Eylem planına dahil edilecek ana riskler ve alt risklerden hangilerinin barındırdığını belirlemek için Pareto Analizi kullanılmıştır. Çalışmanın sonuçlarına göre, en önemli ana risk olarak arz ve talep riskleri olarak belirlenirken; procurement cost; frequency of material design changes, inaccurate demand forecasts, risks arising from supplier, risks arising from costumer, transit time variability, short lead times and product's life cycle riskleri eylem planında en önemli alt riskler olarak belirlenmiştir.

Anahtar Kelimeler: tedarik zinciri risk yönetimi, tedarik zinciri riskleri, yapısal eşitlik modeli, fuzzy, bulanık analitik hiyerarşi süreci, Pareto analisi

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NOMENCLATURE

SCM	Supply chain management
SEM	Structural equation model
MCDM	Multi-criteria decision making
AHP	Analytical hierarchy process
F-AHP	Fuzzy analytical hierarchy process
TOPSIS	Technique for order preference by similarity to an ideal solution
U.S.	United States
IT	Information technology
MS	Microsoft
SPSS	Statistical package for the Social Sciences
AMOS	Analysis of a moment structures
α	Alpha
H	Hypothesis
CMIN/df	Minimum discrepancy per degree of freedom
RMSEA	Root mean squared error approximation
NFI	Normed fit index
CFI	Comparative fit index
IFI	Incremental fit index

1. INTRODUCTION

1.1.Supply Chain Management

The supply chain management section aims to describe the definitions of the supply chain and supply chain risk management, the structure and members of the supply chain, the management processes of the supply chain, the purpose and the benefits of the supply chain management, and the measurement of the supply chain performance. The first section consists of four subsections, which include supply chain, supply chain management, the purpose and benefits of the supply chain management, and the supply chain performance.

1.1.1. Supply Chain

The main purpose of previous supply chains was to maximize productivity by meeting customer needs (Sunil Chopra and Meindl, 2001). With globalization, the supply chain has started to increase its efficiency in many fields of the supply chain.

In this section, the concept of the supply chain will be examined in two subsections. Firstly, the definitions of the supply chain in the literature will be examined and secondly, the structure and the members of the supply chain will be explained.

1.1.1.1. The Definition of Supply Chain

In literature, there is a wide variety of definitions regarding the supply chain. Some of those definitions were explained as:

- The supply chain is the connection between the raw material supply, the production, and the delivery of the final product to the end customer (Lowe, 2002).
- The supply chain can be described as a logistics network (Simchi-Levi et al., 2008)
- The supply chain is the concept adopted by companies providing a product or service to the market (Lambert et al., 1998).
- The supply chain is a network of organizations consisting of the suppliers, the manufacturers, the logistics service providers, the wholesalers/distributors, and the retailers aiming to produce and deliver products and services to the end customer (Sodhi and Tang, 2012).
- The supply chain is the network of organizations creating value and product and service through different connections and additionally perform different processes and activities for the end customer (Christopher and Peck, 2004).

- The supply chain is a network of interrelated units that aim to ensure customer satisfaction (Chapman et al., 2002).
- The supply chain consists of a series of activities and organizations that provide the delivery of materials from the first supplier to the end customer (Waters, 2011).
- The supply chain is a network of services and activities that fulfill product development, material supply from vendors, movement of materials between different facilities, the manufacture of products, and the distribution of finished products to the end customer (Mabert and Venkataramanan, 1998).
- The supply chain is expressed as all the activities related to ensuring the flow and transformation of goods, services, and information from the supply of raw materials to the end-user (Ballou et al., 2000).
- The supply chain is the network of partners who turn raw materials into end products valued by end customers and who manage returns at any stage (Harrison and Van Hoek, 2008).
- The supply chain is a complex network consisting of different players and created to minimize costs, maximize value, and discovering new markets by effectively managing the relationship between its members (Singhal et al., 2011).
- The supply chain consists of all parties, including the manufacturers, the suppliers, the forwarders, the retailers, and the end-users involved directly or indirectly in the process to fulfill customer demand (Sunil Chopra and Meindl, 2001).

Based on the definitions above, the supply chain can be defined as an integrated network enabling the product to reach the end-user from the first supplier. The purpose of the supply chain is to provide a connection between the production and the distribution channels to meet customer needs (Kuei et al., 2001).

1.1.1.2. The Structure and Members of Supply Chain

A standard supply chain is very complex and consists of the suppliers, the manufacturers, and the customers (Kuei et al., 2001). Supply chains are generally simplified as chains covering the supplier's supplier and the customer's customer. In reality, however, the supply chain is a network of organizations with the ability to react to changes in different characteristics (Wieland and Wallenburg, 2012).

The supply chain can be divided into three different categories according to the degree of its complexity (Mentzer et al., 2001); the direct supply chain, the extended supply chain, and the ultimate supply chain.

The structure and members of the supply chain were described below in figures 1a, 1b, and 1c. The direct supply chain consists of one supplier and one customer, being simpler than extended and ultimate supply chains. The direct supply chain is a structure consisting of an organization located in the center, and a customer and a supplier with a flow of material, among them service finance and /or information. The difference between the extended supply chain and the direct supply chain is the addition of the suppliers of the primary supplier and the customers of the primary customer in the extended supply chain. The ultimate supply chain encompasses material, service finance, and/or information flow from the first supplier to the end customer.

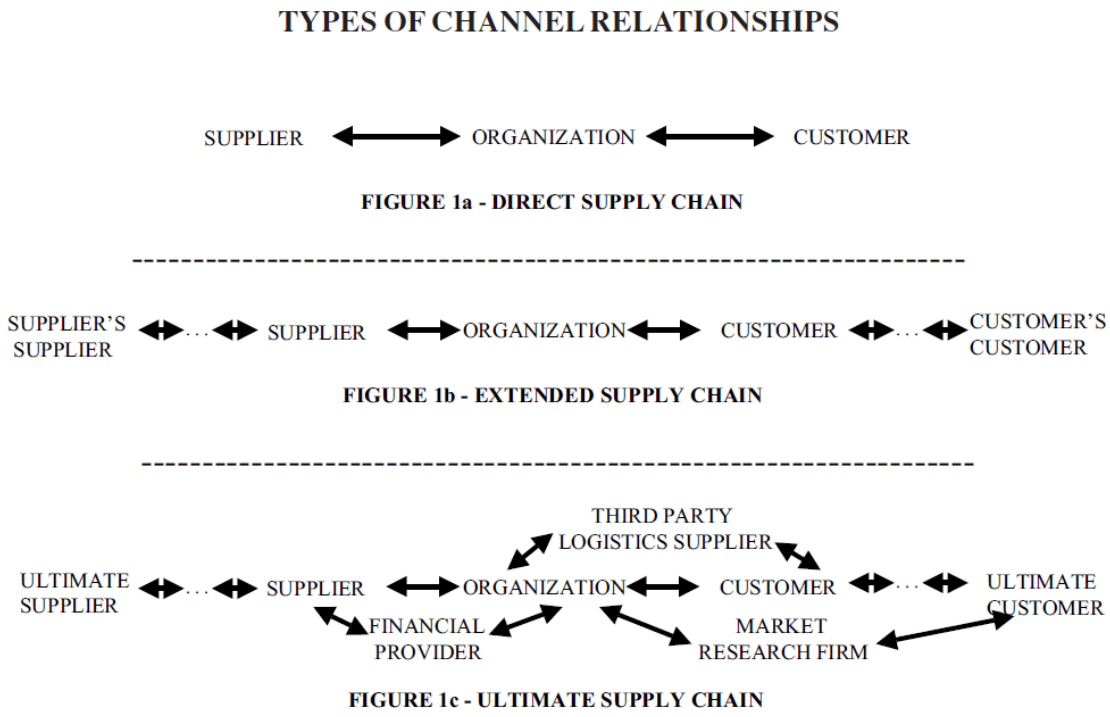

Figure 1. Types of channel relationships (Mentzer et al., 2001). (a) The direct supply chain. (b) The extended supply chain. (c) The ultimate supply chain.

1.1.2. Supply Chain Management

1.1.2.1. The Definition of Supply Chain Management

The concept of a supply chain management took place in literature for the first time in the mid-1980s (Cooper et al., 1997). However, assumptions based on supply chain management such as inter-organizational relations, researching system integration, sharing information, and inventory are much older (Cooper et al., 1997).

Although the definition of supply chain management differs among authors, according to (Mentzer et al., 2001) it can be divided into three categories; management philosophy, management philosophy application, and management processes series.

Supply chain risk management was described in the literature in different ways. Some of these definitions were given below.

- Supply chain management is the coordination and management of the products/services flow, information, and money from the supplier's supplier to the customer's customer (Kumar et al., 2012).
- Supply chain management is the management of a downward and upward relationship between suppliers and customers to create value in the market as a whole, at a lower cost (Christopher, 2016).
- It is the management of material, information, and financial flows along the supply chain (Sodhi and Tang, 2012).
- Supply chain management is the management of supply chain assets, products, and information and money flow to maximize the profitability of the entire supply chain (Sunil Chopra and Meindl, 2001).
- Supply chain management is the planning and control of all business processes from the raw material supplier to the end customer and keeping the supply chain members together to meet the needs of the end customer (Harrison and Van Hoek, 2008).
- Supply chain management defines the integration of all supply chain activities within and outside the firm (Ballou et al., 2000).
- Supply chain management coordinates all processes in the supply chain and gathers them in a perfect process (Lummus et al., 2001).

- Supply chain management is the management of procuring raw materials, converting them into semi-finished and final products, and delivering the product through the distribution system (Heizer and Render, 1993).
- Supply chain management is the network of tools that fulfill the functions of the material supply, the conversion to semi-finished and finished products, and the distribution of finished products to the customer (Lee and Billington, 1993).

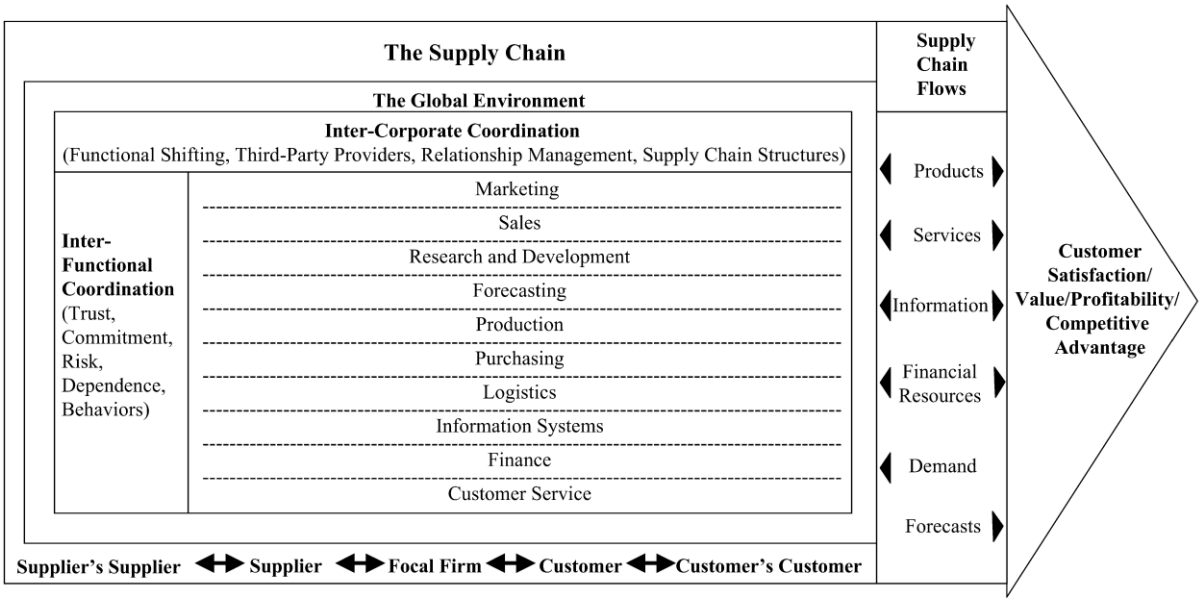

Figure 2. Supply Chain Management Model (Mentzer et al., 2001).

The conceptual model of supply chain management is shown in Figure 3 above. It can be thought of as an interconnected network system of product, service, financial resources, demand, forecasting, and information flows in the supply chain. This supply chain network system, consisting of marketing, sales, research and development, forecasting, production, purchasing, logistics, information systems, finance, and customer service, manages this network from suppliers of suppliers to customers of customers to provide added value to traditional business processes, to obtain competitive advantage and ensure customer satisfaction (Mentzer et al., 2001).

1.1.2.2. Supply Chain Management Processes

Supply chain management consists of the processes associated with each other. Continuity of the supply chain without interruption depends on the execution of supply chain management processes. Supply chain management processes were listed in the eight following sections (Croxton et al., 2001).

- Customer Relations Management
- Customer Service Management
- Demand Management
- Order Fulfillment Management
- Manufacturing Flow Management
- Supplier Relationship Management
- Product Development and Commercialization
- Return Management

Customer relationship management ensures the establishment and maintenance of relations with customers. This way, businesses determine customers and customer groups with customer relations management and include these customers in the company's mission (Croxton et al., 2001). Customer relations management conducts the relations among a company and its customers. The aim of the customer relations management ensures the satisfaction of the customer in all respects from order fulfillment to the service after-sales.

The customer service management process is applied to eliminate situations that will adversely affect the customer by taking proactive action (Bolumole et al., 2003). The main purpose of the customer service management is to solve any problems that may arise during the order fulfillment, delivery and following processes of the products and services offered to the customer before they can affect the customer (Lambert and Schwieterman, 2012).

Customer service management is the direct connection of companies with their customers. With this management process, customers can access information such as product order, delivery dates, and order status. Customers get information about the company's processes such as production and logistics, with real-time information (Croxton et al., 2001).

Demand management is the process that enables the business to meet the demand of the customers. This process ensures that demand forecast works in harmony with other supply

chain functions. Demand management also manages preventive action plans so that the business is not affected by potential problems (Croxton et al., 2001).

Good management of demand minimizes unforeseen factors, and stock quantity is reduced by ensuring that customer demand and production work in balance (Lambert and Schwieterman, 2012). This way, the cost opportunity is provided by mitigating the results generated through unforeseen factors and a big quantity of stock.

The order fulfillment process involves many steps barring getting orders from the customer. Croxton et al. (2001) determined the steps of the order fulfillment progress as following; product research, sales quota, order configuration, order reservation, order confirmation, billing, order planning, order changes, preparation of the order, forwarding, tracing, delivery and return. All departments within a company need to work in harmony for good order fulfillment and also to ensure good customer satisfaction.

Manufacturing flow management enables businesses to meet different customer product demands in a short time and at a reasonable cost by providing flexibility to the production. All factors in the supply chain should be taken into consideration to add flexibility to production (Lambert and Schwieterman, 2012).

Manufacturing flow management forces companies to make decisions in specific areas to determine their manufacturing strategies (Harland, 1994). These strategy decision categories were described below.

Table 1. Manufacturing Strategy Decision Categories (Harland, 1994).

Category	**Definition**
Capacity	Amount, timing and type
Facilities	Size, location, specialization
Technology	Equipment, automation, linkages
Vertical integration and sourcing	Direction, extent, and balance
Workforce	Skill level, wage policies, employment security
Quality	Defect prevention, monitoring, intervention
Production planning/materials control	Sourcing policies, centralization, control decision rules
Organization	Structure, control/reward systems, the role of staff groups

Supplier relationship management enables the reduction of costs, the predictability and sustainability of the purchase, the increase in customer satisfaction by collaboration with the supplier, an increase in competition and reputation, and the selection and management of new suppliers (Choy et al., 2003).

The purpose of supplier relationship management is to develop partnership relationships with key suppliers to reduce costs, develop new products and increase the value for both the supplier and the company through long-term cooperation, When evaluating supplier relations, the following business functions are taken into consideration (Lambert and Schwieterman, 2012): Marketing, sales, finances, production, purchase, logistics and research/development.

The product development and commercialization process require the cooperation of the customers and the suppliers to get the product into the market as soon as possible. Developing the product in a short amount of time and putting it on the market quickly provides continuous competition to the company (Lambert, 2008).

Product development and commercialization process managers must comply with the following statements (Lambert and Cooper, 2000).

- They should work in coordination with the customer relations manager to correctly determine customer needs.
- They should select appropriate supplier selection and supply material for the correct procurement.
- They should develop production technology to ensure continuity in production.

Effective return management is important in supply chain management to ensure continuous competition. This way return management contributes to the enterprises to develop new projects and increases efficiency (Croxton et al., 2001).

Returns management increases customer satisfaction and the profit margin by reducing the return on products. Returns were reviewed in five categories; consumer returns, marketing returns, returns on assets, product recalls, and environmental returns (Rogers et al., 2002).

1.1.3. The Objectives and Benefits of Supply Chain Management

The objective of supply chain management is to ensure efficiency balance while increasing profitability, to ensure that products and materials are transferred to the necessary places on

time and completely, and most importantly, to increase the profitability of the supply chain (Manuj and Mentzer, 2008b).

Supply chain management objectives are stated below as in the business books (Baki, 2004).

- To ensure uninterrupted material, service, and information flow to ensure a smooth production.
- Minimizing inventory costs and losses.
- Sustaining product quality.
- Finding and sustaining reliable suppliers.
- Standardizing the provided services and materials.
- Ensuring the required service and material at the lowest cost.
- To increase the bargaining power and competitiveness of the company.

A good supply chain provides a cost and value advantage to a company, ensures differences from its competitors, and minimizes process costs. With supply chain management practices, all chain steps are reviewed, and productivity is increased, thereby minimizing production and product costs. As a result, the cost advantage is achieved. Thanks to effective supply chain management, companies will be able to better understand the demands of the customers and thus make the necessary improvements. With improvements, the value advantage is achieved (Christopher, 2016).

There are some benefits in supply chain management such as minimizing transit time, responding to the material design changes. The benefits of supply chain management were determined by the Supply Chain Management Professionals Council as following (Oygür, 2011):

- Improving delivery performance,
- Decreasing inventories,
- Shortening of the cycle time,
- Increasing prediction accuracies,
- Increasing efficiency along the chain,
- Decreasing costs along the chain,
- Increasing capacity realization rate.

1.1.4. Supply Chain Performance

Performance measurement is an application that enables companies to effectively maintain resource use to manage their targets at a strategic dimension and to ensure continuous control (Ramaa et al., 2009).

Performance measurement serves different purposes in companies. Some of these supply chain performance measurement objectives are listed below (Parker, 2000).

- Determination of success,
- Questioning whether customer needs are met or not,
- Questioning the organizations whether they know their processes fully or not,
- Identifying where problems, bottlenecks, and waste occur and where improvements are required,
- Making sure that the decisions are based on real information rather than assumptions, feelings, beliefs or intuitions,
- Questioning whether the developments are proceeding as planned.

Performance measurement is made before any productivity increase or improvement work is carried out in the enterprise. The reason for performing a performance measurement first is because improvement can only be made if the points with low performance are detected (Orel and Akkan, 2018).

With supply chain management, businesses gain advantages in many ways like low cost, increased income, and less defective products (Deshpande, 2012). There are also reasons for measuring and evaluating supply chain performance, like better decision making, better communication, performance feedback, and motivation (Monczka et al., 2015).

In Table 2 below, several studies in literature for the measures of supply chain performance were listed.

Table 2. Identification of SCM (supply chain management) performance measures used different studies (Deshpande, 2012).

Authors	Supply chain performance measures
(Beamon, 1999)	Resource, output and flexibility measures Resource measures include inventory level, cost, energy usage, personnel requirements, and equipment utilization. Output measures include customer satisfaction, product quality, the time required to produce a particular item or set of items; and the number of on-time deliveries. Range and response flexibility.
(Jayaram et al., 2000)	Delivery speed, delivery reliability, new product introduction, new product development time, manufacturing lead-time, and customer responsiveness.
(Chan et al., 2003)	Cost, time, capacity, flexibility, capability, productivity, outcome, and utilization.
(Lockamy and McCormack, 2004)	Cost, quality, efficiency.
(LaLonde and Pohlen, 1996)	Cost of ownership and cost of productivity.
(Bechtel and Jayaram, 1997)	Total response time, customer responsiveness.
(Zailani and Rajagopal, 2005)	Quality (includes the ability to deliver products in time and meeting delivery times), delivery speed, delivery reliability, customer relationships, flexibility.
(Christopher and Towill, 2000)	Quality, cost, lead-time, and service level.
(Agarwal and Shankar, 2002)	Lead time, cost, and service level.
(Stewart, 1995)	Delivery performance, flexibility and responsiveness, logistics cost, and asset management.
(Gilmour, 1999)	Customer relationship, customer segmentation, order taking process, order tracking system, and customer satisfaction.
(Gunasekaran et al., 2001)	Supply chain management performances at three different levels are as below: * Strategic: Customer query time level of customer perceived value of product, order lead time, the flexibility of service systems. * Tactical: Product development cycle time, purchase order cycle time, planned process cycle time, delivery reliability, responsiveness to urgent deliveries, the effectiveness of distribution planning. * Operational: Capacity utilization.
(Morgan, 2004)	Cost performance, customer service, quality, operational productivity

1.2. Supply Chain Risk Management

1.2.1. Risk

The risk is the possibility of an unpredictable element causing harm to the organization (Waters, 2011). Organizations are uncertain about whether they can achieve their goals regardless of their activity or capacity. It is defined as a risk in the problems that this uncertainty will bring (Standardization, 2009).

Risk was described by several authors in the literature. Some of these definitions were listed below in Table 3:

Table 3. Definition of risk (Faisal et al., 2007).

Authors	Definition
(Mitchel, 1999)	Risk is commonly assumed as reflecting variation in the distribution of possible results and the objective effects.
(Harland et al., 2003)	Risk is commonly described as a danger, damage, loss, and others and defined as the change in undesired results.
(Norrman and Jansson, 2004)	Risk is the quantitative change of a defined and occurred hazard.
(Spekman and Davis, 2004)	Risk is defined as the probability of occurrence of an expected situation.
(Sinha et al., 2004)	Risk is an action of the uncertainty level and effect of an event.
(Yang and Qiu, 2005)	Risk is a relative issue and depends on probability.
(Aven et al., 2007)	Risk is defined as the synthesis of possible consequences and linked uncertainties.

According to the risk definitions, risks are divided into the following groups (Kurumsal Risk Yönetimi, 2008).

- Risk as an average result: It is the definition of risk depending on whether it resulted as expected.
- Risk as a difference between results: According to this definition, risk management aims to minimize the differences between expected and actual results.
- Risk as to a loss: It is the narrowest comprehensive definition of risk, expressing risk as loss. According to this definition, the risk is the conclusion of the events with a large negative effect due to various reasons.

- Risk as a potential earning factor: Risk is often considered a negative situation, but the risk is also seen as a source of earnings. The concepts of "risk" and "gain" are interrelated. For this reason, the risk is not only a negative situation that should be eliminated but also a factor that will provide significant gain when evaluated correctly.
- Risk by their respective areas: When trying to standardize risks in general, more than one risk arises, and the actual outcome of each risk is different.
- For the groups involved: The different interest groups look to have different parameters for identifying, understanding, and interpreting risks. Clear and precise definitions must be made for all risk groups for each risk.

The concept of risk includes three main components (Pritchard and PMP, 2014). These were listed below:

- A possible event in the future,
- The probability of occurrence of the event,
- Impact in case of occurrence.

While the concepts of risk and uncertainty are thought to have the same meaning, there are differences between the two as the two concepts are given together with the possibilities of possible events that may occur in the future (Waters, 2011).

Risk management activities are mostly based on three main items, these being the identification of risks, the analysis of their results, and the implementation by taking the most appropriate measures. Also, increasing awareness of the companies about risks and taking measures against these risks are important activities in risk management. Risk management activities should be taken into consideration in the decision-making activities of the companies and applied to manage future uncertainties (Waters, 2011). In Figure 3, below the basic processes of risk management activities were shown:

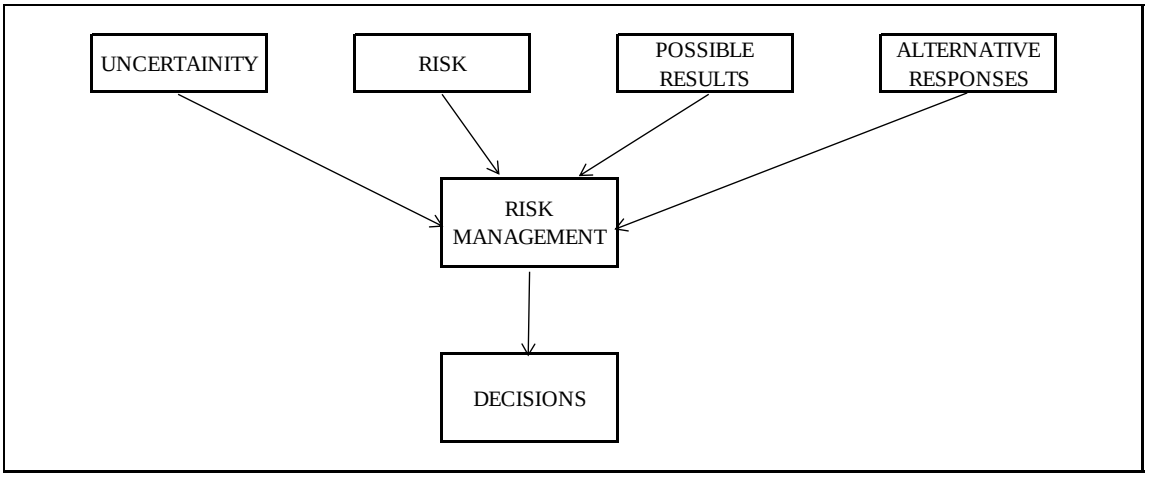

Figure 3. Basic Processes of Risk Management (Waters, 2011).

As seen in Figure 3, risk management processes include the following factors (Waters, 2011):

- Decision maker: Risk manager,
- Purpose: To deal with uncertainty and risk,
- Different alternatives: Suitable measures to be taken against risky situations,
- Decision: Choosing the most appropriate answer,
- Incident/Situation: Risky events and situations that occur,
- Consequences: Effects of risky events and responses.

Generally, an organization's risk management process consists of four stages (Hallikas et al., 2004):

i. Identification of risks: Identification of risks is the first basic step in the risk management application. Thus, the events that cause uncertainty are determined by defining the risks. The main purpose of identifying risks provides action planning for organizations, predicting future uncertainties.
ii. Assessment of risks: Assessment and prioritization of risks are necessary to determine the appropriate risk management activity for the identified risk factors.
iii. Risk management activities: Risk management activities generally include sub-factors such as risk transfer, risk-taking, and risk-mitigating.
iv. Observing Risks: Risks are constantly changing because the organization is dynamic. Since changes are observed in the probabilities and outcomes of the identified risk

factors, it is important to identify these changes and apply the risk assessment according to current changes.

1.2.1.1. Supply Chain Risk

In this section, the definition of supply chain risk, sources, and types of supply chain risks will be explained.

Supply chain risks were first used by Kraljic (1983). In his study, he evaluated the supply risks in terms of availability of materials, number of suppliers, competitive demands of making or buying opportunities, storage risks, and substitution possibilities. He determined that the risks occurred due to a lack of supplier, speed of technology, material substitution, entry barriers, logistic costs/complexity, and monopoly/oligopoly situations.

Supply chain risk is the concept that directly affects the supply chain and causes it to be interrupted (Ghadge et al., 2012). Some of the definitions of the supply chain risk in the literature were listed below:

- Supply chain risks are defined as the negative deviation in the results of a performance measure determined for an organization (Wagner and Bode, 2008).
- Supply chain risks are potential changes in results that cause a decrease in value-added anywhere in the supply chain (Bogataj and Bogataj, 2007).
- Supply chain risks are the potential loss of supply chain efficiency in terms of the expected target as a result of changes due to uncertainty (Heckmann et al., 2015).
- Supply chain risk is inaccuracies and disruptions in material and service supply (Zsidisin et al., 2000).
- Supply chain risk is the risks that occur in the flow of information, materials, and products in the process of the final product from the first supplier to the end customer. Supply and demand are not balanced because processes are affected (Jüttner et al., 2003).

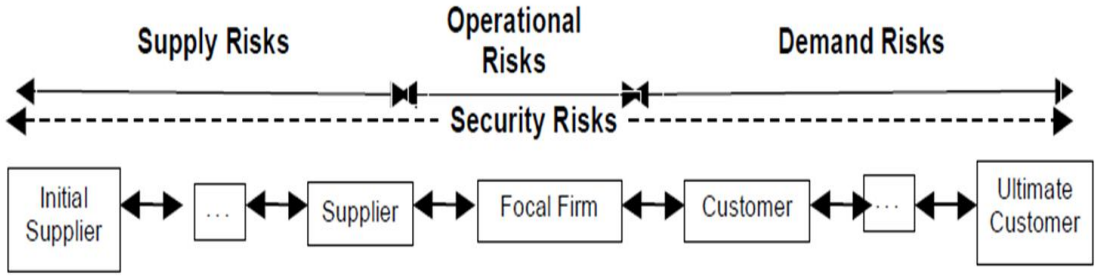

Figure 4. Risk in the extended supply chain (Manuj and Mentzer, 2008a).

In Figure 4, there are risks in the supply chain process. Accordingly, supply risks occur due to deterioration in access to supply, inventory, and technology, price increases, quality problems, technological uncertainty, product complexity, and frequency of material design changes. Operational risks include discontinuation of operations, inappropriate production or processing capacity, high level of process changes, technology change, and exchange rate risk. Factors such as new product launches, changes in demand, and bullwhip effect create demand risks. Security risks include information systems security, infrastructure security, terrorism, vandalism, and sabotage caused by load losses (Manuj and Mentzer, 2008a).

Risk is often defined as the possibility of an unexpected event damaging the organization. In practice, there are a variety of risks, ranging from risks that have an insignificant impact on the supply chain to those that cause very significant damage (Waters, 2011).

Some of the supply chain risk classifications in literature were listed in Table 4 below.

Table 4. Risk sources in the supply chain in the literature (Akkan, 2014).

AUTHORS	RISK SOURCES
(Ritchie and Marshall, 1993)	Environmental risks
	Industrial factors
	Organizational factors
	Factors related to specific problems
	Factors related to decision-makers
(C. S. Tang, 2006)	Operational risks
	Distortion risks
(Sinha et al., 2004)	Standards
	Suppliers
	Technology

	Applications
(Finch, 2004)	Application-level risks
	Organizational level risks
	Inter-organizational level risks
(Faisal et al., 2007)	Information security/corruption risks
	Forecast risks
	Intellectual capital risk
	Information technology/risk of outsourcing the information system
(O. Tang and Musa, 2011)	Material flow risk
	Financial flow risk
	Information flow risk

Ritchie and Marshall (1993) categorized risk sources as an environmental risk, industrial factors, organizational factors, factors related to specific problems, and factors related to decision-makers. Tang (2006) determined two risk sources, which were operational and distortion risks. Risk sources were grouped as standards, suppliers, technology, and applications by Sinha et al. (2004). Finch (2004) categorized supply source risk as application-level risks, organizational level risks, and inter-organizational level risks. Risk sources were categorized as information security/corruption risks, forecast risks, intellectual capital risk, and information technology risks by Faisal et al. (2007). Additionally, risk sources were identified as material flow risk, financial flow risk, and information flow risk by Tang and Musa (2011).

Risk sources were grouped into three categories listed below (Deloach, 2000):

- Outsourced or environmental risk occurs when there are external forces such as competitors, customer needs, technological innovations, political, legal, regulatory, financial markets, and disasters that can affect the performance of a firm or neutralize its different choices.
- Internal-sourced or process risk appears when business processes fail to achieve the goals set for operations, authorization, information processing, price, liquidity, and credit.
- Decision-driven and information risk occurs when the information used to support business decisions related to pricing, contracts, metrics, business reporting, and environmental/strategic issues are incomplete, outdated, incorrect, and late.

It was also stated that risk is changing, and risk groups are interconnected; some risk factors could be the pioneer or supportive power of other risk factors (Deloach, 2000).

When decisions are made in business management, these decisions are considered to include risks. When the importance of the decision is increased, the risk is also increased. Risks in the supply chain can be divided into the following three main categories in terms of their impact on the business (Leenders et al., 2001).

- Operational level risks are those that interrupt product or service processes. Operational risk is the potential change of results related to adverse events that affect the success of a firm in terms of factors such as profitability, quality, and timeliness (Christopher and Peck, 2004). Each organization creates action plans against cuts and delays that may occur. Factors such as weather conditions, accidents during transportation, and deviations in times cause interruptions in product or service processes. Choosing the right supplier reduces the factors that cause interruptions. Establishing strong supplier relationships in the supply of critically important products is important to avoid problems in the product or service process (Leenders et al., 2001).
- Financial level risks are directly linked to changes in prices of goods or purchased services. The simplest example of this type of risk is commodity markets. The change in wood prices directly affects the prices of furniture and wood products and services. Fluctuations in foreign exchange rates, inventory shortages, cuts in supply, tax rates, and customs fees also affect prices. Decreases in sales that may occur in the supply chain and an increase in costs directly affect the organization. That's why the internal processes of the organization and the management of risks arising from customers and suppliers must be maintained very well (Leenders et al., 2001).
- Reputation risk is more important for organizations than operational and financial risks because losing a company's reputation can lead to far more significant negative consequences. A situation that does not comply with the laws that may be experienced in the supply chain may cause the company to lose its reputation. For this reason, every member of the supply chain directly affects the reputation of a business. At the same time, the attitudes of the supply chain employees in the organization have an impact on the

organization. Many factors such as poor quality of the products and services sold in the media, insensitivity to the environment, or wrong environmental policies, working with unethical suppliers affect the organization in a bad way. (Leenders et al., 2001).

The supply chain types were given above according to Leenders et al. (2001), but each author-defined supply chain types differently. In the literature review section, the supply chain risk types will be examined in detail.

1.2.2. Supply Chain Risk Management

1.2.2.1. Supply Chain Risk Definition, Resources, Types, and Processes

Supply chain risk management creates strategies for the management of daily and extraordinary risks occurring in the supply chain (Wieland and Wallenburg, 2012). Jüttner et al. (2003) and Hauer (2003) defined supply chain risk management for the first time in literature. Hauer (2003) defined supply chain risk management as managing processes at low cost and efficiently by prioritizing product quality and customer satisfaction. Jüttner et al. (2003) defined the concept of risk management as the importance of coordination in the supply chain and the risk identification and management process.

There are several definitions of supply chain risk management in literature. Some of these definitions were listed below:

- Risk management can generally be defined as the identification, analysis, and control of risks (Thun and Hoenig, 2011).
- Supply chain risk management is the process of identifying, analyzing, and eliminating risks that affect the supply chain (Waters, 2011).
- Supply chain risk management is the ability of an organization to identify and manage economic, environmental, and social risks in the supply chain (Carter and Rogers, 2008).
- Supply chain risk management is the determination and evaluation of risks in the global supply chain and the losses that may occur as a result of these risks, the reduction of probability, speed of incident, detection time, frequency and exposure situations of the event, through close communication with supply chain members. It is also the strategy management implemented to increase targeted cost advantage and profitability (Manuj and Mentzer, 2008b).

- Supply chain risk management is to manage risk processes by increasing profitability and continuity through coordinated work with supply chain members (C. S. Tang, 2006).

Supply chain risk management is the management of supply chain risks through coordination and cooperation among supply chain members to ensure efficiency and continuity (Blos et al., 2009). In this context, the following Figure 5 shows the relationship between risk management and supply chain risk management:

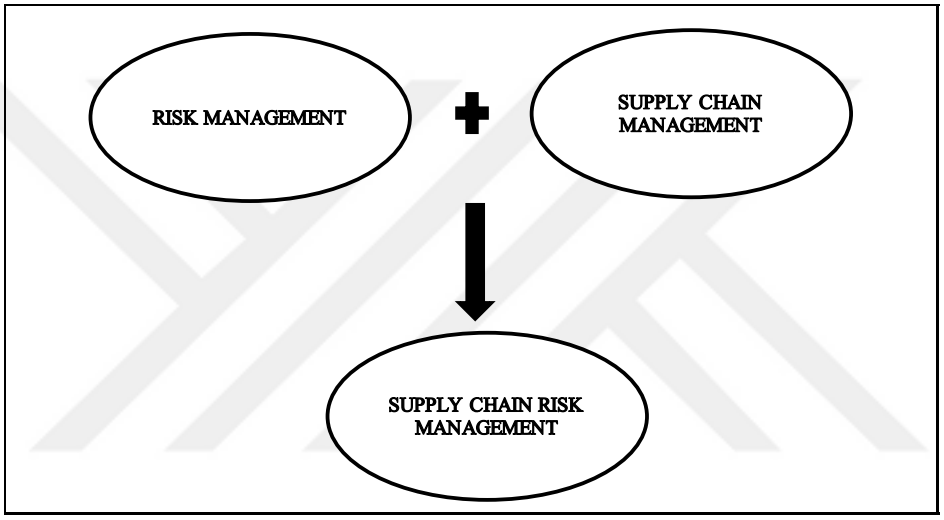

Figure 5. The relationship between supply chain management and risk management (Blos et al., 2009).

Supply chain risk management includes the following four processes (Hallikas et al., 2004).

- Risk identification,
- Risk assessment,
- Decision and implementation of risk management activities
- Risk monitoring.

Risk identification is the basic step of the risk management application. Through the identification of risks, a decision-maker becomes aware of events that cause uncertainty. The main purpose of risk identification is to manage risks by predicting future uncertainties (Hallikas et al., 2004). The risk identification process enables the determination of the risk sources that affect the performance of the supply chain and the determination of the right

strategies for the supply chain risk management and creating an effective supply chain management (Punniyamoorthy et al., 2013).

Risk assessment and prioritization are creating action plans to manage risk factors determined at the company and network level. Two components of risk, the probability, and consequences of a risk event are evaluated separately on a five-grade scale. In Tables 5 and 6 below, there are assessment scales for the outcome and probability of the risk (Hallikas et al., 2004).

Table 5. Impact assessment scale (Hallikas et al., 2004).

Rank	Subjective estimate	Description
1	No impact	Insignificant in terms of the whole company
2	Minor impact	Single small losses
3	Medium impact	Causes short-term difficulties
4	Serious impact	Causes long-term difficulties
5	Catastrophic impact	Discontinue business

Table 6. Probability assessment scale (Hallikas et al., 2004).

Rank	Subjective estimate	Description
1	Very unlikely	Very rare event
2	Improbable	There is indirect evidence of an event
3	Moderate	There is direct evidence of an event
4	Probable	There is strong direct evidence of an event
5	Very probable	Event repeats frequently

When evaluating the subjective probability of a risk event, the company's own experience and the performance of other companies are considered. Potential results should be evaluated in terms of business to determine what kind of effects they may encounter. This is because a harmful event to an organization in a supply chain network is not considered to be effective for another organization in the same business (Hallikas et al., 2004).

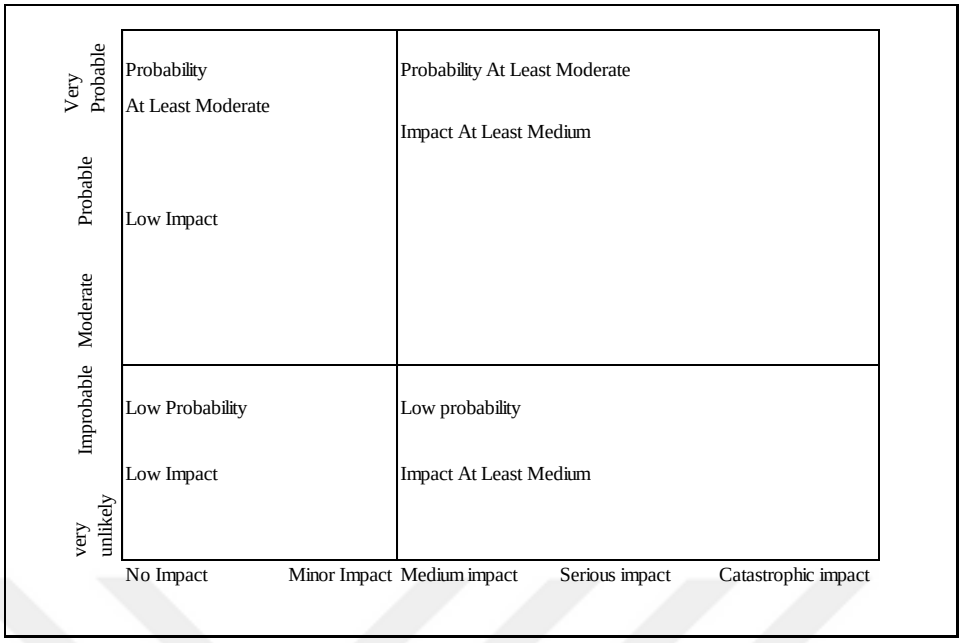

Figure 6. Risk Diagram (Hallikas et al., 2004).

After evaluating the identified risks, it is more practical to see these risks in a risk diagram such as in Figure 6 above. With the risk chart, a general idea is formed about all risks and it is helpful to look at the most important risks more carefully. It also indicates whether the risks are likely to be reduced to probabilities or consequences. A risk diagram can also be used as a method for exchanging information within and between businesses. It only depends on the desire of the companies to share the information (Hallikas et al., 2004).

Once the risks have been assessed, it is necessary to identify and implement possible alternative strategies to help mitigate these risks. Supply chain risk reduction strategies are actions taken by the company to reduce uncertainty and risks caused by different sources of risk (Miller, 1992). Table 7 below contains supply chain risk mitigation strategies (Jüttner et al., 2003).

Table 7. Risk Mitigating Strategies in Supply Chains (Jüttner et al., 2003).

Strategy	Actions
Avoidance	Dropping specific products, geographical markets, supplier and customer organizations
Control	Vertical integration
	Increased stockpiling and the use of buffer inventory
	Maintaining excess capacity in productions, storage, handling and transport
	Imposing contractual obligations on suppliers
Co-	Joint efforts to improve supply chain visibility and understanding

operation	Joint efforts to share risk-related information
	Joint efforts to prepare supply chain continuity plans
Flexibility	Postponement
	Multiple sourcing
	Localized sourcing

Miller (1992) determined to risk mitigating strategies as avoidance, cooperation, control, flexibility, and imitation. Chopra and Sodhi (2004) developed risk mitigation strategies, which are additional capacity, more suppliers, quick response, and flexibility, increasing the number of customers, and increasing the talent.

After assessing risk mitigation strategies, risks need to be monitored. Since the company and its surroundings are dynamic, risk factors are also changing, and new important risk factors may arise. For their identification, network, customer needs, technology, partner strategies, and competitors need to monitor and update risk assessment accordingly.

1.2.2.2. Aim and Advantages of Supply Chain Risk Management

The main purpose of supply chain risk management is to reduce the likelihood of risks occurring and to ensure that risks are managed most appropriately. Therefore, it ensures the resolution of raw material waste, production error, and events that can lead to important results (Shahbaz et al., 2017)

Supply chain risk management includes many advantages (D. D. Wu and Olson, 2010). Some of them are listed below:

- Corporate reputation
- Decrease in debts
- Employee health and safety
- Decrease in costs
- Legal compliance
- Supplier relationships
- Customer relationship
- Product development

The advantages of supply chain risk management were determined and listed below (Waters, 2011):

- Appropriate and correct decisions regarding the risk are made,
- High risk or financially unreliable issues are prevented,
- Risk-related responsibility is distributed to appropriate people,
- Management performance is measured correctly,
- Risks are determined before events occur and have an impact,
- Early assessment of risks ensures better planning, prioritization and proper use of resources,
- Unexpected situation actions are taken quickly when a risky event occurs,
- Operations occur with fewer interruptions and changes
- Operations are constantly monitored to identify possible problems,
- Through the determination of past risks, actions against future risks can be planned.

1.3. Aim and Structure of the Study

The supply chain risk management is gaining importance in business world in today. The businesses are developing the risk elimination and destruction strategies to compete with other businesses. Otherwise with the high competition, they know that they couldn't keep standing. In that context, to determine, classify and prioritize the supply chain risk factors became high importance. The majority of studies in the literature were developed methods on risk assessment of supply chain risk management. The number of studies is very limited in order to identify and prioritize risks. Thereby, this study aims to determine, classify and prioritize the supply chain risk factors to point to the importance of the supply chain risk management. Also, since the supply chain risk factors in literature are messy and untidy, a study integrated and organized was needed.

The main aim of this study is to define, decide, and prioritize the supply chain risk factors. Based on the purpose, the flow diagram of the study was given in the Appendix B. As seen from the flow diagram, firstly supply chain risks from the literature were gathered and then the obtained risks were grouped and combined and a summary risk table to be considered in the study was created. In the next step, a questionnaire was created to evaluate the risks in the created risk table, and evaluations were received from a certain number of users. According to the collected results, the main risks were evaluated statistically with the help of the structural equation model (SEM), and then sub-risks were prioritized by the fuzzy multi-criteria decision-making method (MCDM) according to the model results. With the help of obtained

results, action plan suggestions have been developed for individuals and/or businesses in the supply chain over prioritized risks.

Creating an integrated risk table compiled from literature and analyzing them in an integrated way with SEM and fuzzy MCDM (multi-criteria decision making) adds a unique and holistic value to supply chain risk management studies in the literature. Hereby, it is intended to make contributions to the literature on goals, motivation, and variety.

In the content of the study, the first part includes introductory information about the supply chain, supply chain management, risk management, and supply chain risk management. The second part of the study includes the previously conducted studies about the supply chain risks and their review in addition to the organized summary of the supply chain risks and the risks that are taken into consideration in the scope of this study. The third part contains the data and its characteristics, methods, and detailed information that is used in this study. The fourth part is defined as the results and discussion section which reveals the application of the survey results in detail. The fifth section is the conclusive results of the study.

The flow of the study was given in the Appendix B.

2. LITERATURE REVIEW

Several kinds of research and studies were conducted regarding supply chain risk management. These studies were summarized below.

Needham and Evers (1998) provided an approach to analyze the costs resulting from risk management practices and their suitability. In this study, a simulation method and a meta-model were used.

Chopra and Sodhi (2004) studied supply chain risks and risk management by identifying supply chain risks, they researched to prevent their destructive effects on the supply chain.

In the study of Kleindorfer and Saad (2005), the aim was to evaluate the risks arising from factors such as natural disasters, strikes, economic failures, and terrorist attacks in the US Chemical Industry and present a conceptual study on risk reduction activities. With this study, the effects of risks on the supply chain risk management system are investigated.

The aim of Gaudenzi and Borghesi (2006) was to provide a method to assess supply chain risks affecting the supply chain. Supply chain risk factors were identified by the AHP method. Also, a case study was applied in this study to raise awareness of supply chain risk factors.

T. Wu et al. (2006) identified supply chain risk factors with a comprehensive literature review and several industry interviews, and classified them hierarchically, using the AHP method to sort these risk factors. Finally, a prototype computer application was developed and tested in industry.

In the study of Manuj and Mentzer (2008b), the aim was to explore the concept of risk management and risk management strategies in global supply chains. This study included a comprehensive literature review and a qualitative study with interviews. The study explained the determining risk management strategies regarding environmental conditions.

The research by Schoenherr et al. (2008) aimed to review the process used by a U.S. (United States) manufacturing company to evaluate supply chain risks and to combine the supply chain risks with the AHP approach. Also, this study contributed to making decisions in uncertain conditions.

In the study of Tsai (2008), the risks of cash flow related to the supply chain for a business with deviations in cash inflows, outflows, and net flows were measured. The purpose of this study was to identify the risks that affected the cash conversion cycle to get discounts with early payment.

In the study performed by Tuncel and Alpan (2010), the purpose was to show how a timed Petri network framework could be used to model and analyze a supply chain (SC) network that was exposed to various risks. The study showed that the system performance could be improved through risk management activities and overall system costs could be reduced through mitigation strategies.

In the study of Wagner and Neshat (2010), they tried to measure and reduce the supply chain vulnerability in their research with a method based on Fuzzy graphic theory. The research contributed to the literature on reducing supply chain vulnerability and risk mitigation strategies.

Xie et al. (2011) proposed a comprehensive approach in their research to assess and manage risks in supply chains. They also guided how to make the most appropriate decision in the supply chain risk management process.

Samvedi et al. (2013) measured the risks in the supply chain and collected these risks in a generalized risk study. For this study, the fuzzy analytical hierarchy process (Fuzzy AHP), a fuzzy technique, and the technique for order preference by similarity to an ideal solution (TOPSIS) methods and techniques were used.

In the study of Mangla et al. (2015), the supply chain risks were determined with the help of the fuzzy AHP (analytical hierarchy process) approach. Additionally, a sensitivity analysis was conducted to examine the stability of the identified risk category priority ranking. This study aimed to help take precautions against risk categories and specific risks known in the green supply chain before risks can occur.

Based on the studies in literature, risk factors were predicted individually in each study. Some risks were common in some studies, some were not common. In Table 8 below, the risk factors determined as a result of the literature study were compiled.

Table 8. Supply chain risk types and their literature sources.

Literature Source	Risks
(Needham and Evers, 1998)	Supplier Order Processing Time Variability(Time from order placement to replenishment at the supplier facility)
(Chopra and Sodhi, 2004)	Exchange rate
	Lack of capacity flexibility
	Financial strength of customers
	Ecommerce
	Global outsourcing
	The capacity and responsiveness of alternative suppliers
	High capacity utilization at the supply source
	Inflexibility of supply source
	Poor quality or yield at the supply source
	Percentage of a key component or raw material procured from a single source
	Supply uncertainty
	Rate of product obsolescence
	Inventory holding cost
	Cost of capacity
	Inaccurate demand forecasts
	Bullwhip effect or information distortion
	Demand uncertainty
	Excessive handling due to border crossings or to change in transportation modes
	Information infrastructure breakdown
	System integration or extensive systems networking
	War and terrorism
	Long- vs. Short-term contracts
	Labor dispute and strikes
	Dependency on a single source of supply
	Supplier bankruptcy
(Kleindorfer and Saad, 2005)	Nature disasters
(Gaudenzi and Borghesi, 2006)	Accidents and damages in transportation
	Narrow number of intermediate suppliers
	Low suppliers' integration
	Lack of suppliers' visibility
	Stock driven supply chain
	Warehouse and production disruption
	Short lifetime products
	Linked phases in manufacturing

	Customer fragmentation
	High level of service required by customers
	Short lead times
	Lack of outbound effectiveness
	Transport providers' fragmentation
	Lack of transport providers' integration
	No transport solution alternatives
	Lack of information transparency between logistics and marketing
	Serious forecasting errors
(Wu et al., 2006)	Labor dispute and strikes
	Port strikes and attacks
	Product quality and safety
	Supplier management
	Supplier market strength
	Continuity of supply
	Employee accidents
	Production capabilities/capacity
	Production flexibility
	Technical/knowledge resources
	Financial and insurance issues
	Loss of contract
	Low-profit margin
	Market growth
	Market size
	Fire accidents
	External legal issues
	Political/ economic stability
	On-time delivery
	Remote high-way theft
	Internet security
	Sudden shoot up demand
	Product cost
	Accidents and damages in transportation
(Manuj and Mentzer, 2008b)	Serious forecasting errors
	Inflation and currency fluctuation
	Disruption of Supply
	Frequency of Material Design Changes
	Supplier opportunism
	Inbound product quality
	Transit time variability

	Breakdown of Operations
	High Levels of Process Variations
	Inventory ownership
	Asset and tools ownership
	Demand variability
	Wage rate shifts
	Competitor moves
	Changes in technology
	Technology Uncertainty and changes
	Inadequate Manufacturing or Processing Capability
	Product quality and safety
(Schoenherr et al., 2008)	War and terrorism
	Product cost
	Nature disasters
	Sovereign risk
(Tsai, 2008)	Lead time for internal processing and the timing of its related cash outflows
	Credit periods for accounts receivable to its customers and the pattern of an early collection of accounts receivable
	Credit periods for accounts payable from its suppliers and the pattern of early payment of accounts payable
(Tuncel and Alpan, 2010)	Dependency on transportation and delivery mode chosen
	Labor dispute and strikes
	Long- vs. Short-term contracts
	Scarcity of skilled labor, training, and experience
	Technology Uncertainty and changes
	Inadequate Manufacturing or Processing Capability
	Monopoly
	Low technical reliability
	Operator absence
	Dissatisfaction with work
	Instable manufacturing process
	Loss of motivation
	Insufficient breaks
	Working conditions
	Deficient or missing customer relation management function
	High competition in the marketplace
	Stress on crew
	Lack of training
	Long working times

	Negligently maintenance
	Old technology
(Wagner and Neshat, 2010)	Dependency on a single source of supply
	Small supply base
	Suppliers' dependency
	Lean inventory
	Centralized storage of finished products
	Short products' life cycles
	Customers' dependency
	Low in-house production
(Xie et al., 2011)	Accidents and damages in transportation
	Nature disasters
	Information infrastructure breakdown
	Rate of product obsolescence
	Cost of capacity
	Excessive handling due to border crossings or to change in transportation modes
	Design changes
	Product quality and safety
	The capacity and responsiveness of alternative suppliers
	High capacity utilization at the supply source
	Inflexibility of supply source
	Poor quality or yield at the supply source
	Percentage of a key component or raw material procured from a single source
	Supply uncertainty
	Inventory holding cost
	Inaccurate demand forecasts
	Bullwhip effect or information distortion
	Demand uncertainty
	System integration or extensive systems networking
	Dependency on a single source of supply
	War and terrorism
	Labor dispute and strikes
	Supplier bankruptcy
	Supplier quality risks
	Including responsiveness and delivery performance
	Supplier fulfillment errors
	Selection of wrong partners
	Lower process yields
	Higher product cost

	Order fulfillment errors
	Regional instability
	Government regulations
	Port capacity and congestion
	Custom clearances at ports
	Paperwork and scheduling
	Late deliveries
	Higher costs of transportation
	Lack of compatibility in IT platforms among supply chain partners
	Dependency on transportation and delivery mode chosen
	Port strikes and attacks
(Samvedi et al., 2013)	Sudden shoot up demand
	Changes in technology
	War and terrorism
	Serious forecasting errors
	Machine, equipment or facility failure
	Product quality and safety
	Nature disasters
	Global outsourcing
	Supplier quality risks
	Labor dispute and strikes
	Supplier bankruptcy
	Sudden hike in cost
	Market changes
	Competition changes
	Political instability
	Economic downturns
	Social and cultural grievances
(Mangla et al., 2015)	Competitor moves
	Procurement cost risks
	Key supplier risks
	Green raw material supply disruptions
	Key customer failures
	Financial restrictions
	Sourcing of funds
	Exchange rate
	Inflation and currency fluctuation
	Machine, equipment or facility failure
	Design changes
	Scarcity of skilled labor, training, and experience

	Supplier quality risks

As seen in Table 8 above, some risks were defined in more than one study. The risks that represented the same risk types were summarized and listed in Table 9 below.

Table 9. Summary of the risk types.

Summary of Risks	
Supply Risks	Product/Process Risks
T1. Procurement cost risks **T2.** Frequency of material design changes **T3.** Global outsourcing **T4.** Transit time variability **T5.** Monopoly **T6.** Risks arising from the supplier **T7.** Technology uncertainty and changes	**P1.** Inadequate manufacturing or processing capability and flexibility **P2.** Changes in technology machine and design **P3.** Equipment or facility failure **P4.** Risks arising from the employee **P5.** Cost of capacity, product, and inventory **P6.** Linked phases in manufacturing **P7.** Technical/knowledge resources **P8.** Risks arising from the product **P9.** Working conditions **P10.** Risks arising from inventories and warehouses
Demand Risks	Financial Risks
TL1. Inaccurate demand forecasts **TL2.** Risks arising from the customer **TL3.** Short lead times and product's life cycle **TL4.** Inadequate customer relation management **TL5.** Risks arising from competition and competitor **TL6.** Low in-house production	**F1.** Financial and insurance restrictions **F2.** Inflation and currency exchange rate **F3.** Financial risks arising from the customer **F4.** Low-profit margin **F5.** Market growth and size **F6.** Wage rate shifts **F7.** Product costs **F8.** Inaccurate finance, accounting, and payment plan management
Macro Risks	Logistics Risks
M1. Nature disasters, infectious outbreaks **M2.** War, terrorism and fire accidents **M3.** External legal issues **M4.** Political/economical and regional instability **M5.** Government regulations **M6.** Social and cultural complaints and dissatisfaction	**L1.** Risks arising from transportation mode **L2.** Accidents and damages in transportation **L3.** Working condition **L4.** Lack of training **L5.** Old technology **L6.** Risks arising from transportation management **L7.** Port strikes, attacks, and theft

Information Risks	
B1. System integration or extensive systems networking **B2.** Internet security **B3.** Lack of compatibility and communication in IT platforms among supply chain partners	

In Table 9 above, firstly, the main risk types were determined and then based on those, the sub-risk types were grouped. Beforehand, the common risk types in Table 8 were combined into one risk, meaning similarity. In total, seven main risk types were determined, which were; supply risks, product/process risks, demand risks, financial risks, macro risks, logistics risks, and information risks. According to the determined main risk types, the sub-risk types were situated below the suitable main risk types in table 9 below. In total, 47 sub-risk types were determined. Seven of the 47 sub-risk types belonged to supply risks, ten to product/process risks, six to demand risks, eight to financial risks, six to macro risks, seven to logistics risks, and three to information risks. In this study, these main risk types and sub-risk types were used and analyzed.

3. MATERIAL AND METHODS

Information on the basic materials and methods used in the study were provided in this section.

3.1.Materials

The primary material of the study consisted of enterprise employees with supply chain structures in Turkey. It was decided that data would be collected based on the working employees in any of the supply chain steps.

3.1.1. Data Set

In this study, the determined and prioritized risks hosted in the supply chain were examined and 412 business employees were surveyed. A total of 47 questions compiled from literature surveys were asked to these employees. The 5-point Likert scale (1: Absolutely Disagree; 5: Totally Agree) was taken as a basis for the prepared questions by us and the given answers were compiled according to the scale. The questionnaire questions were presented in Appendix-A. After the evaluation of the questionnaires, 391 of the total 412 answers were deemed suitable for continuation. The collected data was recorded with Microsoft (MS) Excel and pretreatments were performed for the statistical analysis. Before the analysis of the study, the admissibility of the questionnaire was assessed, and the Cronbach's Alpha coefficient was calculated as 0.950.

The collected data were categorized so that the data of the study could be correctly processed, used and the results could be interpreted. The 391 data, which contained the main body of the study, were categorized and the answers given by the users of these categories were saved in an MS Excel file separately. Descriptive statistics of the samples were presented in Table 10 below.

Table 10. Sample characteristics.

Categories		**Percentage of Sample**	**Sample Size**
Gender	Women	45,52%	178
	Men	54,48%	213
Age	Under 35 Age	65,22%	255
	Over 35 Age	34,78%	136

Education	Associate degree and Less	29,67%	116
	Bachelor’s Degree and More	70,33%	275
Experience	Less than 5 Years	56,52%	221
	Equal and More than 5 Years	43,48%	170

3.1.2. Software Used in the Study

IBM SPSS Statistics 21 and MATLAB® programs were used for the thesis study. SPSS (Statistical Package for the Social Sciences) is one of the ready-to-use statistical programs; it is a program that includes basic and advanced single or multivariate statistical data analysis techniques (Özdamar, 2013). With the SPSS package program, operations such as organizing data, displaying descriptive statistics, hypothesis testing (parametric and nonparametric), correlation analysis, variance analysis, covariance analysis, regression analysis, factor analysis, separation analysis, cluster analysis and reliability analysis can be performed easily.

AMOS is statistical software and it stands for analysis of a moment structures. AMOS is an added SPSS module and is specially used for Structural Equation Modeling, path analysis, and confirmatory factor analysis. It is also known as the analysis of covariance or causal modeling software. AMOS is a visual program for SEM. In AMOS, we can draw models graphically using simple drawing tools. AMOS quickly performs the computations for SEM and displays the results

3.2. Methods

Within the scope of the master's thesis, many techniques were used to compile, prioritize, and create action plans within the supply chain. Explanations about these methods used for data collection, statistical analysis, and prioritization were included in this section.

3.2.1. Survey Data Collection and Data Reliability

The questionnaire is a systematic data collection technique where questions were asked to the source people, who form a universe or sample depending on the hypotheses or questions, determined on a certain subject (Balcı, 2001). The data collected must be feasible and accurate. For this reason, the results of the survey applications must pass reliability tests. Some tests are applied for the reliability of the data collected through the survey. Reliability analysis is a method developed to evaluate the properties and reliability of the tests, surveys, or scales used in measurement, and it gives information about the relationships between the

coefficients that determine the reliability of the scales such as Likert and the questions in the scale (Kalaycı, 2010).

Selecting the part that shows all the features of a universe defines the sampling process. A smaller sample size of a whole defines the sample expression. The place where the sample group is taken is the expression of the universe. When selecting a sample from a universe, the selected sample must have the size to represent the main mass in which it is selected. The studies conducted by selecting the sample can be economical in terms of time and cost and can be as valid, healthy, and reliable as the results obtained by examining the entire universe (Gökçe, 2012). The sample size can be determined through some calculations. If the taken sample cannot represent its universe, then errors occur in the results and analysis (Bailey, 2008). An adequate sample is a sample that includes enough elements to provide reliable results (Young, 1968). The sample size is calculated with the standard error formula via the central limit theorem (Kurtuluş, 1998). The sample size was determined as 380 according to the calculations in the literature (Kurtuluş, 1998).

The Alpha (α) Model is a coefficient that investigates whether n problems in the questionnaire express a homogeneous structure and takes a value between 0-1 obtained by the average of the sum of the variances of the n problems (Kalaycı, 2010). This coefficient, which measures the general consistency and question homogeneity in a scale, is a weighted standard change average (Özdamar, 2013). If the alpha coefficient is less than 0.4, the scale is not reliable; scale reliability is low if it is between 0.4 and 0.6; scale reliability is high if it is between 0.6 and 0.8; and scale reliability is very high if it is greater than 0.8 (Kalaycı, 2010).

3.2.2. Fuzzy Analytical Hierarchy Process (Fuzzy-AHP)

The AHP method is based on the conversion of qualitative expressions into quantitative results as a result of many steps and is a method that is frequently used in literature. A related method was developed by Saaty(1980). Steps of the AHP were described below;

i. By showing the problem in a hierarchical structure, the main criteria and sub-criteria belonging to these main criteria are determined according to the purpose.
ii. Pairwise comparisons are performed for the defined main and sub-criteria according to Table 11.

Table 11. AHP comparison table (Saaty, 1980).

Importance Intensity	**Description**
1	Equal importance
3	Moderate importance of one over another
5	Strong importance of one over another
7	Very strong importance of one over another
9	Extreme importance of one over another
2, 4, 6, 8	Intermediate values
Reciprocals	Reciprocals for inverse comparison

iii. The weight scores of the criteria are calculated according to the priority values of the pairwise comparison matrices performed in the previous step.

iv. Determining the distribution of significance for each factor takes place in this step. While determining the importance distributions, column vectors in a comparison matrix are used and a column vector of type n*n is revealed. After the relevant column vectors are normalized, W_i values are obtained, and then each element in the matrix row is multiplied and summed to reveal the V_1 column vector. The arithmetic averages of the V_2 column vector obtained by V_1/Wi are calculated by calculating λ_{max}.

v. After the relevant column vectors and λmax are calculated, the consistency in the comparisons must be measured. Based on the number of criteria for the problem, the consistency indicator and ratios are calculated, and this ratio must be less than or equal to 0.10 to be able to interpret that the relevant matrix is consistent.

vi. As the last step, hierarchically starting from the top criterion, weights are calculated by multiplying and collecting weights at each level, so priority values are determined.

However, in the application of AHP, the pairwise comparisons are performed by decision-makers and the selected values are the exact values for comparisons so that the results become uncertain and non-objective (Chhabile and Dalu, 2012). Additionally, classical AHP does not involve the uncertainty of the decision maker's judgment. Therefore, the fuzzy AHP approach was developed to reduce the negative effects of the classical AHP by using the Fuzzy Sets Theory by Zadeh (1965). Fuzzy AHP integrates the main AHP steps into the fuzzy domain by using fuzzy numbers in pairwise comparisons. Pairwise comparisons are made with linguistic variables by a triangular form (Ayhan, 2013; Chhabile and Dalu, 2012; Dalalah et al., 2010; Petkovic et al., 2012; Zhou et al., 2015). Steps of the fuzzy-AHP method were presented below (Buckley and Uppuluri, 1987);

i. Hierarchy construction: Hierarchy is formed similarly to classical AHP.

ii. Pairwise comparisons: Comparisons between criteria are somehow similar to classical AHP but are performed with a triangular fuzzy scale according to their linguistic terms. Triangular fuzzy scale equivalents and linguistic explanations of classical AHP values are presented in Table 12.

Table 12. Triangular fuzzy scale of AHP values.

Scale of Classic AHP	**Linguistic Terms**	**Fuzzy Triangular Scale**
1	Equally Important	(1, 1, 1)
3	Weakly Important	(2, 3, 4)
5	Fairly Important	(4, 5, 6)
7	Strongly Important	(6, 7, 8)
9	Absolutely Important	(9, 9, 9)
2	Intermittent Values	(1, 2, 3)
4		(3, 4, 5)
6		(5, 6, 7)
8		(7, 8, 9)

iii. Calculation of normalized weights of the criteria: Geometric means of fuzzy comparison values are calculated in this step by using the equation of $r_i = \left(\prod_{j=i}^{n} d_{ij}\right)^{1/n}$ for each criterion.

iv. The relative fuzzy weight of each criterion calculation according to the values of the third step is performed in this step. Afterward, the normalized weights of each criterion is calculated by dividing the value of the relative fuzzy weight with the total value of all the criteria

3.2.3. Structural Equation Model (SEM)

Structural equation modeling, as a second-generation data analysis technique (Bagozzi and Fornell, 1982), is a complex structure model that allows systematic and comprehensive handling of a complex research problem in a single process by modeling the relationships between many dependent and independent variables (Anderson and Gerbing, 1988).

The structural equation modeling method is a model that is particularly successful in testing complex models, making many analyzes at once, recommending new arrangements for the network of relationships in the model under study, and facilitating the examination of the effects of mediation and moderation. It is a method used for the testing of many theories and

in the development of new models since it considers measurement errors. Structural equation models are a statistical technique used to test models that have causal relationships and correlation relationships between observed variables and latent variables. Also, it is a multivariate method for estimating dependency relationships, which is formed by combining analysis such as variance, covariance analysis, factor analysis, and multiple regression (Tüfekçi and Tüfekçi, 2006). The most common method used in the structural equation modeling literature to evaluate whether the data supports the model is the two-step method (Anderson and Gerbing, 1988). In the analysis, firstly, the measurement model is tested (Huchting et al., 2008) and checked whether the measurements of the structures in the model measured the related structures correctly. In the second stage, structural models are examined. If there is not a correct measurement in hand, it will not be meaningful to analyze the structural model.

SEM is a classic multivariate method as some of its features differ from statistical methods. Firstly, SEM, unlike other statistical methods, adopts a confirmatory approach rather than an exploratory approach. Therefore, while many statistical methods outside SEM try to find the relationships on the data set, SEM verifies the compatibility of theoretically established relationships with the data. As such, it can be said that SEM is more successful than other methods for hypothesis testing. Secondly, while traditional multivariate methods do not have any ability to calculate or correct the measurement errors, SEM shows very clear results in error calculations. In this context, while traditional methods deal with measurement errors separately, SEM explicitly takes measurement errors into account in all its analyses. Thirdly, traditional methods can only operate on variables that can be observed in an analysis; SEM can test on both observable and latent variables within the same model. Finally, today there is no better or more accepted method than SEM, in which both observed and invisible variables can be tested simultaneously, direct and indirect multiple relationships or successive indirect relationships can be measured. All these features have made SEM a very popular method today (Meydan and Şeşen, 2011).

4. RESULTS AND DISCUSSION

The results and discussion of the study were presented in this section.

4.1.General Features of the Sample and Data Pre-Processing

Features of the distribution of the data in the scope of the thesis were presented in the 3.1.1 Data Set section. However, before the data could be analyzed, it was necessary to perform some pre-treatment. The reason for this was to make the data suitable for a standard structure and to prevent encountering dominant or insignificant data. To avoid difficulties in comparing the text type data with the numerical type data, pre-processing of the data became essential. Analyzes could be made and interpreted with groupings instead of the existing data. For this thesis study, each variable and its encodings were presented in Table 13. In this study, where descriptive variables were also used for categorical analysis, 47 questions for supply chain risks were directed to users following a Likert scale type of 5. The data were kept on MS Excel 2010. Statistical analysis was performed using IBM SPSS Statistics 21 and IBM SPSS AMOS 22. Multi-criteria decision-making Analysis was carried out using MS Excel 2010.

Table 13. Variables and Codes.

Variable Name	**Code**	**Code Label**
Gender	1	Man
	2	Woman
Age	1	≤35
	2	>35
Level of Education	1	Associate Degree and Less
	2	Bachelor Degree and More
Experience	1	Less than 5 Years
	2	More than 5 Years

Before the statistical analysis, it was important to know whether the taken sample was adequate or not so that the results would reflect the reality. According to the information provided in the 3.2.1. Survey Data Collection, Data Reliability section, it was seen that the sample size of 391 users in this study was sufficient.

The Cronbach Alpha coefficient, which measures the overall consistency and question homogeneity of the used scale, in other words, investigates whether the questions are

homogeneous or not, was calculated as 0.950. It was concluded that the scale reliability related to this coefficient was "very high".

4.2.Findings of the Structural Equation Model of the Study

Within the scope of this study, the structural equation model was established, and hypotheses were formed. In Figure 7, the research model of the study was represented. It was investigated whether each major risk group had an impact on supply management risks and the effects of each sub-risk related to the main risk groups to the groups were examined.

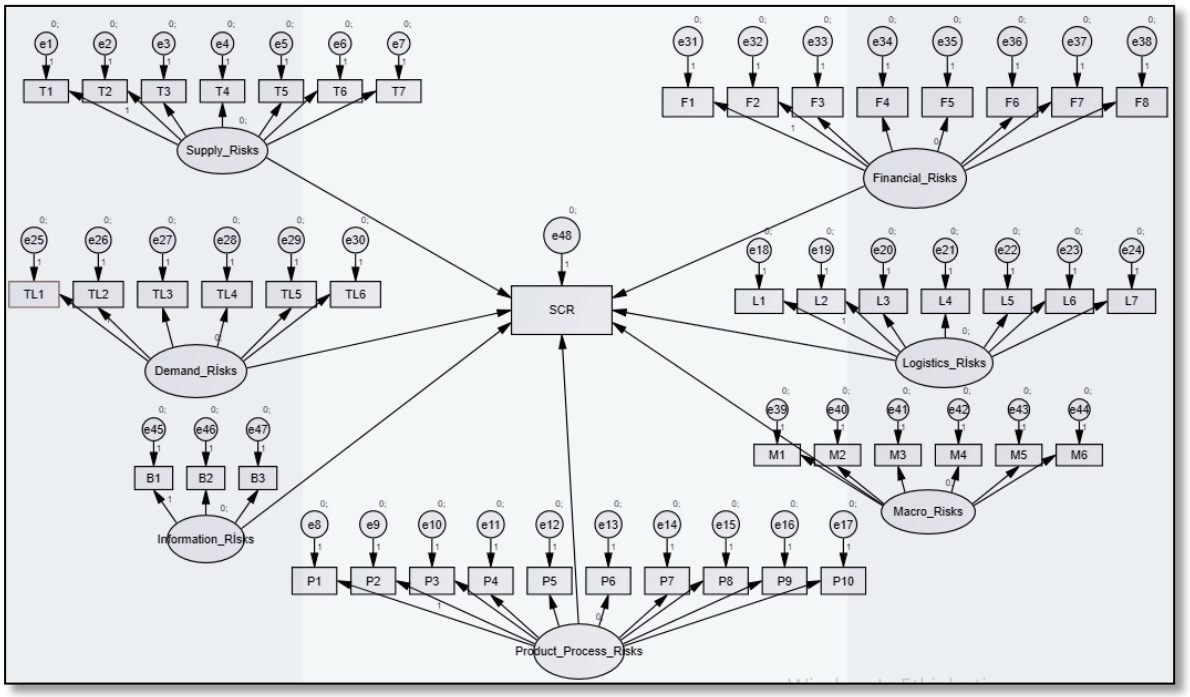

Figure 7. Research model and SEM of the study.

In the research model, supply risks, demand risks, information risks, financial risks, logistics risks, macro risks, and product/process risks were selected as independent variables to measure and explain supply chain management risks. According to the model, the main hypotheses were defined below.

H1: There is a significant relationship between supply risks and supply chain management risks.

H2: There is a significant relationship between demand risks and supply chain management risks.

H3: There is a significant relationship between Information risks and supply chain management risks.

H4: There is a significant relationship between financial risks and supply chain management risks.

H5: There is a significant relationship between logistics risks and supply chain management risks.

H6: There is a significant relationship between macro risks and supply chain management risks.

H7: There is a significant relationship between product/process risks and supply chain management risks.

Along with testing all hypotheses, predictors of supply chain management risks; correlation of independent variables were analyzed in the research model with the help of SEM. Fit indices of the model were presented in Table 14, where how the correct theoretical model fits into the observed data that was collected was revealed.

Table 14. Fit Indices of the research model.

Fit Index	Research Model	Recommended value	Source
CMIN/df	2.753	<5.00	Shin and Shin (2011)
RMSEA	0.054	<0.06	Jöreskog and Sörbom (1996)
NFI	0.956	>0.90	Bentler and Bonett (1980)
CFI	0.928	>0.90	Bentler and Bonett (1980)
IFI	0.929	>0.90	Bentler and Bonett (1980)

Table 14 presents that, all model fit indices satisfy recommended values according to literature values. Hence, the research model is considered that it has a good fit with the data collected. Hypotheses results are presented in Table 15. According to the results, all hypotheses are supported, and they are significant under 0.001 level.

Table 15. Hypotheses results.

Hypotheses	**Supported**	**Explanation**
H1: (Supply risks and SCM Risks)	Yes*	Significant positive relationship
H2: (Demand risks and SCM Risks)	Yes*	Significant positive relationship
H3: (Information risks and SCM Risks)	Yes**	Significant positive relationship
H4: (Financial risks and SCM Risks)	Yes*	Significant positive relationship
H5: (Logistics risks and SCM Risks)	Yes*	Significant positive relationship
H6: (Macro risks and SCM Risks)	Yes**	Significant positive relationship
H7: (Product/Process risks and SCM Risks)	Yes**	Significant positive relationship
	*p<0.001; **p<0.05	

In Table 16, covariances between independent variables were examined to reveal the significance level of the relationships between independent variables. As seen in Table 16. defined covariances were significant at the 0.001 level.

Table 16. Covariance significances.

Covariance			**Supported**
Supply_Risks	<-->	Financial_Risks	Yes*
Supply_Risks	<-->	Logistics_Risks	Yes*
Supply_Risks	<-->	Macro_Risks	Yes*
Supply_Risks	<-->	Product_Process_Risks	Yes*
Information_Risks	<-->	Supply_Risks	Yes*
Supply_Risks	<-->	Demand_Rİsks	Yes*
Logistics_Risks	<-->	Financial_Risks	Yes*
Financial_Risks	<-->	Macro_Risks	Yes*
Product_Process_Risks	<-->	Financial_Risks	Yes*
Information_Risks	<-->	Financial_Risks	Yes*
Demand_Risks	<-->	Financial_Risks	Yes*
Logistics_Risks	<-->	Macro_Risks	Yes*
Product_Process_Risks	<-->	Logistics_Risks	Yes*
Information_Risks	<-->	Logistics_Risks	Yes*
Logistics_Risks	<-->	Demand_Risks	Yes*
Product_Process_Risks	<-->	Macro_Risks	Yes*
Information_Risks	<-->	Macro_Risks	Yes*
Demand_Risks	<-->	Macro_Risks	Yes*

Information_Risks	<-->	Product_Process_Risks	Yes*
Product_Process_Risks	<-->	Demand_Rİsks	Yes*
Information_Risks	<-->	Demand_Rİsks	Yes*
*p<0.001; **p<0.05			

In Table 17, the correlations between independent variables of the model were provided. Highest correlations were formed between supply and product/process risks; supply risks and demand risks; product/process risks and logistics risks; information risks and logistics risks; logistics risks and demand risks; product/process risks and demand risks; information risks and demand risks.

Table 17. Correlation results.

Correlations			**Correlation Status**	
Supply_Risks	<-->	Financial_Risks	0,505	Moderate
Supply_Risks	<-->	Logistics_Risks	0,698	Moderate
Supply_Risks	<-->	Macro_Risks	0,416	Low
Supply_Risks	<-->	Product_Process_Risks	0,842	High
Information_Risks	<-->	Supply_Risks	0,582	Moderate
Supply_Risks	<-->	Demand_Rİsks	0,760	High
Logistics_Risks	<-->	Financial_Risks	0,564	Moderate
Financial_Risks	<-->	Macro_Risks	0,431	Low
Product_Process_Risks	<-->	Financial_Risks	0,614	Moderate
Information_Risks	<-->	Financial_Risks	0,384	Low
Demand_Risks	<-->	Financial_Risks	0,460	Low
Logistics_Risks	<-->	Macro_Risks	0,501	Moderate
Product_Process_Risks	<-->	Logistics_Risks	0,757	High
Information_Risks	<-->	Logistics_Risks	0,736	High
Logistics_Risks	<-->	Demand_Risks	0,700	High
Product_Process_Risks	<-->	Macro_Risks	0,496	Low
Information_Risks	<-->	Macro_Risks	0,420	Low
Demand_Risks	<-->	Macro_Risks	0,526	Moderate
Information_Risks	<-->	Product_Process_Risks	0,583	Moderate
Product_Process_Risks	<-->	Demand_Risks	0,755	High
Information_Risks	<-->	Demand_Risks	0,772	High

In the research model, the predictors of supply chain risks explained 80,6 % of its variance while the strongest predictors resulted in demand risks, supply risks, logistics risks, product/process risks, financial risks, information risks, and macro risks respectively.

Explaining 80,6% percent of the SCM risks, these main risks were shown in Figure 8 when their percentage of disclosure was proportioned. To reduce the number of primary risks to be examined for further analysis, Pareto Analysis was performed and presented in Figure 8 to separate parameters with the decision of 50-50 rule. According to the Pareto chart, the first two main risks should be analyzed further.

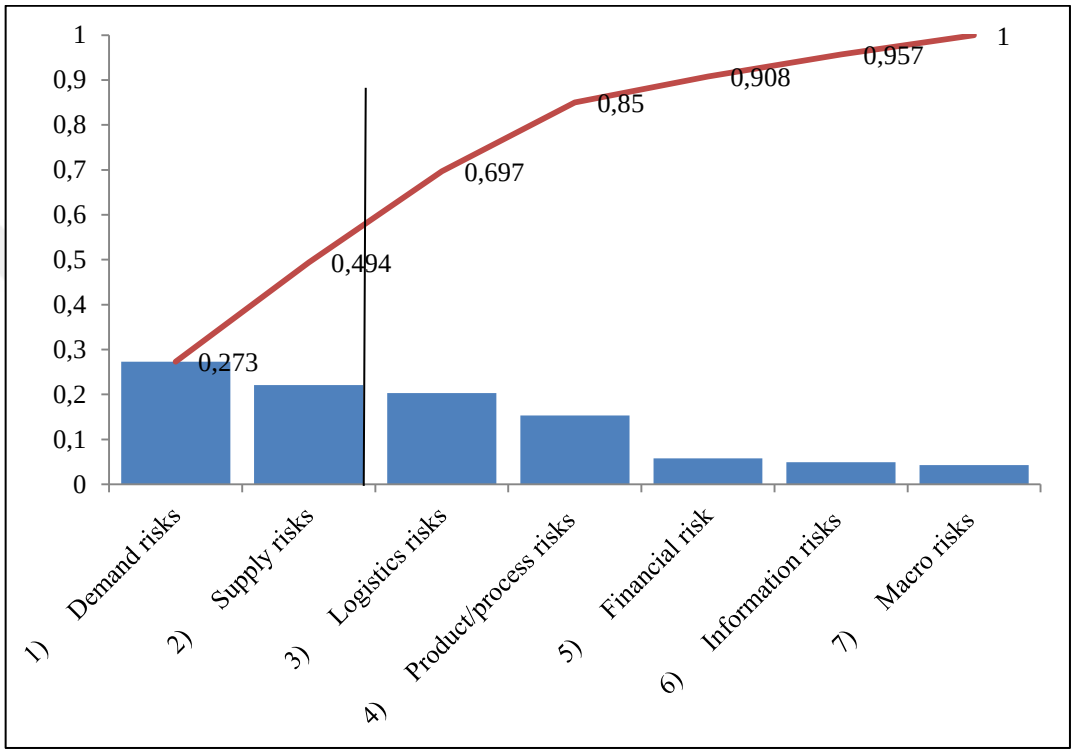

Figure 8. Pareto chart.

4.3.Risk Assessment

According to the results of the hypotheses tested through SEM established in section 4.2, where demand and supply risks explained fifty percent of supply chain management risks, it was decided to examine these two main risks for further. In the literature section, sub-risks under main risks were mentioned. To examine, prioritize and further analyze the selected supply and demand risks, the explanations of related sub-risks and the problems they cause were defined in Table 18 where the groundwork for risk analysis could be laid out.

Table 18. Definition and effects of the selected sub-risks.

	Risk Code	Selected Sub-Risks from SEM	Explanation of The Risks Created by The Sub-Risks
Supply Risks	T1	Procurement Cost	High purchasing costs can be associated with high raw material and shipping costs. In this case, the high cost of raw materials and auxiliary materials loaded as a direct cost to the produced goods increases the cost of the material and the cost of the produced goods. Thus, while the chance of competition for product sales decreases, profit margin also decreases.
	T2	Frequency of Material Design Changes	The frequency of the material design change corresponds to the change in the design of the manufactured product. This leads to the constant change of the line of the machine where the goods are produced. This extra cost also brings an operational burden.
	T3	Global outsourcing	Global outsourcing causes the business to remain external. The arrival time of the goods is prolonged when there is an increase in the price of foreign sources or global crises. This extends product production time and causes customer dissatisfaction.
	T4	Transit time variability	The variability of the time in the supply of the material causes the material's adequacy to be calculated completely and can lead to overstock or understock problems. From another point of view, the late departure of the product that goes to the customer may lead to customer dissatisfaction and further lead to loss of sales.
	T5	Monopoly	Buying the monopoly supplied goods in one place requires submission to the given price. In such a case, bargaining power is very low. Production costs increase with increasing material costs. Also, material supply may be delayed if the supplier experiences any problems.
	T6	Risks arising from supplier	Risks from the supplier can be defined as the risks such as wrongly choosing the supplier, late shipment of the supplier, wrong shipment, or incomplete shipment of the supplier. These risks create a direct or indirect cost to the business. Time, labor, production, and customer losses can occur.

	T7	Technology Uncertainty and changes	Continuous progress and development of technology lead businesses to the unlimited competition. Trying to purchase new machines and equipment without paying for a newly developed technological product is an operational risk that causes businesses to exceed the costs they can bear.
Demand Risks	TL1	Inaccurate demand forecasts;	Incorrect demand estimation can lead to over or under-stock. It leads to loss of sales caused by inventory costs or inventory. From another point of view, due to incorrect or incomplete demand estimation, the quantity discount cannot be used, or an appropriate shipping plan cannot be made.
	TL2	Risks arising from costumer	If the customer places an incorrect order and the company ignores the relevant order, it causes the stock to remain inactive. The delayed debt payment situations arising from the financial difficulties of the customers may hurt the business. Customers' requesting their orders before the delivery date may also cause other displacements in the production plan.
	TL3	Short lead times and product's life cycle	Short delivery times cause the product not to be given within the promised time in case of any setback. In this case, customer dissatisfaction may arise. Also, the short life cycle of the product requires the product to be produced in a short time. This can cause bottlenecks.
	TL4	Inadequate customer relation management	Inadequate customer relationship management can lead to wrong orders being received from the customer and the wrong product being produced. From another point of view, when the customer is not satisfied in terms of quality, the lack of an appropriate quality control procedure will lead to the loss of customers. The lack of customer management can negatively affect all supply chain processes from material demand forecasting to sales.
	TL5	Risks arising from competition and competitor	As competitors supply the goods cheaper as a result of supplying materials at low prices, the chance of competition may decrease. Or it reduces the chance of competing, who cannot analyze the market well. From another point of view, competitors can offer product flexibility to adapt to the market. If the company cannot produce such products,

			the market will remain on a limited product scale and remain weak in competition.
	TL6	Low in-house production	The fact that the production within the enterprise is limited, that is, the fact that the product it produces results in many sub-materials from the outside brings foreign commitment. It cannot make a profit in terms of cost. Disruptions in the procurement process also bring about time, labor, raw material, and operational problems.

To prioritize among the sub-risks, to eliminate certain risks, or to minimize its impact, a risk analysis was carried out with the Fuzzy Analytical Hierarchy Process. The pairwise comparisons among 13 sub-risks were scored by 5 different managers in the sample group and the scores were averaged. Fuzzy AHP results were presented in the following tables. In Table 19, pair wise comparisons with a triangular fuzzy scale were presented for all criteria.

Table 19. Pair Wise comparisons with a triangular fuzzy scale.

Criteria	T1	T2	T3	T4	T5	T6	T7	TL1	TL2	TL3	TL4	TL5	TL6
T1	(1, 1, 1)	(2, 3, 4)	(7, 8 9)	(4, 5, 6)	(3, 4, 5)	(5, 6, 7)	(5, 6, 7)	(2, 3, 4)	(3, 4, 5)	(3, 4, 5)	(6, 7 8)	(7, 8 9)	(5, 6, 7)
T2	(1/4, 1/3, 1/2)	(1, 1, 1)	(7, 8 9)	(3, 4, 5)	(3, 4, 5)	(3, 4, 5)	(3, 4, 5)	(2, 3, 4)	(3, 4, 5)	(2, 3, 4)	(7, 8, 9)	(7, 8 9)	(3, 4, 5)
T3	(1/9, 1/8, 1/7)	(1/9, 1/8, 1/7)	(1, 1, 1)	(1/4, 1/3, 1/2)	(1/3, 1/2, 1)	(1/5, 1/4, 1/3)	(1/6, 1/5, 1/4)	(1/5, 1/4, 1/3)	(1/5, 1/4, 1/3)	(1/5, 1/4, 1/3)	(1, 1, 1)	(1, 1, 1)	(1/4, 1/3, 1/2)
T4	(1/6, 1/5, 1/4)	(1/5, 1/4, 1/3)	(2, 3, 4)	(1, 1, 1)	(1/3, 1/2, 1)	(1, 1, 1)	(2, 3, 4)	(2, 3, 4)	(1/3, 1/2, 1)	(1/5, 1/4, 1/3)	(2, 3, 4)	(3, 4, 5)	(2, 3, 4)
T5	(1/5, 1/4, 1/3)	(1/5, 1/4, 1/3)	(1, 2, 3)	(1, 2, 3)	(1, 1, 1)	(1/5, 1/4, 1/3)	(1/3, 1/2, 1)	(1/5, 1/4, 1/3)	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1, 1, 1)	(2, 3, 4)	(1/3, 1/2, 1)
T6	(1/7, 1/6, 1/5)	(1/5, 1/4, 1/3)	(3, 4, 5)	(1, 1, 1)	(3, 4, 5)	(1, 1, 1)	(5, 6, 7)	(1, 1, 1)	(1, 1, 1)	(1/4, 1/3, 1/2)	(4, 5, 6)	(5, 6, 7)	(2, 3, 4)
T7	(1/7, 1/6, 1/5)	(1/5, 1/4, 1/3)	(4, 5, 6)	(1/4, 1/3, 1/2)	(1, 2, 3)	(1/7, 1/6, 1/5)	(1, 1, 1)	(1/3, 1/2, 1)	(1/4, 1/3, 1/2)	(1/3, 1/2, 1)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)
TL1	(1/4, 1/3, 1/2)	(1/4, 1/3, 1/2)	(3, 4, 5)	(1/4, 1/3, 1/2)	(3, 4, 5)	(1, 1, 1)	(1, 2, 3)	(1, 1, 1)	(5, 6, 7)	(7, 8, 9)	(3, 4, 5)	(5, 6, 7)	(1/4, 1/3, 1/2)
TL2	(1/5, 1/4, 1/3)	(1/5, 1/4, 1/3)	(3, 4, 5)	(1, 2, 3)	(1, 2, 3)	(1, 1, 1)	(2, 3, 4)	(1/7, 1/6, 1/5)	(1, 1, 1)	(2, 3, 4)	(3, 4, 5)	(5, 6, 7)	(2, 3, 4)
TL3	(1/5, 1/4, 1/3)	(1/4, 1/3, 1/2)	(3, 4, 5)	(3, 4, 5)	(1, 2, 3)	(2, 3, 4)	(1, 2, 3)	(1/9, 1/8, 1/7)	(1/4, 1/3, 1/2)	(1, 1, 1)	(3, 4, 5)	(5, 6, 7)	(2, 3, 4)
TL4	(1/8, 1/7, 1/6)	(1/9, 1/8, 1/7)	(1, 1, 1)	(1/4, 1/3, 1/2)	(1, 1, 1)	(1/6, 1/5, 1/4)	(1/4, 1/3, 1/2)	(1/5, 1/4, 1/3)	(1/5, 1/4, 1/3)	(1/5, 1/4, 1/3)	(1, 1, 1)	(2, 3, 4)	(1/3, 1/2, 1)
TL5	(1/9, 1/8, 1/7)	(1/9, 1/8, 1/7)	(1, 1, 1)	(1/5, 1/4, 1/3)	(1/4, 1/3, 1/2)	(1/7, 1/6, 1/5)	(1/4, 1/3, 1/2)	(1/7, 1/6, 1/5)	(1/7, 1/6, 1/5)	(1/7, 1/6, 1/5)	(1/4, 1/3, 1/2)	(1, 1, 1)	(1/4, 1/3, 1/2)

TL6	(1/7, 1/6, 1/5)	(1/5, 1/4, 1/3)	(2, 3, 4)	(1/4, 1/3, 1/2)	(1, 2, 3)	(1/4, 1/3, 1/2)	(1/4, 1/3, 1/2)	(2, 3, 4)	(1/4, 1/3, 1/2)	(1/4, 1/3, 1/2)	(1, 2, 3)	(2, 3, 4)	(1, 1, 1)

In Table 20, calculations of the geometric means of the fuzzy comparison values were presented.

Table 20. Geometric means of fuzzy comparison values.

Criteria	**r_i**		
T1	3,580165975	4,462980019	5,309832212
T2	2,179261556	3,334117175	4,095244266
T3	0,281152357	0,335341655	0,281152357
T4	0,815994999	1,089222584	1,464242073
T5	0,458439384	0,638469418	1,045252811
T6	1,217079102	1,445230169	1,698612491
T7	0,583405981	0,732121036	1,109043436
TL1	1,251402635	1,601292141	2,036086124
TL2	1,057054223	1,433564415	1,810136752
TL3	0,978113669	1,346871766	1,755151915
TL4	0,338687849	0,410168557	0,523259905
TL5	0,226020141	0,268233538	0,33542156
TL6	0,52376016	0,73576469	1,014123543
Total	13,49053803	17,83337716	22,47755944
Reverse (r_i^{-1})	0,074126028	0,056074629	0,044488816
Increasing order	0,044488816	0,056074629	0,074126028

To calculate the relative fuzzy weights, the geometric means of fuzzy values were multiplied with the total of the reverse fuzzy geometric means in increasing order. Calculations were presented in Table 21.

Table 21. Relative fuzzy weights.

Criteria	Wi		
T1	0,159277344	0,250259947	0,393596771
T2	0,096952766	0,186959382	0,303564191
T3	0,012508135	0,018804159	0,020840708
T4	0,036302651	0,061077752	0,108538449
T5	0,020395425	0,035801935	0,077480439
T6	0,054146408	0,081040745	0,125911397
T7	0,025955041	0,041053415	0,082208985

TL1	0,055673421	0,089791862	0,150926977
TL2	0,047027091	0,080386592	0,134178248
TL3	0,043515119	0,075525334	0,13010244
TL4	0,015067821	0,023000049	0,038787178
TL5	0,010055368	0,015041096	0,024863468
TL6	0,023301469	0,041257732	0,07517295

As the last step, to find the final weights of the criteria, normalized weights of each criterion were calculated by dividing each value of the relative fuzzy weight with the total of all criteria's values. The results were presented in Table 22.

Table 22. The final weights of the criteria

Criteria		**Ni**	**Rank**
T1	Procurement cost	0,245881	1
T2	Frequency of material design changes	0,179857	2
TL1	Inaccurate demand forecasts	0,090741	3
TL2	Risks arising from costumer	0,080087	4
T6	Risks arising from supplier	0,079936	5
TL3	Short lead times and product's life cycle	0,076276	6
T4	Transit time variability	0,063042	7
T7	Technology uncertainty and changes	0,045683	8
TL6	Low in-house production	0,042779	9
T5	Monopoly	0,040926	10
TL4	Inadequate customer relation management	0,023529	11
T3	Global outsourcing	0,015967	12
TL5	Risks arising from competition and competitor	0,015295	13

According to the fuzzy AHP results; risks that arise from procurement cost; Frequency of material design changes; inaccurate demand forecasts constituted the three most critical and important sub-risks within the supply chain management, respectively. Hence, action plans were needed to be established according to these rankings from the fuzzy AHP results. Preparing and implementing an action plan according to the rankings in the fuzzy AHP results could create operational problems for businesses. For this reason, it was revealed with the help of Pareto Analysis, for which sub-risks in the action plan was created in the first stage, according to the determined rankings. When the 80-20 rule was applied; prior action plan was prepared for risks arising from procurement cost, frequency of the material design changes, inaccurate demand forecasts, and risks arising from supplier, risks arising from the costumer,

transit time variability, and short lead times and product's life cycle. The Pareto chart according to fuzzy AHP results was illustrated in Figure 9. Suggestions and recommendations were made in the last section of this study.

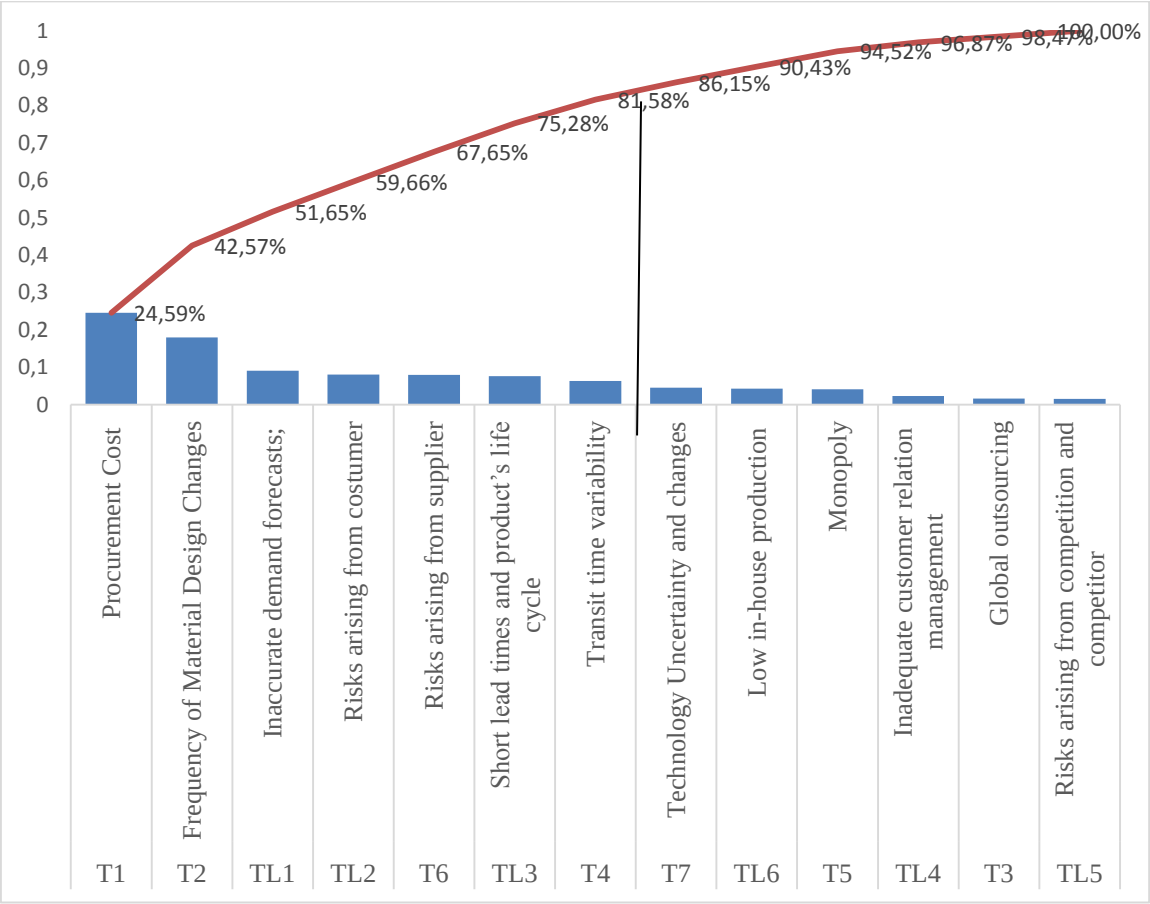

Figure 9. Pareto chart for the sub-risks.

With the results obtained from fuzzy AHP and Pareto analysis, the suggestive action plan created for the sub-risks that should be included in the priority action plan was presented in Table 23.

Table 23. Action plan recommendations for sub-risks.

Sub-Risk	**Action Plan Recommendations**	**The Common Studies in Literature**
T1. Procurement Cost	* Better planning and coordination of supply and demand * Multiple source strategy	(Mangla et al., 2015)

	* Ability to supply from more than one supplier for a product * By increasing the communication with the supplier, find out if the supplier is producing from the same order to receive the order given in smaller quantities at less cost. * To get substitute material for the material to be purchased	(Manuj and Mentzer, 2008b) (Wagner and Neshat, 2010)
T2. Frequency of Material Design Changes	* Including customer tastes in product designs * To be able to respond quickly to changes in material design by increasing flexibility in machines and workbenches * Increasing the training for the workforce to ensure that the changes adapt quickly	(Manuj and Mentzer, 2008b) (Tuncel and Alpan, 2010) (Xie et al., 2011) (Samvedi et al., 2013)
TL1. Inaccurate demand forecasts;	* Managing demand through promotions and incentives can be given to customers. * Better planning and coordination of demand * Purchase demand forecasting system program	(S. Chopra and Sodhi, 2004) (Xie et al., 2011)
TL2. Risks arising from costumer	* Investing in good communication infrastructure, avoiding miscommunication due to lack of communication * Better planning and coordination of supply and demand * Managing demand through promotions and giving incentives to customers * Contracting through banks to guarantee customer payments	(T. Wu et al., 2006) (Manuj and Mentzer, 2008b) (Tsai, 2008) (Wagner and Neshat, 2010)
T6. Risks arising from supplier	* Better strategy development in supplier evaluation and selection * Creating supplier development programs. * Better planning and coordination with suppliers * Working with multiple supplier systems * Establish binding contracts with suppliers	(Needham and Evers, 1998) (S. Chopra and Sodhi, 2004) (Gaudenzi and Borghesi, 2006) (Samvedi et al., 2013)
TL3. Short lead times and product's life cycle	* To prapere the proactive action plan avoiding the bottlenecks. * Increasing flexibility to enable more production on determined time. * Better training of employee to adapt short lead times.	(Gaudenzi and Borghesi, 2006) (Tsai, 2008) (Wagner and Neshat, 2010)
T4. Transit time variability	* To set tolerance time and plan accordingly, considering that the shipping times may change in material supply or order delivery to the customer. * To create an optimum transport plan by	(S. Chopra and Sodhi, 2004) (Manuj and Mentzer, 2008b) (Xie et al., 2011)

	considering the times and variations in ship, road, and airline transports. * To determine the duration of the contract against the loss that will occur due to time changes and thus to get the return for the loss that may occur	

5. CONCLUSION

Today, supply chain risk management is gaining in importance. The businesses are developing risk strategies to gain advantages over their competitors. Therefore, they need to determine and prioritize their supply chain risk factors. According to the assessed risk factors, the risk mitigation strategies need to be improved to overcome the risk factors. Otherwise, they can't keep up with the high competition.

Based on the information above, in this study, it was aimed to define and prioritize supply chain risk factors. Therefore, firstly the supply chain risks were collected from literature, then the obtained risks were grouped and combined, and finally a summary risk table consisting of the seven main risks and 47 sub-risks was created to be considered in the study. Secondly, a questionnaire was created to evaluate the risks in the risk table. Thirdly, evaluations were received from 391 users.

To investigate whether the questions directed to the participants were homogeneous or not, the Cronbach Alpha coefficient was calculated as 0,950. According to the obtained coefficient, the scale reliability of the questions was very high.

The level of education of the participants in this research was as follows: 116 (29.67%) associate degree and less, 275 (70.33%) bachelor's degree, and more. Also, it was observed that 56.52% of the participants had a work experience of 5 years and less and 43.48% had a work experience of 5 years and more.

The structural equation model was established, and hypotheses were formed to investigate whether each major risk group had an impact on supply management risks, and the effects of each sub-risk related to the main risk groups to the groups were examined. In the research model for testing established hypotheses, it was determined that the main identified risks in our study were those that explained 80,6% of the risks in the supply chain management. These risks were demand risks, supply risks, logistics risks, product/process risks, financial risks, information risks, and macro risks respectively. To reduce the number of primary risks to be examined for further analysis, Pareto analysis was performed and the first two main risks, demand risks and supply risks were analyzed.

To examine, prioritize, and further analyze the selected supply and demand risks, related sub-risks, and the problems they caused were defined. Then, to prioritize among the sub-risks and to eliminate certain risks or to minimize its impact, a risk analysis was designed with the Fuzzy Analytical Hierarchy Process. As a result of the fuzzy AHP, risks that arose from procurement cost, frequency of material design changes and inaccurate demand forecasts constituted the three most critical and important sub-risks within the supply chain management, respectively. Creating an action plan for each sub-risk was difficult in terms of cost, time, and other factors. Therefore, the Pareto analysis according to the fuzzy AHP results was applied. Procurement cost, frequency of material design changes, inaccurate demand forecasts, risks arising from supplier, risks arising from the costumer, transit time variability, short lead times, and product's life cycle risks were identified as the most important sub-risks in the action plan.

This study contributes a unique and holistic value to supply chain risk management studies in literature by creating an integrated risk table collected from literature and analyzed in an integrated way with SEM (structural equation model) and fuzzy MCDM (multi-criteria decision making).

6. RECOMMENDATIONS

There are several directions for future research. These are as following.

One is that the sample size can be increased and the risk factors in different sectors can be compared. Other is that the all sub-risks factors would be prioritized. Based on the all sub-risks prioritized, the mitigation strategies can be developed. It may also be interesting to identify the impact of a particular mitigation strategy on various partners in the supply chain.

The study can be expanded to analyze the risk not only after it was occurred, but also by calculating the probability and effects of occurrence of risky events.

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8. APPENDIX

8.1. Appendix A

The survey presented to the participants was displayed below its original format.

Değerli Cevaplayıcı;

Bu anket, Adana Alparslan Türkeş Bilim ve Teknoloji Üniversitesi'nde **"Endüstri Mühendisliği-Tedarik Zinciri Risk Yönetimi"** alanında hazırlanan bir yüksek lisans tez çalışmasında kullanılacaktır. Ankete vereceğiniz doğru ve sizi yansıtan cevaplar, sadece akademik amaçlarla kullanılacak ve verilen bilgiler kesinlikle gizli tutulacaktır.

Gösterdiğiniz İlgiye Şimdiden Teşekkür Ederiz.

I. Bölüm: Aşağıda tedarik zincirinde doğabilecek risk maddeleri vardır, lütfen sizde üretim ve hizmet sektöründe çalışan bir bakış açısıyla aşağıdaki risk unsurlarını önem derecesine göre aşağıdaki ölçeği kullanarak görüşlerinize uygun düşen kutucuğu işaretleyiniz. Bu sorularda doğru ya da yanlış cevap yoktur.

ÖNEM DERECESİ	**5**	**1**
TANIM	**AŞIRI ETKİLİ**	**ETKİSİZ**

İFADELER					
Aşağıdaki 7 risk ifadesi tedarik kaynaklı risklerle ilgilidir.					
1.1. Satın alma faaliyetlerinde yüksek maliyet	5	4	3	2	1
1.2.Teknolojide ki değişimler ve belirsizlikler	5	4	3	2	1
1.3. Malzeme tasarımındaki sık değişiklikler	5	4	3	2	1
1.4. Küresel dış kaynaklara bağlılığın getirdiği dış satıcılara bağlılık, işten çıkarmalar gibi doğacak riskler	5	4	3	2	1
1.5.Tedarik edilen ürünün yolda geçirdiği sürelerin değişkenliği	5	4	3	2	1
1.6. Piyasadaki tekelleşme	5	4	3	2	1
1.7. Tedarikçi kaynaklı doğabilecek riskler	5	4	3	2	1
Aşağıdaki 10 risk ifadesi üretim-proses kaynaklı risklerle ilgilidir.					

2.1. Üretim ve prosesin kapasitesinin, esnekliğinin, kabiliyetinin yetersiz olması.	5	4	3	2	1
2.2. Makine ve tasarım teknolojisindeki meydana gelen sık değişimler	5	4	3	2	1
2.3. İşletme veya işletmede kullanılan ekipman-teçhizatlar da ki bozukluklar ve aksamalar	5	4	3	2	1
2.4. Çalışan personelden kaynaklanan riskler	5	4	3	2	1
2.5. Kapasite, ürün ve stok maliyetinin yüksekliği	5	4	3	2	1
2.6. Üretimle bağlantılı durumlardan doğan riskler	5	4	3	2	1
2.7. Teknik bilgi kaynaklarının yetersiz olması	5	4	3	2	1
2.8. Üretimden çıkan nihai üründen doğabilecek riskler	5	4	3	2	1
2.9. Çalışma koşullarının elverişsizliği	5	4	3	2	1
2.10. Stoklama ve depo alanından doğan riskler	5	4	3	2	1
Aşağıdaki 6 risk ifadesi talep kaynaklı risklerle ilgilidir.					
3.1. Yanlış talep tahmini	5	4	3	2	1
3.2. Müşteri kaynaklı doğan riskler	5	4	3	2	1
3.3. Ürün hayat döngüsünün ve teslim sürelerinin kısalığı	5	4	3	2	1
3.4. Müşteri ilişkileri yönetiminin yetersiz olması	5	4	3	2	1
3.5. Rekabet ve rakiplerden doğan riskler	5	4	3	2	1
3.6. Kendi işletmesi içerisinde olan düşük üretim, dış işletmelere bağlılık	5	4	3	2	1
Aşağıdaki 8 risk ifadesi finans kaynaklı risklerle ilgilidir.					
4.1. Finansal ve sigortayla ilgili konulardaki kısıtlar	5	4	3	2	1
4.2. Enflasyon ve para birimindeki kur değişikleri	5	4	3	2	1
4.3. Müşterinin kötü finansal durumundan doğan riskler	5	4	3	2	1
4.4. Düşük kar marjları	5	4	3	2	1
4.5. Pazar büyüme oranlarının belirsizliği ve pazar büyüklüğü	5	4	3	2	1
4.6. Ücret oranlarının değişimi	5	4	3	2	1
4.7. Ürün maliyetinin yüksekliği	5	4	3	2	1
4.8. Yanlış finans, muhasebe ve ödeme planı yönetimi	5	4	3	2	1
Aşağıdaki 7 risk ifadesi lojistik kaynaklı risklerle ilgilidir.					
5.1. Yanlış lojistik modu seçimi ve seçilen moda bağlılık	5	4	3	2	1

5.2. Lojistik sırasındaki kaza ve hasarlar	5	4	3	2	1
5.3. Uygun olmayan çalışma koşulları	5	4	3	2	1
5.4. Eğitim eksikliği	5	4	3	2	1
5.5. Eski teknoloji kullanımı	5	4	3	2	1
5.6. Yanlış lojistik yönetimden doğan riskler	5	4	3	2	1
5.7. Liman gibi taşıma bölgelerinde meydana gelebilecek saldırı, hırsızlıklar	5	4	3	2	1
Aşağıdaki 6 risk ifadesi makro risklerle ilgilidir.					
6.1. Doğal afetler, salgın hastalıklar	5	4	3	2	1
6.2. Savaş, terörizm ve yangınlar	5	4	3	2	1
6.3. Dış yasal konulardan doğan belirsizlikler	5	4	3	2	1
6.4. Politik, ekonomik ve bölgesel belirsizlikler	5	4	3	2	1
6.5. Hükümet düzenlemelerindeki değişiklik ve belirsizlikler	5	4	3	2	1
6.6. Sosyal ve kültürel memnuniyetsizlik ve şikâyetler	5	4	3	2	1
Aşağıdaki 3 risk ifadesi bilgi-iletişim risklerle ilgilidir.					
7.1. Sistem entegrasyonun veya yaygın sistem ağlarının hatalı kurulması	5	4	3	2	1
7.2. İnternet ağının güvenliliğin yetersiz olması	5	4	3	2	1
7.3. Tedarik zinciri partnerleri arasındaki bilgi-işlem platformlarının iletişim ve bağdaşmasının eksik olması	5	4	3	2	1

II. Bölüm: Demografik Özellikler

Bu bölümde istatistik amaçlı çeşitli sorular yer almaktadır. Lütfen uygun seçeneği işaretleyiniz

1. Cinsiyetiniz

( )Erkek ( )Kadın

2. Yaşınız

( ) 18-24 ( ) 25-34 ( ) 34 ve üzeri

3. Öğrenim durumunuz (En son bitirdiğiniz öğrenim düzeyini işaretleyiniz)

( ) Okur / Yazar ( ) Ortaokul ( ) Yüksekokul ( ) Master

( ) İlkokul ( ) Lise ( ) Üniversite ( ) Doktora

4. Bitirdiğiniz Bölüm Adı ( )

5. Toplam İş Tecrübeniz

( ) 1 yıldan az ( ) 3-5 yıl arası ( ) 1-3 yıl arası ( ) 5 yıldan fazla

6. Çalıştığınız departman ( )

7. Çalıştığınız Pozisyon ( )

8.2. Appendix B

The flow of the study is as following.