SUPPLY CHAIN MANAGEMENT CONSIDERING RISK FACTORS: A CASE STUDY

(RİSK FAKTÖRLERİ GÖZÖNÜNDE BULUNDURULARAK TEDARİK ZİNCİRİ YÖNETİMİ: VAKA ÇALIŞMASI)

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Güray GÜMÜŞ, M.R.

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prepared by **Güray GÜMÜŞ** in partial fulfillment of the requirements for the degree of **Master of Science in Logistics and Financial Management** at the **Galatasaray University** is approved by the

Examining Committee:

Assist. Prof. Dr. Mehtap DURSUN (Supervisor)
Department of Industrial Engineering
Galatasaray University -------------------------

Assist. Prof. Dr. İlke Bereketli ZAFEİRAKOPOULOS
Department of Industrial Engineering
Galatasaray University -------------------------

Assist. Prof. Dr. Ethem ÇANAKOĞLU
Department of Industrial Engineering
Bahçeşehir University -------------------------

Date: -------------------------

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LIST OF SYMBOLS

SCM	: Supply Chain Management
SC	: Supply Chain
SCI	: Supply Chain Integration
SCS	: Supply Chain Strategy
SCRF	: Supply Chain Risk Factor
PC	: Performance Criteria
SCC	: Supply Chain Configuration
II	: Internal Integration
CI	: Customet Integration
SI	: Supplier Integration
SCRM	: Supply Chain Risk Management
DM	: Decesion Maker
RF	: Risk Factor
MF	: Membership Function
COG	: Center of Gravity
MATLAB	: Matrix Labarotory
FCM	: Fuzzy Cognitive Map
ANP	: Analytic Network Process
DEMATEL	: Decision-Making Trial and Evaluation Laboratory
ROI	: Return on Investment
ROS	: Return on Sale

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ABSTRACT

Today's competitive business world make supply chain management (SCM) much more complex and dynamic. Besides this competitive environment, growing uncertainties also impact firms seriously and force them to develop sustainable approaches along supply chain (SC) operations.

The aim of this study is constructing a comprehensive configuration to help decision makers during the supply chain management process and simplify to understand relationships among Supply Chain Integration (SCI), Supply Chain Strategies (SCSs), Supply Chain Risk Factors (SCRFs) and Performance Criterias (PCs).

Criteria of SCI, SCSs and PCs are based on literature rewiev and we handle all concepts of our reference study about them. SCRFs are also based on literature but our reference study about SCRFs includes 20 RFs and they are reduced to 4 main RFs by experts to compose more compact model. Our experts are working in automotive sector in Turkey.

First, Supply Chain Configuration (SCC) is designated in this survey. Then, direction and strength of relationship among concepts are identified according to experts' answers and all relationships are examined by the means of Fuzzy Logic and Fuzzy Cognitive Map (FCM) methodologies. The results, paralelled to literature, show that proposed SCC can help us to analyze relationships from the broad perspective and it also enables to react risks immediately.

ÖZET

Günümüzün rekabetçi iş dünyası, tedarik zinciri yönetimini (TZY) çok daha karmaşık ve dinamik hale getirmektedir. Bu rekabetçi ortamın yanı sıra, artan belirsizlikler de firmaları ciddi bir şekilde etkilemekte ve tedarik zinciri (TZ) operasyonları boyunca sürdürülebilir yaklaşımlar geliştirmeye zorlamaktadır.

Bu çalışmanın amacı, tedarik zinciri yönetimi sürecinde kapsamlı bir konfigürasyon oluşturarak karar vericilere yardımcı olmak ve tedarik zinciri entegrasyonu (TZE), tedarik zinciri stratejileri (TZS) tedarik zinciri risk faktörleri (TZRF) ve performans kriterleri arasındaki ilişkiyi inceleyebilmektir.

Tedarik zinciri entegrasyonu, tedarik zinciri stratejileri ve performans kriterleri literatür araştırmalarına dayanmaktadır ve bu konularda referans çalışmalarda ki tüm kavramlar ele alınmıştır. Tedarik zinciri risk faktörleri de literatür araştırmalarına dayanmaktadır fakat referans çalışmamızda yer alan 20 risk faktörü, daha kompakt bir model oluşturmak için uzman görüşlerine gore 4’e indirilmiştir. Uzmanlar Tükiye’ de otomobil sektöründe çalışmaktadır.

Bu araştırmada, öncelikle Tedarik Zinciri Konfigürasyonu (TZK) dizayn edilmiştir. Daha sonra ise uzmanların cevaplarına göre kavramlar arasındaki ilişkilerin yönü ve gücü belirlenmiş ve tüm ilişkiler Bulanık Mantık ve Bulanık Bilişsel Haritalama (BBH) metotları vasıtasıyla incelenmiştir. Literatürle paralellik gösteren sonuçlar, önerilen tedarik zinciri konfigürasyonun ilişkileri geniş perspektiften analiz etmemize yardımcı olabileceğini ve ayrıca bu konfigürasyonun, karşılan risklere göre hızlı reaksiyon verebilme imkanı sağladığı göstermiştir.

1. INTRODUCTION

Today's world intense and multi-dimensional cross-firm and other environmental interactions cause a serious of uncertainties. In addition to these, competitive market condition and evolved organizational structure compel firms to design their supply chain (SC) more efficiently. The definition of supply chain involves all process that start from raw materials to final products and include delivering of them to end consumer by organizational network and reverse logistic (Iansiti & Levien, 2004).

Basically, supply chain management (SCM) is the management of all process of SC that has several basic phases like planning, implementing and controlling (Park et al., 2005; Simchi-Levi et al., 2004). SC becomes more important because of growing global competence and "effectiveness" concept. Therefore, professionals endeavor to find best supply chain configuration (SCC) for their firms (Brandenburg et al., 2014).

In the beginning, SC managers give priority to cost reduction. Lately, for the best SCC they focus on SC continuity and resiliency that based on mutual beneficial relations with other organizations (Lambert & Cooper, 2000; Wisner & Keah, 2000). With this strategy, on the one hand organization would be more responsive to the market expectations (Richey et al., 2009), but on the other hand firms would have much more complex and great number of relationships with each other to manage (Narasimhan & Kim, 2002).

Uncertainty plays a crucial role as a result of today’s highly dynamic market environment. This paper investigates the detailed concepts of a SCM to analyze relationships and strength of them to determine best reaction during the risks. Besides decreasing impact of risks on SC, this configuration provides to view concepts, which one or ones have to be improved when there is unwilling result on your operational performance score. And we will use fuzzy sets theory which is suitable to apply in real-world decision making problems for SCM.

The present study is organized as follows: There is literature review on SCM concepts to compose a new SCC model in section 2. Section 3 analyzes the fuzzy logic and Fuzzy Cognitive Map (FCM) methodologies that employed in this paper for the identification of SC concepts relationship. In Section 4, a case study in automotive sector is illustrated. Finally, Section 5 presents conclusions and future research directions.

2. LITERATURE REVIEW

2.1 Supply Chain Integration

"Integration" term is defined as "1. the combination of two or more things so that they work together effectively. 2. the process of getting people of different races to work together instead of separately (Longman, 2008)". Supply chain integration (SCI) is defined as "managing all organizational structure to obtain perfect coordination, collaboration, products and services (Leuschner et al., 2013)".

SCI has gained quite a lot attention for researchers (Lambert et al., 1978). But there has been a little systematic approach about relationships among other supply chain measurements. Global competitive structure has dragged firms to develop more beneficial and strategic partnership and they start to make progress quickly (Lambert & Cooper, 2000; Zhao et al., 2008). However, useful relations help firms to minimize market negative effects, increasing uncertainties and risk factors emerge as critical challenges for them (Koufteros et al., 2014; Wong et al., 2015).

There are many studies and approaches about SCI construct according to different definition and dimensions in the existing literature (Van der Vaart & Van Donk, 2008). Some papers handle SCI as a single structure (Lambert et al., 1978), others study dimensions of SCI (Cousins & Menguc, 2006). Generally, SCI construct build upon two main dimensions including internal integration (II) and external integration. And external integration is composed of customer integration (CI) and supplier integration (SI) (Stank et al., 2001).

We argue three dimensions of SCI separately. Supplier Integration: SI is the ability of organizations to contact long term and strategic cooperation with suppliers (Ragu-Nathan et al., 2006). This vital collaboration enables time, effort, cost reductions and effectiveness through trust and reputation (Suhaiza & Premkumar, 2005). As we can infer from lots of study (Yang &Wei, 2013; Dyer & Nobeoka, 2000, Kannan & Tan, 2003, Ketchen & Giunipero, 2004) selection of proper suppliers and constitute functional structure for information and material flow provide numerous advantages. Customer Integration: CI consists of three primary titles, which are customer complaints to minimize, customer relationships to organize, customer satisfaction to sustain. To manage CI accurately, organizations need constant feedback from customers. Also, it is required working closely and exchanging information continuously (Suhaiza & Premkumar, 2005). Internal Integration: II is the construction of organization's departments and functions dynamically to satisfy customer expectations and achieve the goal (Flynn et al., 2010). The purpose of II in SCI is backing up external integration (supplier and customer integration) in order to improve internal efficiency and team work (Kim, 2013).

2.2 Supply Chain Risk Factors

Increasing uncertainties make difficult to predict future events and induce manufacturers to develop their supply chain (Trkman & McCormack, 2009). Therefore, supply chain risk management (SCRM) starts to draw more attention for business world and researchers (Narasimhan & Talluri, 2009; Gurnani et al., 2011; Tang,O. et al., 2012). There are obvious differences between uncertainty and risk in the literature. Lawrance (1980) defines risk as measurable adverse effects originated from uncertainties that can emerge anytime during supply chain processes (Aqlan & Lam, 2016).

Decision makers (DMs) determine supply chain risk management strategies according to risk factors (RFs). RFs are changeable from time to time and competitive firms update their risk maps periodically to decrease their influences on business and operational strategies (Antunes & Mourao, 2011).

While Trkman and McCormack (2009) classify RFs in two major groups: exogenous and endogenous, Chopra and Sodhi (2004) classify them into four main groups that are increase of prices, disrespect of the procedures for environmental protection, loss of intellectual property rights and interrupts in the working process or RFs have classified as operational, economic, environmental and social RFs (Hofmann, 2011; Giannakis & Papadopoulos, 2016).

Our study based on paper (Song et al., 2017) that categorized RFs into following certain group: 1) demand and supply uncertainty, 2) the selection of proper suppliers, 3) lower responsiveness performance, 4) the inflexibility of supply source, 5) poor quality or process yield at supply source, 6) coordination complexity/effort, 7) powerful technologies and information, 8) lack of sustainable knowledge and technology, 9) the volatility of price and cost risk factor, 10) inflation and currency exchange rates risk factor, 11) market share reduction risk, 12) reputation loss or brand damage risk is possible, 13) natural disasters risk factor, 14) inefficient use of resources risk factor, 15) environmental pollution risk factor, 16) hazardous waste generation risk, 17) the unhealthy/dangerous working environment risk factor, 18) violation of human rights, 19) failure to fulfill social commitment risk, 20) violation of business ethics.

2.3 Supply Chain Strategies

Supply chain strategy (SCS) is another significant subject for sustainability of complex supply chain systems. DMs take into account all inputs that effect SC and decide strategy to reach their goals. This strategy should be thought over elaborately because of its results which are directly concerned about operations, efficiency and organization success (Qi et al., 2011). Researchers develop several classification approaches about supply chain strategies. To give examples: 1) efficient and responsive, 2) lean and agile, 3) efficient, responsive, risk-hedging and agile, 4) pull and push (Flynn et al., 2010). In this study we will focus on "lean and agile" concepts among all others.

Lean Supply Chain Strategy: "leanness" is the strategy for the eliminating all waste along SC operations and concentrate on value-oriented activities only. Flexibility is an important factor for operations but it is not a vital for lean strategy (Naylor et al., 1999).

Agile Supply Chain Strategy: On the contrary lean SCS, flexibility and speed emerge as two keys term (Goldman et al., 1995). Agility refers to respond fluctuations in demand and shortened lead-time with considered cost efficiency. Although it is harder in consequence of growing uncertainties in the world and complexity of implementation, competitive market conditions and demands of customized products make agility inevitable for manufacturers (Qi et al., 2011).

2.4 Operational Performance

Generally, organization's performance is measured according to operational and business performances. DMs must consider all criteria of operations to determine best strategy. Correct performance criteria (PC) selection is a significant step to evaluate organization performance. While some researchers allege financial performance measurement is the most vital indicator for organizations, others claim operational performance measurement is more important. Basically, operational performance indicates the ability of meeting customer expectation or we can say that it is the indicator of efficiency and effectiveness of implemented strategies. We can find a great number of studies about operational performance. In this paper, we handle operational performance with four parameters: delivery, cost, quality, and flexibility.

Delivery: Global market conditions entail firms to have powerful, dynamic distribution planning. Optimal delivery operation is delivering accurate kind of product with correct quantity to right point on time (Ivanov et al., 2015).

Cost: Cost efficiency is crucial for organizations and plays an important role for sustainability. Simplicity, it is composed of profit maximization and cost minimization. According to Terpstra and Verbeeten (2014) customer satisfaction and cost efficiency have conflicted area where should be balanced very well. Because operations like increasing the capacity/productivity, decreasing overhead costs can reduce customer satisfaction.

Quality: Product/service quality is very practical instrument to gain customer loyalty and improve profitability. Customers evaluate a product/service quality in comparison with their expectation and have a perception about it. For the current quality management, customer requirements should be analyzed clearly and low defective high quality products should be produced (Chen et al., 2015).

Flexibility: Flexibility is meeting differential necessities and requirements by the existing manufacturing ability despite all constraints. As a result of the rapid changes of customer expectations and environmental uncertainties flexibility become a very strategic tool for today's market. Broad product line, introducing the new product to market and rapid production volume changing are cornerstone operations of flexibility (Chan, 2004).

3. METHODOLOGY

3.1 Fuzzy Logic

Obtaining continuous and correct information flow is vital operation in order to use increasing knowledge-based decision making system successfully (Yazdani et al., 2017). At this point, besides imperfect information and information asymmetry, many uncertainties emerge as a result of modern complex business world to overcome carefully.

Fuzzy sets are useful, suitable tool to figure out vagueness by categorizing objects un-sharp limitations in which membership function is identifier (Zadeh, 1965). After theorized of fuzzy set, researchers start to study about fuzzy logic which obtain a mathematical output during uncertainty. Designing fuzzy logic using fuzzy set has several specific steps given Figure 3.1.

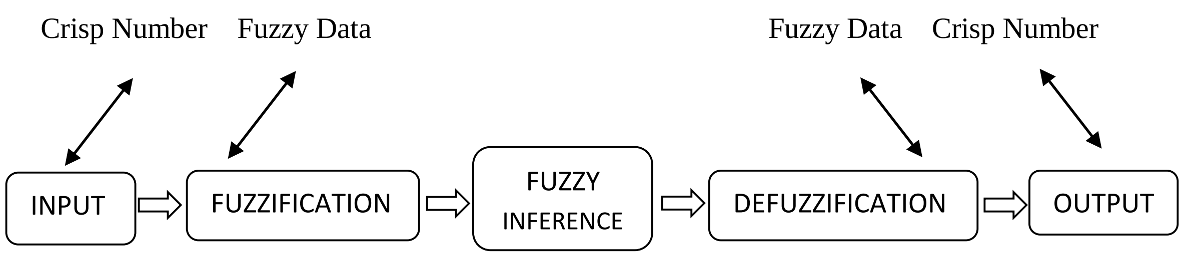


Figure 3.1: Fuzzy Logic Application Steps

3.1.1. Membership Function

The membership function (MF) allows us to graphically represent of membership in a set. The interval of the degree of membership of an element in a fuzzy set is as follows.

$$\mu_{\tilde{A}}(x) \in [0,1] \tag{3.1}$$

where $\mu_{\tilde{A}}(x)$ refers to the degree of membership or membership value of element x in fuzzy set $\tilde{A}$ (Ross, 2010). The core of a membership function contains elements x of the universe such that $\mu_{\tilde{A}}(x) = 1$. The support of a membership function involves elements x of the universe such that $\mu_{\tilde{A}}(x) > 0$. The crossover points of a membership function include elements x of the universe such that $\mu_{\tilde{A}}(x) = 0.5$ (Ross, 2010).

Two example membership functions where each element of x is mapped to a value between 0 and 1 for a crisp set and a fuzzy set are given in Figure 3.2 and Figure 3.3, respectively.

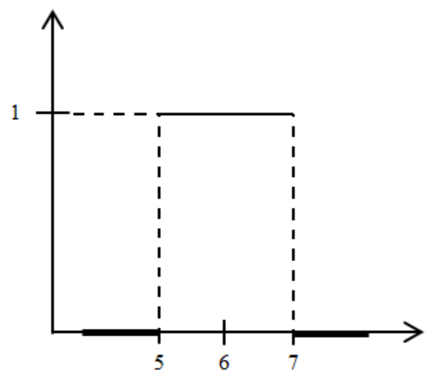


Figure 3.2: Crisp set membership function (Ross, 2010)

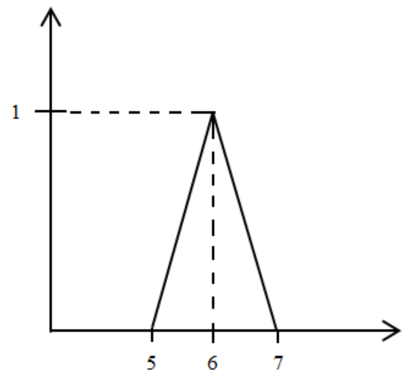


Figure 3.3: Fuzzy set membership function (Ross, 2010)

3.1.2. Fuzzy Set

Fuzzy sets enable a wider range of applicability than the classical sets. Basically, these sets help cope with problems in which the source of imprecision is the absence of determined criteria of class membership rather than the presence of random variables (Zadeh, 1965).

There are some basis definitions about fuzzy sets in literature:

i) Normal fuzzy set, whose membership function has at least one element x in the universe with a membership value that is equal to unity (Ross, 2010).

ii) Subnormal fuzzy set, whose membership function has no element x in the universe with a membership value that is equal to unity (Ross, 2010).

iii) Convex fuzzy set, if the elements x, y and z in a fuzzy set and $\tilde{A}$ has a relation such that $x < y < z$, which implies that $\mu_{\tilde{A}}(y) \geq \min[\mu_{\tilde{A}}(x), \mu_{\tilde{A}}(z)]$ (Ross, 2010).

iv) The maximum value of a membership function is the height of a fuzzy set $\tilde{A}$, which is denoted by the following formulation (Ross, 2010).

$$hgt(\tilde{A}) = \max\{\mu_{\tilde{A}}(x)\} \tag{3.2}$$

A notation for a fuzzy set $\tilde{A}$ with the universe of discourse, x, which is discrete and finite, is as follows (Ross, 2010).

$$\tilde{A} = \left\{ \frac{\mu_{\tilde{A}}(x_1)}{x_1} + \frac{\mu_{\tilde{A}}(x_2)}{x_2} + \ldots \right\} = \left\{ \sum_i \frac{\mu_{\tilde{A}}(x_i)}{x_i} \right\} \tag{3.3}$$

A notation for a fuzzy set $\tilde{A}$, with the universe of discourse, x, which is continuous and infinite, is as (Ross, 2010):

$$\tilde{A} = \left\{ \int \frac{\mu_{\tilde{A}}(x)}{x} \right\} \tag{3.4}$$

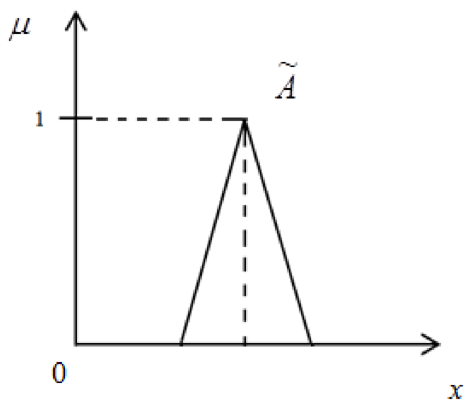


Figure 3.4: Membership function for fuzzy set $\tilde{A}$ (Ross, 2010)

3.2 Fuzzification

This section of methodology involves transformation or coding crisp input to fuzzy linguistic input by using defined, associated MFs. And also it allows to classify all inputs. After determining the sign of the causal links, we have to determine a linguistic category for all input such as "weak" or "high", "old" or "young", "hot" or "cold", etc. X_a is the given value of x. X_a could be belongs to one or more MFs which is defined before. We calculate the y value of each MFs. Its interval can be between 0 and 1 or -1 and 1. In this section, imprecise data are represented as fuzzy sets according membership functions.

3.3 Fuzzy Inference

There are two important fuzzy inference system named Mamdani fuzzy inference system and Takagi Sugeno fuzzy model. We will apply Mamdani inference system that was proposed firstly in 1975. Fuzzy inference handles fuzzificated input by settled rules. If-than logic statements are using to design rule-based matrix according to expert knowledge.

3.4 Defuzzification

Defuzzification is the last process of fuzzy logic system that transform a fuzzy set or fuzzy number into a crisp number or value according to corresponding MFs. Unlike fuzzification, this stage produces a quantifiable result to control system. Let $\tilde{A}$ is a fuzzy set, A_λ is a lambda-cut set, where $0 \leq \lambda \leq 1$. A_λ , which is called as the lambda (λ)-cut (or alpha-cut), is a crisp set of the fuzzy set $\tilde{A}$, where $A_\lambda = \{x | \mu_{\tilde{A}}(x) \geq \lambda\}$ (Ross, 2010).

There are many different methods of defuzzification: adaptive integration, basic defuzzification distributions, bisector of area, constraint decision defuzzification, center of area, center of gravity, extended center of area, extended quality method, fuzzy clustering defuzzification, fuzzy mean, first of maximum, generalized level set defuzzification, indexed center of gravity, influence value, last of maximum, mean of maxima, middle of maximum, quality method, random choice of maximum, semi-linear defuzzification, weighted fuzzy mean. Implementing method should be chose depending on the kind of actions that DMs want to system to take. In this paper we mention about four main methods of defuzzification in the literature (Ross, 2010).

- ***Max membership principle:***

$$\mu_{\tilde{A}}(z^*) \geq \mu_{\tilde{A}}(z), \qquad \text{for all } z \in Z, \tag{3.5}$$

where z^* is the defuzzified value.

- ***Center of gravity (COG):***

$$z^* = \frac{\int \mu_{\tilde{A}}(z).z \; dz}{\int \mu_{\tilde{A}}(z)\, dz}, \tag{3.6}$$

where $\int$ refers to an algebraic integration.

- ***Weighted average method:***

$$z^* = \frac{\sum \mu_{\tilde{A}}(\bar{z}).\bar{z}}{\sum \mu_{\tilde{A}}(\bar{z})}, \tag{3.7}$$

where $\sum$ represents the algebraic sum and $\bar{z}$ is the center of gravity of each symmetric membership function.

- ***Mean max membership principle:***

$$z^{*} = \frac{a+b}{2} \tag{3.8}$$

where a and b are the points that are located on the plateau. In some cases, the maximum membership can be a plateau rather than a single point.

3.5 Fuzzy Cognitive Map

FCM is viable modeling for researchers to reveal and analyze interrelationship among the identified concepts for tracking impacts of factors in the system. It is a practical method to apply for large number of variable. Generally, construction of FCM bases on causal human experience, knowledge and historical data. FCM method process all data by using its system which is combined of fuzzy logic and neural network basically (Kosko, 1986).

FCM is modeled using graphical representations with feedbacks which concept nodes and weighted edges are the elements. Edges represent relations between the concepts by means of direction of causality: whether the causal relationship is positive, negative or null, and connect the nodes through which causal relationships between concepts are produced (Büyükavcu et al., 2016).

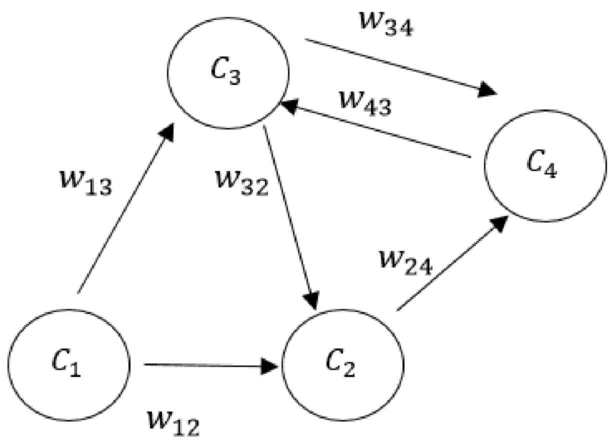


Figure 3.5: Graphical representation of FCM

$C = \{C_1, C_2, ..., C_n\}$ is the representation of concepts set that usually represent a state, variable, event, action, goal, target, value or other element of systems (Xirogiannis & Glykas, 2004). And edges (C_j, C_i) demonstrate how much effect concept C_j causes concept C_i, and are utilized for causal relationships among concepts. The intensity of causality links value in the interval [-1,1] or can be represented with linguistic variables such as “negatively medium”, “zero”, “positively very strong”, etc. Figure 3.5 indicate the graphical presentation of a FCM.

The sign of w_{ji} indicates the direction of causal links between concepts. If $w_{ji} > 0$, then there is a positive cause-effect relationship, if $w_{ji} < 0$, then there is a negative cause-effect relationship between concepts C_j and C_i. Besides, if $w_{ji} = 0$, then there is no causality between associated concepts. In addition, the direction of causal links represents if concept C_j causes concept C_i, or vice versa. A value assign to weight w_{ji}, so that system determines the power of these causal relations. For instance, in Figure 3.5, concept C_3 causes an increase or a decrease in C_4 with a degree of W_{34}. The value of each concept is calculated, taking into account effects of the other concepts on the under-evaluation concept, by running the given iterative formulation.

$$A_i^{(k+1)} = f\left(A_i^{(k)} + \sum_{\substack{j \neq i \\ j=1}}^{N} A_j^{(k)} w_{ji}\right) \quad (3.9)$$

where $A_i^{(k)}$ is the value of concept C_i at k^{th} iteration and w_{ji} is the weight (intensity) of the connection from C_j to C_i , and f is a threshold function.

All concepts activation levels are synchronously updated in FCM, which indicates a discrete time system. Therefore, the system is updated in a simultaneous way. Concept C_i activation level is denoted by A_i^t and t is the time step. The vector $A^t = \left[A_1^t, A_2^t, ..., A_n^t\right]$ shows the entity of the FCM at time step t, n is the number of concepts. Each concept has an initial and a final vector, which represent a state for the system at the initial and the last time step, respectively. FCM modeling main objective is to identify the final vector that provides decisive value of each concept (Büyükavcu et al., 2016).

4. A CASE STUDY IN AN AUTOMOTIVE SECTOR

FCM is very beneficial method when there is only linguistic variable of fuzzy numbers at decision process. It also provides to view negative relationships unlike ANP (Analytic Network Process) and DEMATEL (Decision-Making Trial and Evaluation Laboratory) approaches. When it is difficult or impossible to formulate quantitative mathematical model due to lack of numerical data, knowledge based on cognitive map is successful method to make decision for complex systems (Kosko, 1986).

In this section, FCM approach is applied in order to survey interrelations between SCC criterias. The application steps are given in Figure 4.1.

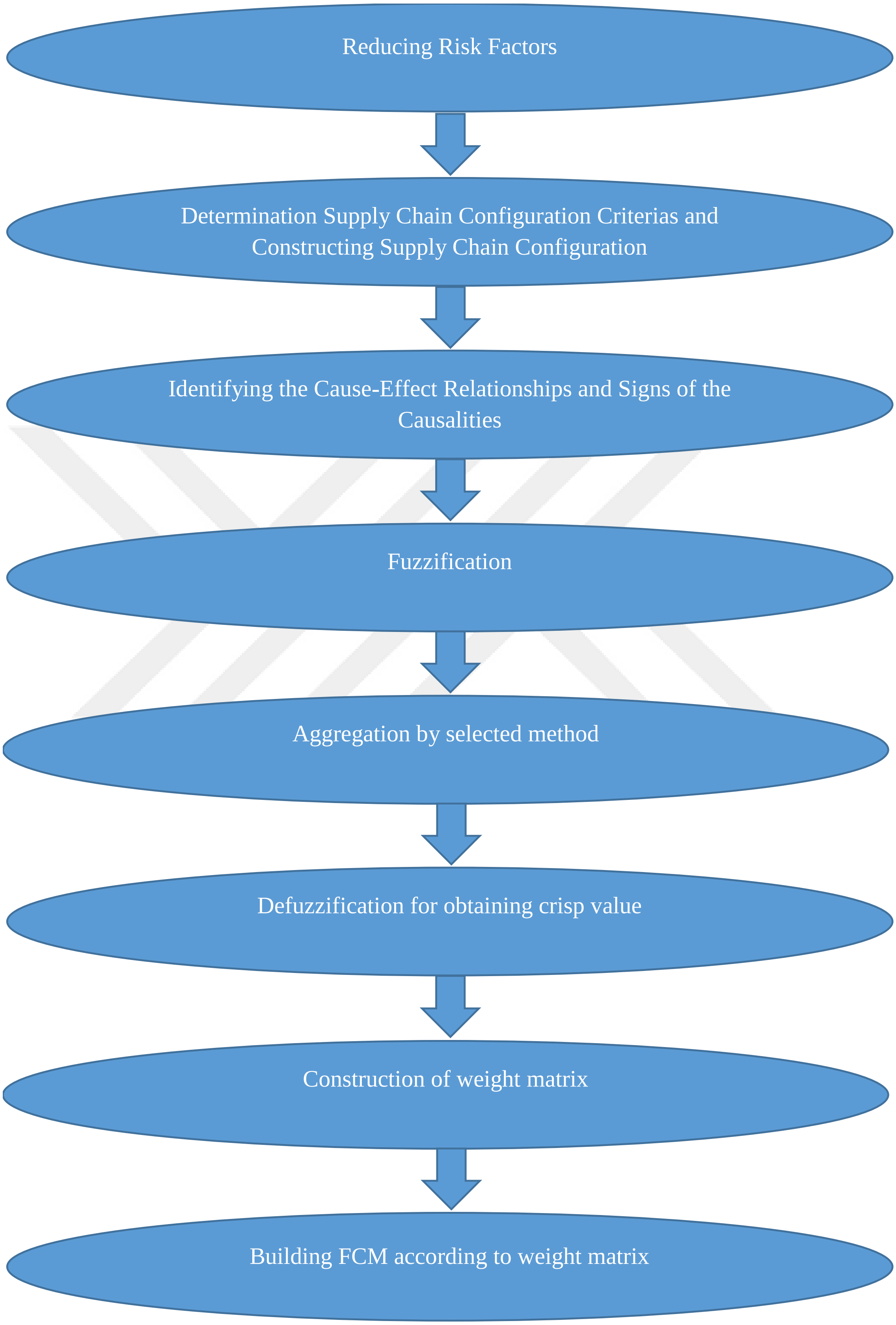


Figure 4.1: Application steps of the study

FCM are shaped by integrating the human past personal and professional experiences to simulate, analyze the existing system and predict future system behavior (Kaufmann et al., 2016). Therefore, selection of expert is a critical factor that effect model deeply and directly.

The application is conducted in an automobile factory which is one of the largest manufacturers in Turkey. Experts' characteristics are presented in Table 4.1, indicating their position, years in current position and total years in the company.

Table 4.1: Experts characteristics

	Position	Years in current position	Years in factory
Expert 1	Top Manager	4	24
Expert 2	Middle Manager	3	10
Expert 3	Middle Manager	1	7

4.1 Supply Chain Configuration

The first step to construct SCC is determining concepts. There are various perspective and configurations in the literature. Some of researchers investigate SCI and PCS, some of them focus on SCSs and there are lots of papers about supply chain risk factors (SCRFs). We will compose a new configuration that includes SCI, SCSs, PCs and SCRFs altogether. The main goal of this research is designating best configuration of SC to help DMs or systems to control SC dynamically and take an action according to relationship and degree of relationship of parameters.

In our model, SCI contains 3 concepts named II, SI and CI; SCS contain 2 concepts named lean and agile and PC contain 4 concepts named cost, delivery, flexibility and quality. Another main topic is SCRF. But frequency and impact of each risk factors make some of factor much more noteworthy among 20 factors that we were considered in our research. And the number of concepts shouldn't be so high because it is hard to cope with relationships and to evaluate the strength of connections. Decreasing the number of concepts makes output more useful and realistic. In order to compose compact model and get practical, proper results we will identified most influential risk factors according to strength the influence of them on SCM for our case.

4.1.1. Reduction of Risk Factors

Defining risk and calculating the total risk value is first step to reduce risk factors. Risk factors are based on Song et al. (2017) survey that we mentioned in literature review. Generally, literatures describe the risk as:

$$\text{Risk}i = P_i \times L_i \tag{4.1}$$

where Risk$i$ is the ith risk event, P_i is the possibility of happening of the ith risk event, and L_i is the intensity of the ith risk event. P_i can be determined while handling all the factors that affect risk events. Historical records and experts knowledge, experience can be used to estimate P_i (Aqlan et al., 2015). We will apply expert knowledge in our survey.

First, a mail containing how total value of Risk Factor calculating and which RFs we are examining was send to experts. All information was written from literature without any transformation. After that, we hold meetings with experts and clarify their questions by explaining our model exhaustively. 3 experts who are working in an automobile factory in Turkey evaluate all 20 RFs concepts and they have identified 4 common risk factors which are emerging frequently and effecting SC operations directly in their factory. The ratio percentage of RFs is given Table 4.2. These are 1) demand and supply uncertainty, 2) lower responsiveness performance, 3) a poor quality or process yield at work, 4) the selection of proper suppliers.

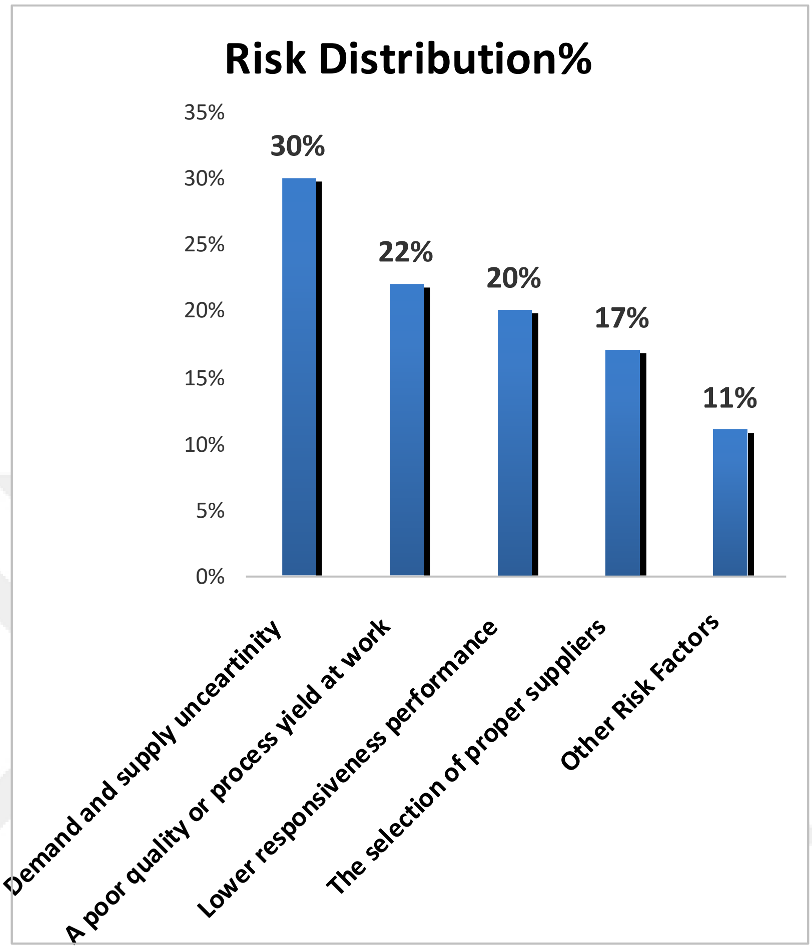


Figure 4.2: Risk Distribution graph

After reducing risk factors our FCM models contain 13 concepts that each of them can be inputs and outputs in our configuration given in Table 4.2. This approach makes our configuration more realistic, applicable and useful for our case.

Table 4.2: SCC Criteria

Label	**Concept**	**Definiton**
C_1	Supplier Integration	SI is the ability of organizations to contact long term and strategic cooperation with suppliers.
C_2	Internal Integration	II is the construction of organization's departments and functions dynamically to satisfy customer expectations and achieve the goal.
C_3	Customer Integration	CI consists of three primary titles, which are customer complaints to minimize, customer relationships to organize, customer satisfaction to sustain.
C_4	Delivery	It is delivering accurate kind of product with correct quantity to right point on time.
C_5	Quality	It is customers' evaluation a product/service quality in comparison with their expectation.
C_6	Flexibility	Flexibility is meeting differential necessities and requirements by the existing manufacturing ability despite all constraints.
C_7	Cost	It is composed of profit maximization and cost minimization.
C_8	Lean	"Leanness" is the strategy for the eliminating all waste along SC operations and concentrate on value-oriented activities only.
C_9	Agile	Agility refers to respond fluctuations in demand and shortened lead-time with considered cost efficiency.
C_{10}	Demand and supply uncertainty	Fluctuations of demand and supply according to past years records or experience.
C_{11}	Lower responsiveness performance	Lack of readiness to react suggestions, influences, appeals or efforts.
C_{12}	A poor quality or process yield at work	Lack of quality or process along operations.
C_{13}	The selection of proper suppliers	Selecting the right suppliers to deliver your products and services on time, at the right price, and in compliance with your quality standards.

And we have formed our SCC Model as in Figure 4.3 to analyze relationship and degree of relationship among parameters.

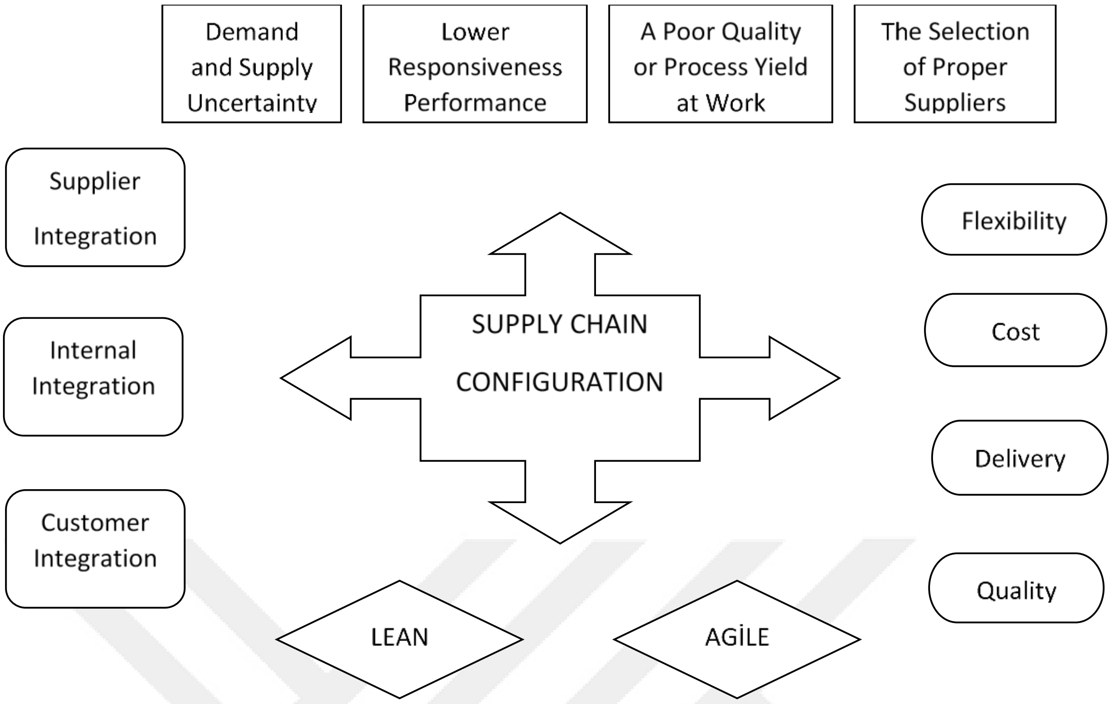


Figure 4.3: Proposed Supply Chain Configuration

4.2 Identifying the Cause-Effect Relationships and Signs of the Causalities

Our SCC model which is designated through literature and experts' knowledge is analyzed by three experts who have solid background and deep knowledge about Supply Chain Management. They indicate the effect of one concept on another.

Initially, decision makers determine existence of causal relationship between each pair of concepts. If there is a causal link, they indicate the direction of the relation such as positive or negative. Positive relation means from C_i to C_j, C_j increases when C_i increases and C_j decreases when C_i decreases. Negative relation means from C_i to C_j, C_j increases when C_i decreases and C_j decreases when C_i increases (Kosko 1986). If there is no relation between two concepts, they skip the associated pair of concepts. The composed matrix which is supposed to fill by three experts given in Table 4.3, and three decision makers' sign matrices are provided in Table 4.4, Table 4.5, Table 4.6, respectively.

Table 4.3: The matrix that is sent to experts

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1													
C2													
C3													
C4													
C5													
C6													
C7													
C8													
C9													
C10													
C11													
C12													
C13													

Table 4.4: The matrix of sign according to the expert 1

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1		+	+	+	+	+	-	+	+		-	-	-
C2	+		+	+	+			+		+			
C3	+	+		+	+		-			-	-	-	-
C4													
C5			+				+	+			-	-	+
C6								-	+	-	-	+	+
C7					+				-	+			
C8					+	-			-	-		-	-
C9				-	-	+		-		-	-	+	+
C10	-		-	-		-	+	-	+		+	+	
C11	-	-	-			-			-	+			
C12	-		-		-		+			+	+		+
C13	-			-	-	-	-	-	-		+	+	

Table 4.5: The matrix of sign according to the expert 2

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1			+	+	+	+	-	+	+	-	-	-	-
C2	+		+	+	+	+	-	+	+		-	-	
C3	+	+		+		+	-	+	+	-	-		
C4							-				-		
C5			+				+				-	-	+
C6				+	-		+	-	+	-	-	+	+
C7					+				-	+	-		
C8					+	-			-	-		-	-
C9					-	+	+	-		-	-	+	+
C10	-		-	-		-	+	-	+		+		+
C11	-	-	-	-		-	+		-	+			
C12	-	-		-	-		+				+		+
C13	-			-	-	-	-	-	-	+	+	+	

Table 4.6: The matrix of sign according to the expert 3

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1		+	+	+	+	+	-	+	+	-	-	-	-
C2			+	+	+		-	+	+			-	
C3				+	+	+				-	-	-	
C4							-		+		-		
C5							+				-	-	+
C6				+			-	-	+	-	-	+	+
C7				-	+	-			-	+			
C8						-			-	-		-	-
C9				-	-	+	+	-		-	-	+	+
C10	-		-	-		-	+	-	+		+	+	+
C11	-	-	-	-		-	+		-	+			
C12	-	-	-	-	-		+			+	+		+
C13	-				-	-	-	-	-	+	+	+	

4.3 Fuzzification

After identifying the cause-effect relationships and signs of the causalities, another step is defining a qualitative linguistic category for each one of concepts such as "few", "some", "very" to indicate the degree of influence. In this survey, nine different linguistic terms are utilized such as negatively very strong (nvs), negatively strong (ns), negatively medium (nm), negatively weak (nw), zero (z), positively weak (pw), positively medium (pm), positively strong (ps), positively very strong (pvs).

Final step of fuzzification is transforming linguistic variables to numerical values according to membership functions which are defined as triangular fuzzy numbers in this paper. Each of numerical values belong to one membership functions at least. The corresponding membership functions for defined linguistic categories are reported in Figure 4.4. They are referred as $\mu_{nvs}, \mu_{ns}, \mu_{nm}, \mu_{nw}, \mu_{z}, \mu_{pw}, \mu_{pm}, \mu_{pm}, \mu_{ps}, \mu_{pvs}$.

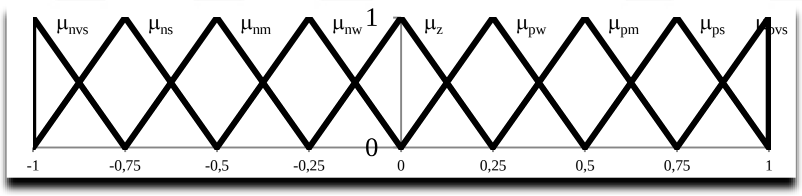


Figure 4.4: The nine membership functions corresponding to each fuzzy term of influence

Three experts' causalities power matrices are given in Table 4.7, Table 4.8 and Table 4.9 by using linguistic variables. The transformed matrices to triangular fuzzy numbers are reported in Table 4.10, Table 4.11 and Table 4.12, respectively.

Table 4.7: The matrix of power of causalities by using linguistic variables according to the expert 1

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1	z	pw	pm	pm	ps	ps	nw	pvs	ps	z	nvs	ns	nvs
C2	pw	z	pw	pw	ps	z	z	pw	z	pm	z	z	z
C3	pm	pw	z	pvs	pvs	z	nvs	z	z	nvs	nvs	nm	nm
C4	z	z	z	z	z	z	z	z	z	z	z	z	z
C5	z	z	pw	z	z	z	ps	pw	z	z	ns	nm	pvs
C6	z	z	z	z	z	z	z	nm	pm	nm	nm	pm	ps
C7	z	z	z	z	ns	z	z	z	nm	ps	z	z	z
C8	z	z	z	z	pm	nm	z	z	ns	nw	z	ns	nm
C9	z	z	z	nw	pw	pm	z	ns	z	nw	ns	pm	pm
C10	ns	z	ns	nvs	z	nm	ps	nm	pw	z	pm	pvs	z
C11	nm	nm	ns	z	z	nvs	z	z	ns	pm	z	z	z
C12	ns	z	nm	z	nvs	z	pvs	z	z	pvs	ps	z	ps
C13	ns	z	z	ns	nvs	ns	nvs	nm	ns	z	pvs	ps	z

Table 4.8: The matrix of power of causalities by using linguistic variables according to the expert 2

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1	z	z	pw	pm	pvs	ps	nm	ps	pvs	nw	nvs	ns	nvs
C2	pw	z	pw	pm	pw	pm	nw	pw	pm	z	nw	nm	z
C3	ps	pw	z	pvs	z	ps	nm	z	ps	ns	nw	z	z
C4	z	z	z	z	z	z	nw	z	z	z	nw	z	z
C5	z	z	pw	z	z	z	pvs	pw	z	z	ns	ns	ps
C6	z	z	z	pw	nm	z	pm	nvs	pvs	ns	ns	ps	ps
C7	z	z	z	z	ns	z	z	z	nm	pm	nm	z	z
C8	z	z	z	z	ps	nvs	z	z	ns	nw	z	nm	ns
C9	z	z	z	z	ns	pvs	pw	ns	z	ns	ns	ps	pm
C10	ns	z	ns	ns	z	nw	pm	nm	ps	z	ps	z	pm
C11	nm	nm	nm	nm	z	nvs	pw	z	nvs	pw	z	z	z
C12	nm	nm	z	pw	nvs	z	pvs	z	z	z	ps	z	ps
C13	ns	z	z	nw	ns	nm	ns	nw	ns	pw	ps	ps	z

Table 4.9: The matrix of power of causalities by using linguistic variables according to the expert 3

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1	z	pw	ps	pm	pvs	pvs	nm	pvs	pvs	nw	ns	ns	ns
C2	z	z	pw	ps	pm	z	nw	pw	pw	z	z	ns	z
C3	z	z	z	pw	pm	z	z	z	z	ns	nw	nw	z
C4	z	z	z	z	z	z	nw	z	ps	z	nw	z	z
C5	z	z	z	z	z	z	pm	z	z	z	nm	ns	ps
C6	z	z	z	pw	z	z	nw	nw	pm	nm	nw	pm	pm
C7	z	z	z	nw	ns	nw	z	z	nw	pm	z	z	z
C8	z	z	z	z	z	nm	z	z	ns	nw	z	nw	nw
C9	z	z	z	nw	nm	ps	pw	ns	z	nw	nm	pw	pm
C10	nw	z	nw	nvs	z	nw	pm	ns	pw	z	pm	pw	pw
C11	nw	nm	nm	nw	z	ns	pm	z	ns	ps	z	z	z
C12	ns	nw	ns	pw	nvs	z	ps	z	z	pm	pw	z	pm
C13	ns	z	z	z	nm	nw	ns	nw	nw	pw	ps	ps	z

Table 4.10: The matrix of power of causalities that are transformed to triangular fuzzy numbers according to the expert 1

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1	(-0.25,0,0.25)	(0,0.25,0.5)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(0.5,0.75,1)	(0.5,0.75,1)	(-0.5,-0.25,0)	(0.75,1,1)	(0.5,0.75,1)	(-0.25,0,0.25)	(-1,-1,-0.75)	(-1,-0.75,-0.5)	(-1,-1,-0.75)
C2	(0,0.25,0.5)	(-0.25,0,0.25)	(0,0.25,0.5)	(0,0.25,0.5)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)	(-0.25,0,0.25)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C3	(0.25,0.5,0.75)	(0,0.25,0.5)	(-0.25,0,0.25)	(0.75,1,1)	(0.75,1,1)	(-0.25,0,0.25)	(-1,-1,-0.75)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-1,-1,-0.75)	(-1,-1,-0.75)	(-0.75,-0.5,-0,25)	(-0.75,-0.5,-0,25)
C4	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C5	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.5,0.75,1)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-1,-0.75,-0.5)	(-0.75,-0.5,-0,25)	(0.75,1,1)
C6	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.75,-0.5,-0,25)	(0.25,0.5,0.75)	(-0.75,-0.5,-0,25)	(-0.75,-0.5,-0,25)	(0.25,0.5,0.75)	(0.5,0.75,1)
C7	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.5,0.75,1)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.75,-0.5,-0,25)	(0.5,0.75,1)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C8	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.25,0.5,0.75)	(-0.75,-0.5,-0,25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-1,-0.75,-0.5)	(-0.5,-0.25,0)	(-0.25,0,0.25)	(-1,-0.75,-0.5)	(-0.75,-0.5,-0,25)
C9	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(0,0.25,0.5)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-1,-0.75,-0.5)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(-1,-0.75,-0.5)	(0.25,0.5,0.75)	(0.25,0.5,0.75)
C10	(-1,-0.75,-0.5)	(-0.25,0,0.25)	(-1,-0.75,-0.5)	(-1,-1,-0.75)	(-0.25,0,0.25)	(-0.75,-0.5,-0,25)	(0.5,0.75,1)	(-0.75,-0.5,-0,25)	(0,0.25,0.5)	(-0.25,0,0.25)	(0.25,0.5,0.75)	(0.75,1,1)	(-0.25,0,0.25)
C11	(-0.75,-0.5,-0,25)	(-0.75,-0.5,-0,25)	(-1,-0.75,-0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-1,-1,-0.75)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-1,-0.75,-0.5)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C12	(-1,-0.75,-0.5)	(-0.25,0,0.25)	(-0.75,-0.5,-0,25)	(-0.25,0,0.25)	(-1,-1,-0.75)	(-0.25,0,0.25)	(0.75,1,1)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.75,1,1)	(0.5,0.75,1)	(-0.25,0,0.25)	(0.5,0.75,1)
C13	(-1,-0.75,-0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-1,-0.75,-0.5)	(-1,-1,-0.75)	(-1,-0.75,-0.5)	(-1,-1,-0.75)	(-0.75,-0.5,-0,25)	(-1,-0.75,-0.5)	(-0.25,0,0.25)	(0.75,1,1)	(0.5,0.75,1)	(-0.25,0,0.25)

Table 4.11: The matrix of power of causalities that are transformed to triangular fuzzy numbers according to the expert 2

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)	(0.25,0.5,0.75)	(0.75,1,1)	(0.5,0.75,1)	(-0.75,-0.5,-0,25)	(0.5,0.75,1)	(0.75,1,1)	(-0.5,-0.25,0)	(-1,-1,-0.75)	(-1,-0.75,-0.5)	(-1,-1,-0.75)
C2	(0,0.25,0.5)	(-0.25,0,0.25)	(0,0.25,0.5)	(0.25,0.5,0.75)	(0,0.25,0.5)	(0.25,0.5,0.75)	(-0.5,-0.25,0)	(0,0.25,0.5)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(-0.75,-0.5,-0,25)	(-0.25,0,0.25)
C3	(0.5,0.75,1)	(0,0.25,0.5)	(-0.25,0,0.25)	(0.75,1,1)	(-0.25,0,0.25)	(0.5,0.75,1)	(-0.75,-0.5,-0,25)	(-0.25,0,0.25)	(0.5,0.75,1)	(-1,-0.75,-0.5)	(-0.5,-0.25,0)	(-0.25,0,0.25)	(-0.25,0,0.25)
C4	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(-0.25,0,0.25)	(-0.25,0,0.25)
C5	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.75,1,1)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-1,-0.75,-0.5)	(-1,-0.75,-0.5)	(0.5,0.75,1)
C6	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)	(-0.75,-0.5,-0,25)	(-0.25,0,0.25)	(0.25,0.5,0.75)	(-1,-1,-0.75)	(0.75,1,1)	(-1,-0.75,-0.5)	(-1,-0.75,-0.5)	(0.5,0.75,1)	(0.5,0.75,1)
C7	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.5,0.75,1)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.75,-0.5,-0,25)	(0.25,0.5,0.75)	(-0.75,-0.5,-0,25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C8	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.5,0.75,1)	(-1,-1,-0.75)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-1,-0.75,-0.5)	(-0.5,-0.25,0)	(-0.25,0,0.25)	(-0.75,-0.5,-0,25)	(-1,-0.75,-0.5)
C9	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-1,-0.75,-0.5)	(0.75,1,1)	(0,0.25,0.5)	(-1,-0.75,-0.5)	(-0.25,0,0.25)	(-1,-0.75,-0.5)	(-1,-0.75,-0.5)	(0.5,0.75,1)	(0.25,0.5,0.75)
C10	(-1,-0.75,-0.5)	(-0.25,0,0.25)	(-1,-0.75,-0.5)	(-1,-0.75,-0.5)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(0.25,0.5,0.75)	(-0.75,-0.5,-0,25)	(0.5,0.75,1)	(-0.25,0,0.25)	(0.5,0.75,1)	(-0.25,0,0.25)	(0.25,0.5,0.75)
C11	(-0.75,-0.5,-0,25)	(-0.75,-0.5,-0,25)	(-0.75,-0.5,-0,25)	(-0.75,-0.5,-0,25)	(-0.25,0,0.25)	(-1,-1,-0.75)	(0,0.25,0.5)	(-0.25,0,0.25)	(-1,-1,-0.75)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C12	(-0.75,-0.5,-0,25)	(-0.75,-0.5,-0,25)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(-1,-1,-0.75)	(-0.25,0,0.25)	(0.75,1,1)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.5,0.75,1)	(-0.25,0,0.25)	(0.5,0.75,1)
C13	(-1,-0.75,-0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(-1,-0.75,-0.5)	(-0.75,-0.5,-0,25)	(-1,-0.75,-0.5)	(-0.5,-0.25,0)	(-1,-0.75,-0.5)	(0,0.25,0.5)	(0.5,0.75,1)	(0.5,0.75,1)	(-0.25,0,0.25)

Table 4.12: The matrix of power of causalities that are transformed to triangular fuzzy numbers according to the expert 3

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1	(-0.25,0,0.25)	(0,0.25,0.5)	(0.5,0.75,1)	(0.25,0.5,0.75)	(0.75,1,1)	(0.75,1,1)	(-0.75,-0.5,-0,25)	(0.75,1,1)	(0.75,1,1)	(-0.5,-0.25,0)	(-1,-0.75,-0.5)	(-1,-0.75,-0.5)	(-1,-0.75,-0.5)
C2	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)	(0.5,0.75,1)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(0,0.25,0.5)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-1,-0.75,-0.5)	(-0.25,0,0.25)
C3	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-1,-0.75,-0.5)	(-0.5,-0.25,0)	(-0.5,-0.25,0)	(-0.25,0,0.25)
C4	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(-0.25,0,0.25)	(0.5,0.75,1)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(-0.25,0,0.25)	(-0.25,0,0.25)
C5	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.75,-0.5,-0,25)	(-1,-0.75,-0.5)	(0.5,0.75,1)
C6	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(-0.5,-0.25,0)	(0.25,0.5,0.75)	(-0.75,-0.5,-0,25)	(-0.5,-0.25,0)	(0.25,0.5,0.75)	(0.25,0.5,0.75)
C7	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(0.5,0.75,1)	(-0.5,-0.25,0)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C8	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.75,-0.5,-0,25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-1,-0.75,-0.5)	(-0.5,-0.25,0)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(-0.5,-0.25,0)
C9	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(-0.75,-0.5,-0,25)	(0.5,0.75,1)	(0,0.25,0.5)	(-1,-0.75,-0.5)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(-0.75,-0.5,-0,25)	(0,0.25,0.5)	(0.25,0.5,0.75)
C10	(-0.5,-0.25,0)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(-1,-1,-0.75)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(0.25,0.5,0.75)	(-1,-0.75,-0.5)	(0,0.25,0.5)	(-0.25,0,0.25)	(0.25,0.5,0.75)	(0,0.25,0.5)	(0,0.25,0.5)
C11	(-0.5,-0.25,0)	(-0.75,-0.5,-0,25)	(-0.75,-0.5,-0,25)	(-0.5,-0.25,0)	(-0.25,0,0.25)	(-1,-0.75,-0.5)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-1,-0.75,-0.5)	(0.5,0.75,1)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C12	(-1,-0.75,-0.5)	(-0.5,-0.25,0)	(-1,-0.75,-0.5)	(-0.5,-0.25,0)	(-1,-1,-0.75)	(-0.25,0,0.25)	(0.5,0.75,1)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.25,0.5,0.75)	(0,0.25,0.5)	(-0.25,0,0.25)	(0.25,0.5,0.75)
C13	(-1,-0.75,-0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.75,-0.5,-0,25)	(-0.5,-0.25,0)	(-1,-0.75,-0.5)	(-0.5,-0.25,0)	(-0.5,-0.25,0)	(0,0.25,0.5)	(0.5,0.75,1)	(0.5,0.75,1)	(-0.25,0,0.25)

4.4 Aggregation of Fuzzy Numbers

First, every decision maker decide interrelationship for concepts, after that the causal links of same interrelationship are determined. And before the defuzzicifation process the fuzzy numbers that are assigned from the three experts, converted into one single fuzzy set by MAX method, which is included in MATLAB Fuzzy Toolbox.

4.5 Defuzzification Process

In defuzzification step obtained single fuzzy set is converted into numerical value w_{ji}, via COG method, which is included in MATLAB Fuzzy Toolbox. COG method formulation is presented as follow (Ross, 2010).

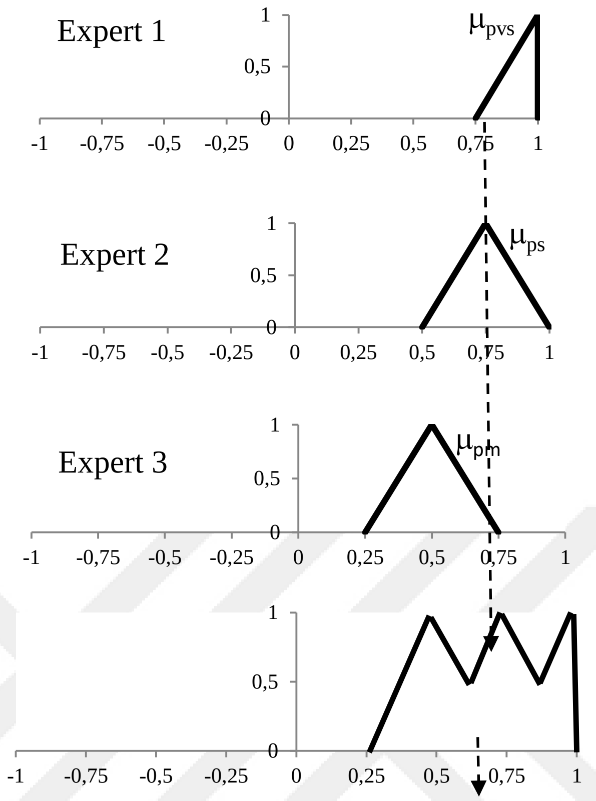
$$z^{*} = \frac{\int \mu_{\tilde{A}}(z).z \quad dz}{\int \mu_{\tilde{A}}(z)\, dz} \tag{4.2}$$

There is an example of aggregation in Figure 4.5. The decision makers opinions for a specific interrelation are illustrated by using linguistic variable in first three figures. After the aggregation of linguistic variables via MAX method, we apply COG method to compose a single numerical weight that is shown in last figure. The expert assessments for this particular example are as below.

Expert 1: The selection of proper supplier influences quality with a positive very strong degree of causation.

Expert 2: The selection of proper supplier influences quality with a positive strong degree of causation.

Expert 3: The selection of proper supplier influences quality with a positive medium degree of causation.



Result of defuzzification: 0.673

Figure 4.5: Aggregation and defuzzification of three linguistic variables

It means that the selection of proper suppliers influences quality with a degree of causation of 0.673 (e_{62}).

4.6 Construction of the Weight Matrix

Defuzzification process is implemented for relationship between each pair of (112) connected concepts and weight matrix for SCC is constructed. As shown in Table 4.13 and FCM is modelled by using graphical representations with the results of the weight matrix as given in Figure 4.6. Other important parameters, indices, are shown in Table 4.15.

Table 4.13: The weight matrix according to three experts' opinions

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
C_1	0.00	0.25	0.50	0.50	0.80	0.80	-0.38	0.80	0.38	-0.13	-0.80	-0.75	-0.80
C_2	0.13	0.00	0.25	0.50	0.50	0.25	-0.13	0.38	0.25	0.00	-0.13	-0.40	0.00
C_3	0.40	0.13	0.00	0.49	0.39	0.40	-0.39	0.00	0.37	-0.80	-0.49	-0.25	-0.25
C_4	0.00	0.00	0.00	0.00	0.00	0.00	-0.13	0.00	0.37	0.00	-0.13	0.00	0.00
C_5	0.50	0.00	0.25	0.00	0.00	0.00	0.67	0.25	0.00	0.00	-0.63	-0.63	0.80
C_6	0.00	0.00	0.00	0.13	-0.25	0.00	0.10	-0.51	0.65	-0.63	-0.50	0.63	0.63
C_7	0.00	0.00	0.00	-0.13	0.75	-0.13	0.00	0.00	-0.38	0.63	-0.25	0.00	0.00
C_8	0.50	0.00	0.00	0.00	0.40	-0.65	0.00	0.00	-0.75	-0.25	0.00	-0.50	-0.50
C_9	0.63	0.00	0.00	-0.13	-0.50	0.67	0.25	-0.75	0.00	-0.50	-0.63	0.50	0.50
C_{10}	-0.50	0.00	-0.56	-0.80	0.00	-0.38	0.63	-0.63	0.50	0.00	0.63	0.31	0.25
C_{11}	-0.38	-0.50	-0.63	-0.25	0.00	-0.80	0.25	0.00	-0.80	0.50	0.00	0.00	0.00
C_{12}	-0.50	-0.25	-0.40	-0.25	-0.92	0.00	0.80	0.00	0.00	0.39	0.50	0.00	0.63
C_{13}	-0.75	0.00	0.00	-0.35	-0.63	-0.50	-0.80	-0.38	-0.50	0.13	0.80	0.75	0.00

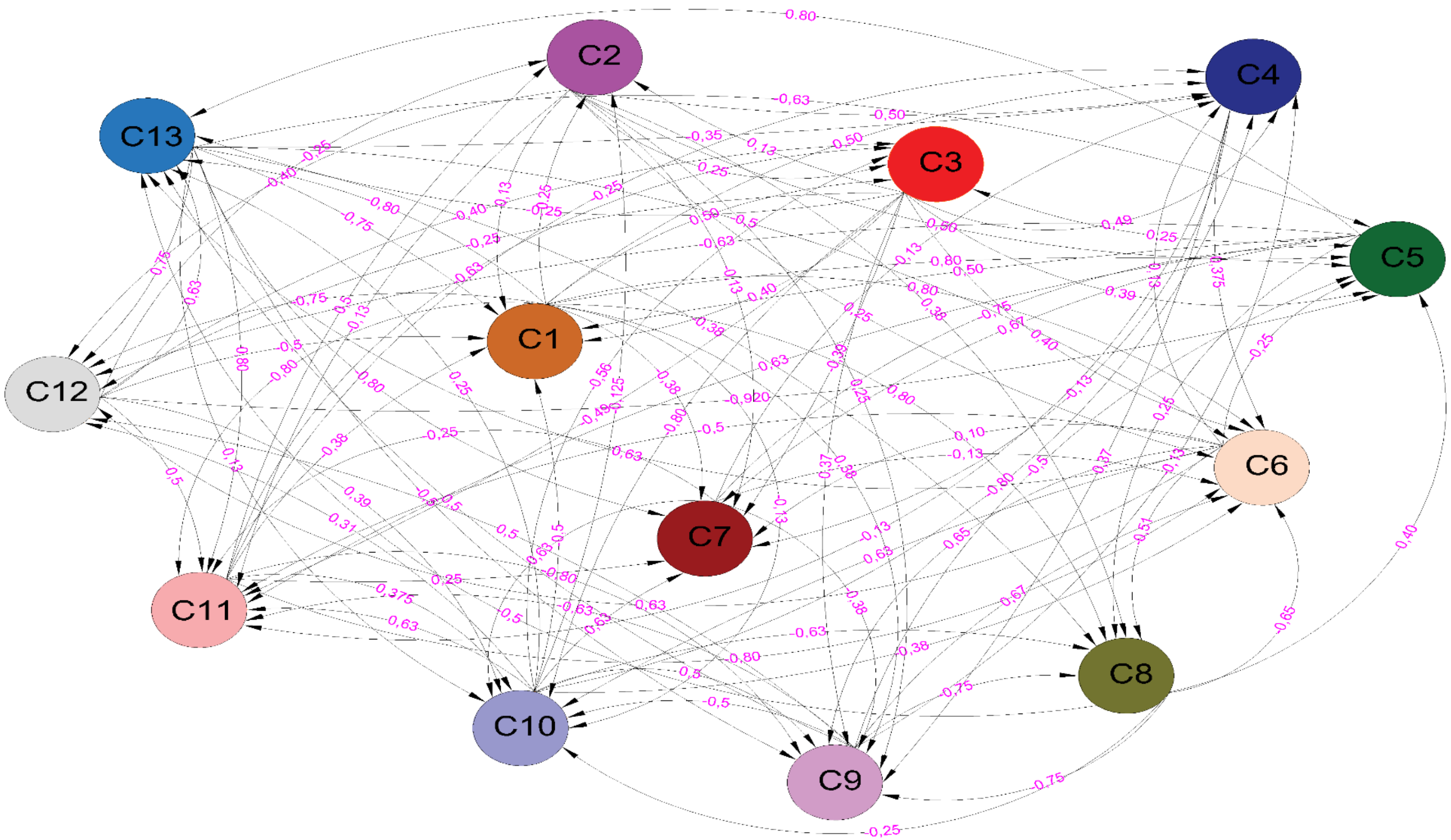


Figure 4.6: FCM

Table 4.14: Indices

Label	Concepts	Outdegree	Indegree	Centrality
C_1	Supplier integration	6.86	4.27	11.14
C_2	Internal integration	2.90	1.13	4.03
C_3	Customer integration	4.35	2.58	6.93
C_4	Delivery	0.62	3.51	4.14
C_5	Quality	3.73	5.14	8.86
C_6	Flexibility	4.01	4.56	8.57
C_7	Cost	2.25	4.52	6,77
C_8	Lean	3.55	3.68	7.22
C_9	Agile	5.05	4.94	9.99
C_{10}	Demand and supply uncertainty	5.17	3.94	9.11
C_{11}	Lower responsiveness performance	4.10	5.46	9.56
C_{12}	A poor quality or process yield at work	4.64	4.71	9.35
C_{13}	The selection of proper suppliers	5.57	4.35	9.92

Weight matrix provides outdegree, indegree and centrality for each node. Definition of outdegree values is the sum of absolute values along the row elements of the weight matrix. Indegree value shows the sum of absolute values along the column elements of the weighted matrix. Centrality values represent the sum of the outdegree and indegree values for the same weighted matrix. In our weighted matrix, for the second row, sum of absolute values is 2.90; For the second column, sum of absolute values is 1.13 and 4.03 states the sum of 2.9 and 1.13. 2.9 represents the total influence of C_2 on the other concepts. 1.13 indicates the total effect of the concepts on C_2.

4.7 Calculating Concepts' Values

FCMapper software provides us concepts' values to evaluate SCC given by Formulation (4.8). C_i concept's A_i value is calculated by regarding the effect of the interrelated concepts (C_j) on the specific concept C_i. Each concept C_i is signified by notation A_i^t that expresses the activation degree of concept C_i at the time of step t. The vector $A^t = [A_1^t, A_2^t, \ldots, A_n^t]$ represents the situation of the FCM at the time of step t.

The formulation (4.8) commence to be activated with the initial vector $A^0 = [1,1,\ldots,1]$ and all values of this vector finalized by using the formulation (4.8) and a threshold function. $f(x)$ = tanh (x) is the appropriate threshold function because A_i values can be negative and these values are changing between [-1.1]. We use the new vector as initial vector for the next iteration, which is derived by running the iterative formulation with this threshold function. This process continues for each vectors until negative as well as positive interrelations between the concepts have balanced. In other saying, iteration proceed till $|vector(t) - vector(t+1)| \leq \varepsilon$, where $\varepsilon > 0$, and small enough (Büyükavcu et al.. 2016). System is balanced after 54 iterations and values are stabilized. Reached concepts' values of SCC are listed as in Table 4.15.

Table 4.15: The concepts' values of SCC criteria

Label	**Concepts**	**Concepts' Values**
C_1	Supplier integration	0.67
C_2	Internal integration	0.64
C_3	Customer integration	0.64
C_4	Delivery	0.64
C_5	Quality	0.70
C_6	Flexibility	0.71
C_7	Cost	0.74
C_8	Lean	0.47
C_9	Agile	0.74
C_{10}	Demand and supply uncertainty	0.49
C_{11}	Lower responsiveness performance	0.31
C_{12}	A poor quality or process yield at work	0.67
C_{13}	The selection of proper suppliers	0.86

Table 4.15 indicates that the selection of proper suppliers and a poor quality or process yield at work are powerful risk factors unlike lower responsiveness performance and demand and supply uncertainty, moreover the selection of proper suppliers is most powerful factors of SCC. All of SCI concepts are powerful but SI is the first one. And cost which is one of the operational performance criteria seems other important concept of our SCC but all operational performance criteria are very powerful. When SCSs are analyzed with regard to our approach, agile strategy is much more powerful than lean strategy. Table 4.15 shows all concepts degree, relatively. Proposed SCC model's factors are decided in a detailed way by both reviewing the literature and experts' knowledge/experience. Criteria are evaluated several times and some criteria are eliminated to limit our configuration. Therefore, we focus on main factors by the means of limitations and this lead to result such a rational distribution.

4.8 Scenario Analyses

Scenario 1:

If SI, strongest concept of SCI, value reduces, many concepts are affected positively or negatively. But some of them affected more than others such as: customer integration, delivery, flexibility, agile, demand and supply uncertainty, lower responsiveness performance. For RFs, this change leads all of them increase, because it is vital criteria for sustainability of SC. For SCs, agile and lean concepts values are decreased but it influences agility deeply. For PCs, flexibility has similar dynamics with agility and decreasing flexibility is expected results for us. Besides the flexibility, delivery and quality values decrease unlike cost. Also, SCI concepts are influenced negatively. The results of Scenario 1 are listed in Table 4.16.

Scenario 2:

Flexibility and agility are two key terms to cope with growing expectation and differentiated requirements and uncertainties. When we decrease these concepts value, lean concept increases more than others. A poor quality or process yield is most influenced concepts. Its value decreases as a result of increasing leanness. Besides these significant changes; quality, demand and supply uncertainty, lower responsiveness performance are affected positively unlike the selection of proper suppliers, cost, delivery. For SCI, there is minor positive and negative changes on the concepts' value. Therefore, we can say that decreasing flexibility and agility affect SCI less than other concept groups. The resulting concepts' values according to the Scenario 2 are given in Table 4.16.

Scenario 3:

Lower responsiveness performance and poor quality or process yield at work are risk factors that can be minimize by operational effectiveness more than others. And if these risk factors values are equal to zero, we can evaluate effects of environmental uncertainties better. All concepts change positively except cost, the selection of proper suppliers, demand and supply uncertainty. SI, cost, demand and supply uncertainty has significant changes among concepts. The results of this scenario analysis are provided in Table 4.16.

Table 4.16: The results of scenario analyses

	No change	Scenario 1	Scenario 2	Scenario 3
Supplier integration	0.67	**0.20**	0.6570351	0.86
Internal integration	0.639060	0.529934	0.6406662	0.743570
Customer integration	0.642684	0.420564	0.6370711	0.8200560
Delivery	0.641180	0.402176	0.6279233	0.8161463
Quality	0.699990	0.574211	0.8552261	0.8477400
Flexibility	0.711735	0.414020	**0.2**	0.8447574
Cost	0.735448	0.825161	0.7203896	0.5153427
Lean	0.470815	0.371262	0.6740559	0.560879
Agile	0.736395	0.533355	**0.2**	0.833450
Demand and supply uncertainty	0.484772	0.731810	0.6370049	0.232589
Lower responsiveness performance	0.305915	0.647381	0.418131	**0.0**
A poor quality or process yield at work	0.665078	0.764145	0.401687	**0.0**
The selection of proper suppliers	0.862870	0.889248	0.737896	0.784874

5. CONCLUSION

In addition to increasing and differentiated uncertainties, technological developments, fast changing market condition and of course clients' growing requirements force firms to cope with hard challenges in order to maintain their competitive advantages. Organizations measure their performance generally in two categories such as business performance (return on investment (ROI), market share, return on sale (ROS), etc.) and operational performance (flexibility, cost, delivery, quality, etc.). These are important output to evaluate system effectiveness but operational performance criteria play an important role as an input of business performance criteria. SCM is the strategic component of operations, efficient well-design configuration provide firm many advantages, as well as potential disadvantages.

There are lots of studies about SCM that include conceptual framework, case studies and empirical in literature. Our approach, which is started with construction of SCC and continue to reveal relationship among all concepts, is contributed to SCM system by its coverage of many SCM tools to handle them altogether. Hence, identifying concepts and construction of compact model is one of the important step in this survey.

In this thesis, SCC criteria were determined both reviewing the literature and using knowlegde of experts. Afterwards, 20 RFs were sent to three different experts whose jobs are related to SCM. First, they reduced them into 4 main RFs that effect SCM more frequent and strongly. Lately our SCC model was composed and forwarded to same decision makers again. In this step, experts decided whether there is causality or not. If there is causality between each pair of concept, then they determine the sign of the relationship. After that the weight of outlined causal links was decided according to specified linguistic variables. These linguistic variables are converted into fuzzy numbers according to the associated membership function and they were aggregated by using

MATLAB Fuzzy Toolbox. Finally, aggregated fuzzy numbers were defuzzified by using MAX and center of gravity methods to compose weight matrix. FCM was build according to weight matrix. Additionally, constructed weight matrix provides us outdegree, indegree, centrality and concept values by FCMapper application.

The weight matrix of 13 factors has 112 different connections totally. There is no transmitter concept all of 13 concepts are ordinary concepts, hence, there is no receiver one, too. The result of FCMapper reveals particularly three factors more powerful, which are the selection of proper suppliers, agility and cost. On the other hand, it shows that lower responsiveness performance, lean and demand and supply uncertainty concepts, respectively, have a low degree of strenght. Addition to these powerful and weak concepts we can infer from the concepts values that the other factors are quite important impact on SCM.

With this investigation, we contribute to the literature by handling fundamental SCM factors comprehensively and specified our model according to risks environment. Our dynamic provides SC managers to integrate our model to their SCM. Constructed SCC can be very useful and practical for firms because uncertain business world entail them not only give the right decision but also decide as soon as possible to compete. Also we obtained significant results by implemented FCM methodology because it is suitable for complex decision model and uncertainties.

Further researches should focus on different RFs that are changing according to sectors, legal regulation, geography, etc. Besides, increasing expert number can provide more correct result. Also, as an important parameter to evaluate firms themselves, business performance criteria can be surveyed and SCS can be diversified such as leagile, risk-hedging, responsive, etc.

In our study, we have reduced risk factors according to Formula 4.1 which is based on the possibility of risk event and intensity of it. As a result of the formula we haven't study risk factors that have never happened along experts' careers. But it is obvious that some RFs affect systems excessively such as natural disasters, environmental pollution, violation of human rights, reputation loss or brand damage and violation of business ethics etc. Therefore, further researches should handle those RFs because of their destructive effects and increasing people's sensitivity about environmental protection and human rights.

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BIOGRAPHICAL SKETCH

Güray GÜMÜŞ was born in Ankara on August 25, 1989. He studied at Naval High School where he was graduated in 2007. He started his undergraduate studies at the Ocean Engineering and Naval Architecture Department of Naval Academy in 2007. In 2011, he commissioned as a naval officer. Since December 2011, he has been working as a logistic manager in Navy. Currently, he is studying master's degree in Logistics and Financial Management under the supervision of Assist. Prof. Dr. Mehtap DURSUN the Institute of Science and Engineering Galatasaray University.