EVALUATING PERFORMANCE INDICATORS OF BUSINESS PROCESS OUTSOURCING USING FUZZY COGNITIVE MAP METHODOLOGY

(İŞ SÜREÇLERİNDE DIŞ KAYNAK KULLANIMI PERFORMANSININ BULANIK BİLİŞSEL HARİTALAMA YÖNTEMİ İLE DEĞERLENDİRİLMESİ)

by

Nazlı GÖKER

Thesis

Submitted in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE

in

INDUSTRIAL ENGINEERING

in the

GRADUATE SCHOOL OF SCIENCE AND ENGINEERING

of

GALATASARAY UNIVERSITY

June 2016

This is to certify that the thesis entitled

EVALUATING PERFORMANCE INDICATORS OF BUSINESS PROCESS OUTSOURCING USING FUZZY COGNITIVE MAP METHODOLOGY

prepared by **Nazlı GÖKER** in partial fulfillment of the requirements for the degree of **Master of Science in Industrial Engineering** at the **Galatasaray University** is approved by the

Examining Committee:

Prof. Dr. Y. Esra ALBAYRAK (Supervisor)
Department of Industrial Engineering
Galatasaray University -------------------------

Prof. Dr. E. Ertuğrul KARSAK
Department of Industrial Engineering
Galatasaray University -------------------------

Prof. Dr. Şule ÖNSEL EKİCİ
Department of Industrial Engineering
Doğuş University -------------------------

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

ACKNOWLEDGEMENTS

I would like to express my gratitude to my advisor Prof. Dr. Y. Esra ALBAYRAK for her guidance, endless help, patience, knowledge, and precious support. I would also thank to my dear professors Assist. Prof. Dr. Mehtap DURSUN and Assist. Prof. Dr. Zeynep ŞENER for their help and support.

I would like to thank to my mother Assist. Prof. Dr. Bahar GÖKER and my father Prof. Dr. Kamil GÖKER, who were there for me any time I needed, and supported all my decisions about my career.

Finally, my dear friends and colleagues Michele CEDOLIN and Elif DOĞU, thank you very much for your friendship, fraternity, and all your support.

Nazlı GÖKER

June 2016

TABLE OF CONTENTS

LIST OF SYMBOLS

MATLAB	:	Matrix Laboratory
CM	:	Cognitive Map
FCM	:	Fuzzy Cognitive Map
MCDM	:	Multi-Criteria Decision-Making
AHP	:	Analytic Hierarchy Process
ANP	:	Analytic Network Process
DEMATEL	:	Decision-Making Trial and Evaluation Laboratory
TOPSIS	:	Technique for Order Preference by Similarity to Ideal Solution
COG	:	Center of Gravity
BPO	:	Business Process Outsourcing
IT	:	Information Technology
CRM	:	Customer Relationship Management
HR	:	Human Resources
HRO	:	Human Resources Outsourcing
3PL	:	Third Party Logistics
4PL	:	Fourth Party Logistics
ERP	:	Enterprise Resource Planning

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Outsourcing, which had been initially emerged as a process that aims at reducing costs, has already become a main component of strategic management due to the increasing market competition. Firms prefer to outsource their peripheral activities to the external service providers in order to focus on their core competencies. Besides, companies that utilize outsourcing services keep up with developing and changing business life and technology, and improve strategically by obtaining managerial flexibility. Moreover, labor requirement decreases depending on outsourcing.

Nowadays, outsourcing contains main processes such as information technologies, e-commerce, finance, accounting, purchasing, warehousing, logistics, distribution, human resources management, sales and marketing; although it was initially limited to sub-processes. On the other hand, firms may avoid outsourcing because of the schedule of the contract that is signed between client and provider, worry about having difficulty in market competition, risk of the opportunistic behavior of the service provider, increased costs and inadequate innovation.

Due to the factors mentioned above, performance assessment of the service provider is crucial and necessary to provide the sustainability of the financial achievement and intellectual capital of the client; and to increase the efficiency, accomplish the objective of the service provider as well as minimize the number of its mistakes by providing a self-evaluation.

The aim of this thesis is evaluating and analyzing the performance assessment of business process outsourcing. The criteria influencing the performance of business process outsourcing are indicated through a large literature survey and experts' opinions, and a multi-criteria decision model is thought to be appropriate because of the complexity of the problem. Fuzzy Cognitive Map methodology is a suitable tool due to

the presence of causalities, positive as well as negative directions of relationships among criteria, and the difficulty of expressing the interrelations with crisp numbers. The data are collected from three different experts whose job description contains business process outsourcing. Decision makers initially identify whether there is a relationship between each pair of concepts, or not. If there is a relationship, then they state its power by utilizing linguistic variables. Subsequently, each linguistic variable is denoted by corresponding fuzzy number according to the membership function. By use of "MATLAB (Matrix Laboratory) Fuzzy Toolbox", fuzzy numbers are aggregated with MAX method and then defuzzified with the center of gravity method. The resulting matrix, weight matrix, helps construct the fuzzy cognitive map and state the causal links with crisp numbers. In order to reach the value of each concept, the iterative formulation of the fuzzy cognitive map method is employed, and the results are evaluated. Scenario analyses are incorporated to understand the effect of an increase or a decrease of the importance of specific concept(s) on other concepts.

Although the problem of performance evaluation in outsourcing necessitates complicated and ambiguous decision model, very few studies in literature take into consideration the complexity and ambiguousness. In general, scholars evaluate the problem by utilizing statistics. However, the fact that there are both positive and negative relationships between concepts reveals that a method, which considers two-way relationships is more appropriate to be employed. This study introduces a novel approach to the literature, any other scholar has not used Fuzzy Cognitive Map in performance assessment of outsourcing. In addition, the proposed methodology provides an evaluation for clients to assess their service providers, a self-evaluation for service providers. Hence, this work proposes a mutual assessment.

ÖZET

Dış kaynak kullanımı, öncelikle maliyetlerin düşürülmesi amacıyla şirketler tarafından ihtiyaç duyulan bir süreç olmanın yanında, günümüz piyasalarındaki artan rekabetin bir sonucu olarak stratejik yönetimin önemli bir parçası haline gelmiştir. Firmalar temel yetkinliklerine daha iyi odaklanabilmek amacıyla çevresel aktivitelerin yönetiminde, hizmet sağlayıcılara yönelmektedirler. Aynı zamanda dış kaynak kullanımı gerçekleştiren şirketler iş yaşamındaki değişim ve gelişimlere ayak uydurabilmekte, teknolojik gelişmeleri takip ederek ve yönetsel esneklik kazanarak stratejik ilerleme sağlamaktadırlar. Bununla birlikte, dış kaynak kullanımı organizasyonlardaki iş gücü gereksinimini de azaltmaktadır.

Öncelerde alt süreçlerle kısıtlı halde olan dış kaynak kullanımı günümüzde bilgi teknolojileri, insan kaynakları yönetimi, satış ve pazarlama, e-ticaret, satın alma, finans, muhasebe, depolama, lojistik ve dağıtım gibi ana süreçleri kapsar hale gelmiştir. Öte yandan firmalar, hizmet sağlayıcıyla imzalanan sözleşmenin yapısı, pazardaki rekabette geri kalma endişesi, hizmet sağlayıcının fırsatçı davranış sergileme ihtimali, maliyet artışı ve inovasyon kısıtlılığı gibi faktörler nedeniyle dış kaynak kullanımına önyargıyla yaklaşabilmektedirler.

Yukarıda bahsedilen sebepler çerçevesinde hizmet sağlayıcının dış kaynak kullanımı sürecinde gösterdiği performansının ölçümü, hem müşterinin finansal başarısının ve entelektüel sermayesinin sürdürülebilirliğinin sağlanması, hem de hizmet sağlayıcının özdeğerlendirme yapmasına olanak vererek hatalarını enküçüklemesi, etkinliğini arttırması ve gelecekteki hedeflerine ulaşabilmesi açısından önemli ve gereklidir.

Bu çalışmanın amacı iş süreçlerinde dış kaynak kullanımının performans ölçümü ve analizini gerçekleştirmektir. Kapsamlı yazın taraması ve uzman görüşü yardımıyla iş süreçlerinde dış kaynak kullanımının performansını etkileyen ölçütler belirlenmiş olup

problemin karmaşıklığı sebebiyle çok ölçütlü bir karar modeli kurulması uygun görülmüştür. Ölçütler arasındaki ilişkilerin nedensellik içermesi, söz konusu sebep-sonuç ilişkilerinin hem pozitif, hem negatif yönde olması ve ölçütler arasındaki ilişkilerin kesin sayılarla ifade edilememesi nedeniyle Bulanık Bilişsel Haritalama yönteminin kullanılmasına karar verilmiştir. Çalıştığı firmada dış kaynak kullanımı içeren süreçlerde görev alan üç ayrı karar vericiyle görüşülüp her ölçüt çifti için nedensellik ilişkisinin varlığı, eğer varsa ilişkinin gücünün sözel değişkenler kullanılarak belirlenmesi sağlanmıştır. Ardından her bir sözel değişken, kullanılan üyelik fonksiyonunda kendisine karşılık gelen bulanık sayıyla ifade edilmiştir. Her bir karar vericinin görüşü sonucu elde edilen bulanık sayılar "MATLAB Fuzzy Toolbox" kullanılarak birleştirilmiş ve ağırlık merkezi yöntemi yardımıyla kesin sayılara dönüştürülmüştür. Bu işlemlerin sonucunda elde edilen ağırlık matrisi, bulanık bilişsel haritanın oluşturulmasını sağlamış olup, performans ölçütleri arasındaki sebep-sonuç ilişkileri kesin sayılarla ifade edilmiştir. Her bir ölçütün değerini bulmak için Bulanık Bilişsel Haritalama yönteminin yinelemeli formülü "FCMapper" adı verilen yazılım ile çalıştırılmış, sonuçlar incelenmiş ve yorumlanmıştır. Bazı ölçütlerin öneminin değişik etmenler sebebiyle azalması veya artması durumunun diğer ölçütler üzerinde yaratacağı değişimi, nedensellikleri göz önünde bulundurarak gözlemlemek amacıyla senaryo analizleri yapılmıştır.

Dış kaynak kullanımında performans ölçümün problemi karmaşık ve belirsiz bir karar modeli gerektirmesine rağmen, literatürde çok az sayıda çalışma bu karmaşıklığı ve belirsizliği göz önüne almaktadır. Araştırmacılar çoğunlukla istatistiksel yöntemler ile problemi değerlendirmektedirler. Hâlbuki ölçütler arasında hem negatif hem de pozitif ilişkiler bulunması çift yönlü etkileşimleri hesaba katan bir yöntemin kullanılmasının daha uygun olduğunu gözler önüne sermektedir. Dış kaynak kullanımının performans ölçümünde Bulanık Bilişsel Haritalama yöntemi daha önce hiçbir akademik çalışmada kullanılmamış olup bu çalışma literatüre yeni bir yaklaşım önermektedir. Tüm bunlara ek olarak, bu tezde önerilen yaklaşım hem dış kaynak kullanan firmalar hem de hizmet sağlayıcıların yararlanabileceği, değerlendirme / özdeğerlendirme yapabileceği iki yönlü bir bakış açısı sağlamaktadır.

1. INTRODUCTION

Outsourcing, being a term utilized when firms tend to disintegrate activities, is the practice of collaborating with a vendor instead of in-house personnel to carry out a job (Tsai et al., 2010; Liu et al., 2008). It is in the position of a strategic management component which affects the performance of a value chain, has been a significant part of operations management worldwide, even though it had been initially used widely in the early 1990s by means of a success obtained by Eastman Kodak in information technologies outsourcing with aiming at just cost and technical efficiency (Chou et al., 2006; Tjader et al., 2014; Gunasekaran et al., 2015). It helps outsourcers gain cost efficiency, i.e. operational, production, administrative, overhead costs, focus on core competencies (Gunasekaran et al., 2015). At the same time, they are allowed to catch up fast changes and developments in business, acquire a strategic advance by following the unstable technology, and obtain the managerial flexibility (Mojsilovic et al., 2007; Yang et al., 2007). Outsourcing helps also access to the specific technology and operational knowledge, in addition, it can decrease the amount of employment (Chen et al., 2011). Therefore, a lot of firms are willing to outsource their some processes in global business circle so that they commend to some works to service providers (Li & Wan, 2014). Several studies reveal that outsourcing expands according to both the number of outsourcing firms and the number of jobs to be outsourced. Increasing need for workforce and keeping up with developing technology may be quite hard and costly for companies. For that reason, nearly all of sectors take advantage of some type of outsourcing (Kinange & V, 2011). Besides, organizations are motivated for outsourcing because of the increasing globalization, rapid advances in technology and requirements to cost savings (Tjader et al., 2014). Outsourcing was once restricted to sub-processes; however organizations preferred to expand the kind of jobs to outsource, afterwards (Rapp, 2009). Nowadays, outsourcing may comprise various business processes such as information technologies/systems, human resources, sales & marketing, e-commerce, purchasing, finance, accounting, warehousing, logistics & distribution and tasks related to manufacturing; or only some functions of these processes.

On the other hand, outsourcing may involve some shortcomings because of which firms refuse it such as alliance challenges, regressing in competition, opportunist attitudes of the provider, increasing costs, limited innovation, etc (Gunasekaran et al., 2015). By taking into consideration both effective and ineffective aspects of outsourcing, its performance assessment is crucial and essential for the one who buys and the one who provides the service to be able to sustain the success of the outsourcing process. Many firms suffer from inaccessibility of high-quality goods and services at the right time and the minimum cost because of the lack of performance measurement for outsourcing decisions (Gunasekaran et al., 2015). If managers are willing to maintain a successful outsourcing performance management, they must include the key performance indicators in the outsourcing contract and control service provider's performance with regard to client-vendor relationship (Ibrahim & Hanafi, 2013). The outsourcer should check over the performance of provider so that a performance evaluation (bonus or penalties if they are necessary) is required to assess the work performed by the vendor (Krakovics et al., 2008). The service provider also should accomplish a self-evaluation to maintain the success of outsourcing relationship and to develop itself by considering its flaws by means of the performance assessment. Performance measurement was once significant particularly on the purpose of cost efficiency; yet it contains now all client-oriented requirements which have priorities and should be met on time. Any system of performance evaluation is crucial to comprehend the indicators of efficiency, customer service and flexibility against technological developments. Moreover, performance assessment provides both quantitative and qualitative evaluations, the measurements may be numerical or subjective such as customer satisfaction (Krakovics et al., 2008). In addition, outsourcing performance evaluation requires complex decision systems where many criteria have to be taken into account which may be complementary, contrary and competitive.

The objective of this study is to propose a fuzzy cognitive map (FCM) approach in order to determine the significance of performance indicators in business process outsourcing (BPO) decisions. For this purpose, a framework is constructed by carrying out a large literature survey and an analysis of expert opinions in order to determine factors influencing BPO success and the causal relationships among them. Hereafter, a FCM approach is developed for the evaluation of these criteria by considering their effect on BPO performance, and causal links between each pair of factors. Lastly, several scenario analyses are observed.

FCM, arising from the integration of fuzzy logic and neural networks, is a discrete time system and a causal knowledge-based method which is used for modeling complicated decision systems (Kosko, 1986). FCM achieves depicting human experience and knowledge, indicating concepts to determine the principal elements and causal relationships among the concepts for modeling a system's behavior. It has been widely utilized as a tool in different scientific and administrative cases to model decision support systems (Buyukavcu et al., 2016).

Although outsourcing performance indicators assessment necessitates a complex and ambiguous decision framework, very few studies in the literature have considered this complexity and uncertainty. Many studies evaluated the outsourcing performance criteria just by providing a statistical analysis. However, there are positive as well as negative relations among outsourcing performance factors. Since FCM methodology considers that two-way influences, it is an appropriate mathematical tool to evaluate outsourcing performance. Moreover, there is no work which combines outsourcing performance and FCM methodology. Hence, this study will provide a novelty to the literature by employing an approach that has not been proposed by any scholar before. In addition, it will be useful to outsourcers and providers by helping them assess the performance of their BPO, therefore, this study provides a mutual assessment.

The rest of this thesis is organized as follows. Section 2 provides basic concepts of outsourcing processes. Subsequent section outlines literature review on outsourcing performance evaluation and business process outsourcing, respectively. Section 4 explains the proposed methodology, section 5 gives application steps and then a numerical example in order to illustrate the robustness of the proposed approach. Conclusions and future research directions are delineated in the section 6.

2. BASIC CONCEPTS OF OUTSOURCING

The marketplace has become more and more globalized, therefore firms require conducting their operations keeping up with changings in the market. Firms should obtain competitive advantages by considering performance measures such as flexibility, responsiveness, price, and quality. These objectives can be achieved by disintegrating organizational operations in order to focus on their core competencies (Gunasekaran et al., 2015).

Outsourcing, a term being utilized when a firm tends to disintegrate activities, is the practice of collaborating with a vendor instead of in-house personnel to carry out a job (Tsai et al., 2010; Liu et al., 2008). Outsourcing is an operational strategy that affects the performance of a value chain and a strategic component of operations management. Outsourcing helps reduce costs of assets, production costs, managerial and overhead costs and provide flexibility. Furthermore, clients can straightforwardly focus on their core competencies by outsourcing their peripheral activities (Gunasekaran et al., 2015).

Several organizations are not likely to outsource their activities because of the implementation issues, the risk of opportunistic behavior of the outsourcing provider, rising coordination and procurement costs and inadequate innovation. In spite of these limitations, outsourcing will continue to become a strategic part for surviving in competitive market (Gunasekaran et al., 2015). For maintaining competitiveness, outsourcing has to improve cost, production effectiveness and quality in the value chain systems. The requirement of benefitting from outsourcing opportunities obligates organizations to evaluate their efficiency. An efficiency analysis of outsourcing possibilities should reveal the evaluation strategies of providers. Potential service providers have to be evaluated and selected with a priori assessment process. Service quality must be taken into consideration and experiences of the vendor in related area can be used as guideline to select the suitable providers (Wang et al., 2010). These are the main criteria that should be considered along with cost reduction.

In today's market, outsourcing is widely utilized in all business fields. It is seen that outsourcing has become prevalent and varied over the years since its first usage. Diversity in the use of outsourcing may be the demonstration of the fact that it can be used in different ways and areas. At the beginning, outsourcing was used only on the purpose of reducing costs, however, companies now outsource their functions in order to achieve many different objectives. For that reason, the opportunities emerged due to the outsourcing should be evaluated scientifically. In addition, legal contracts which are signed between vendor and client have to be assessed in a detailed way in order to avoid or minimize the risks related to contracts (Apak et al., 2012).

2.1. Types of Outsourcing Usage

Outsourcing processes are varied within the type of outsourcing. The outsourcing usage may be based on a single task or an entire function. Different types of outsourcing are observed in six groups such as selective outsourcing usage, tactical outsourcing usage, strategic outsourcing usage, co-sourcing usage, utility based outsourcing usage, foreign outsourcing (offshore) usage. These terms are given in Table 2.1 with their definitions.

Table 2.1: Types of Outsourcing Usage (adapted from Apak et al., 2012)

Type of Outsourcing Usage	**Definition**
Selective Outsourcing Usage	Outsourcing only for some part of the activities by providing a good risk reduction.
Tactical Outsourcing Usage	Outsourcing for short period of time usage focused on specific problem solving with the use of short term contract
Strategic Outsourcing Usage	Long term outsourcing between client and vendor based on mutual trust. Objectives are accomplished without being limited to the structure of the contract, outsourcing relationship will be for a long term.
Co-sourcing Usage	Collaboration between client and vendor instead of buying a service from an outsourcing firm only.
Utility Based Outsourcing Usage	Outsourcing in which two firms are influenced positively or negatively by the entire outsourcing process. Utility based outsourcing relationship is considered as “win-win situation”.
Foreign Outsourcing Usage (Offshore Outsourcing)	Outsourcing an activity or an entire process to an oversea company.

2.2. Advantages of Outsourcing

In order to improve the decision making process of companies, the advantages of outsourcing can be utilized. “Equipment support” or “operations management and organizational development” are the main types of these wide range advantages.

Firms can make use of outsourcing when they need to manage the functions more efficiently. Thus, the efficient usage of the sources positively influences the profitability of firms. Alternatively, outsourcing the material-focused activities to an external provider is an essential application, which provides the transformation of fixed assets to current assets. Therefore, the current ratio and cash ratios, and then the flexibility will be improved.

Transferring or utilizing the information of the service provider firms brings fast growth rate. The firms has the work knowledge, however, they lack of technical capabilities for generating and then maintaining the process. Hence, they outsource technical processes to an expert for surviving in competitive markets and growing rapidly (Apak et al., 2012).

2.3. Disadvantages of Outsourcing

Outsourcing decisions should be made by considering both advantages and disadvantages of the related process. There can be critical issues and risks which may cause big losses to the companies in the short and long term.

When the outsourced activity needs to a big investment, investment cost will be added to the outsourcing provider firm cost, and an additional cost, in other words, cost of opportunity, may be arise because of the failure of the provider (Apak et al., 2012). In addition, opportunistic behavior of outsourcing firm because of its accessibility to confidential information is the main risk of outsourcing (Gunasekaran et al., 2015). It is the crucial disadvantage of outsourcing if it occurs.

2.4. Outsourcing According to the Departments

2.4.1. Information Management Outsourcing

2.4.1.1. Information Technology Outsourcing

Over the last 30 years approximately, rapid advances in information systems/technology, provide firms realizing the strategic importance and competitive edge of information technology (IT). Companies seek for IT cost reduction even though they aim to maintain the beneficial outputs of technology by downsizing the IT activities and outsourcing them to reliable and operational efficient providers (Mojsilovic et al., 2007). The decision whether IT should be outsourced or not, is a strategic and effective on sustainability of the company. The only factor that motivates a company to outsource its IT function is not the cost, yet also service quality and flexibility (Tsai et al., 2010). The other criteria influence IT outsourcing excluding cutting the costs, are being able to focus on core competencies, improving the flexibility of IT department, avoiding troublesome, accessing to new technology, conducting legacy systems, keeping up with rapid changes in businesses and technologies (Mojsilovic et al., 2007; Chen et al., 2011).

Throughout the last decade, IT outsourcing has got a dramatic development in complexity and scope: Progress in sophistication of outsourcing contracts, grand transfer of functions, employees and assets. In such a trustful situation, risks are inevitable while expected benefits are excessive (Mojsilovic et al., 2007). Moreover, IT outsourcing may be a scary task for managers who have not an adequate knowledge about its different implications and needed IT support. In order to deal with these difficulties, a decision framework can be constructed in which the influences of decreasing in-house employee number and the ways to overcome the unexpected effects by using the knowledge management should be explained in detail (Aydin & Bakker, 2008). Moreover, since wrong IT outsourcing decisions may become the main reason of IT outsourcing failure, outsourcing decisions process should be conducted scientifically to achieve the success rate of outsourcing. Hence, the manner of IT outsourcing decision making is a crucial problem (Chen et al., 2011).

Li & Wan (2014) stated IT outsourcing process by dividing it into seven steps: (1) IT demand and performance assessment of the related department, (2) development and programing of IT; (3) outsourcing plans; (4) forming outsourcing contract; (5) service provider selection process; (6) negotiation, implementation and supervising of the contract; (7) task agreement.

2.4.1.2. E-business Outsourcing

Due to the varying knowledge about technology, e-business tasks seem to be more and more complex to firms. Integrating a new technology into a software projects increases risks; therefore companies should use advanced technology to use new e-business infrastructures, communicate with and implement new e-business systems. Moreover, to keep up with changing technology and do not become deprecated, e-business projects have to be developed and implemented in a very rapid way (Agrawal et al., 2006).
In order to overcome the difficulties mentioned above, a firm can prefer to outsource their e-business activities for maintaining them successfully thanks to an external provider who is specialized in this field, and to focus on its core competencies. Outsourcing decision of an e-business project has an important effect on a company's capability for balancing competitive requirements and its lack of knowledge depended on assets (Agrawal et al., 2006).

2.4.1.3. Customer Relationship Management Software Outsourcing

Customer relationship management (CRM) indicates a company’s activities to establish and maintain contacts with its customers. It involves sales, marketing, customer support, customer services, commitment programs, customer statistics, data mining and warehousing.

The outsourcing decision of CRM is crucial to organizations especially in the industrialized market economies such as United States, Canada, Japan and European countries because of the fact that the requirements of cost efficiency, high-speed, global communication and information processing network force many firms to outsource some components of their CRM to external providers located in other countries with considerably lower employment costs.

Over the last decade, improving technology throughout the world forces firms to outsource to offshore providers a wide range of business processes consisting of specific information-based elements (Kalaignanam & Varadarajan, 2012).

2.4.2. Production Outsourcing

Tendency of companies to outsource their production activities such as; product design & development, process management, maintenance, quality & control, is because of restriction of resources. When market demand is superior to a company's production capacity, the company has to get service from an outsourcing provider (Ray et al., 2008; Mohanty et al., 2009). To succeed in outsourcing process, financial analysis should be made to test the feasibility of business goals. Outsourcing did not emerge only in case of lack of resources; but also reduces manufacturing costs and restructures resources (Mohanty et al., 2009). In order to get the competitive advantage, client must make gain production efficiency in their value chain systems by means of outsourcing (Wang et al., 2010).

Moreover, to manage successfully the outsourcing process, both outsourcer and provider should be flexible for keeping up with changing market demand. Though there are many advantages of outsourcing, risks related to this process are inescapable. Outsourcers leave their production activities to a third-party firm by taking chance the opportunistic behavior of the provider, however, many companies outsource their production processes. Hence, the outsourcer should follow a proper outsourcing process management and financial analyses (Mohanty et al., 2009). Client firms should consider the following factors when selecting production outsourcing provider: machine treatment capability in precise data; delivery time, service quality, research & development, flexibility, risk in fuzzy and uncertain environment; production capability and interval in negotiable cases (Leng et al., 2014).

2.4.3. Human Resources Outsourcing

Nowadays, companies are looking for efficient tools to reduce operational costs. For that purpose, human resources outsourcing (HRO) emerges as a useful technique. U.S.A and European countries which are the most developed countries have already implemented and managed HRO properly. HRO is developing all around the world by adopting the logic that if a company has not an ability to offer a high-quality service, then it should outsource this service to a provider who has this ability. Outsourcing decisions are very critic and crucial in today's changing technology which influences human resources management. HR department, that is significant to any company, selects outsourcing option in order to reduce costs and manage the time efficiently. However, organizations should not outsource all their HR activities, nevertheless. They should focus on their core HR activities and outsource al the peripheral HR functions. This provides the leanness in business systems and the good organizational performance (Kinange & V, 2011).

Even though some HR functions are not apt to be outsourced due to the potential high transaction costs, economies of scale enable service providers to perform outsourced jobs at lower costs than outsourcer companies, providing an advanced profitability. Client firms tend to maintain outsourcing activities as a result of increased cash flows. Although an investor regards HRO as weakness in HR activities, an outsourcer expects that the investor will interpret this action positively because of the anticipated increased profits and cash flows to the company in the long-term by providing cost efficiency and saving. In real world, firms which outsource their HR functions get a positive reaction from capital market. The capital market response to client firms is positive when they outsource the HR functions that are routine and do not need any assets such as payroll, employment & income affirmation (Butler & Callahan, 2014).

2.4.4. Marketing & Sales Outsourcing

In outsourcing of marketing and sales department, while outsourced activities were originally restricted in peripheral functions such as advertising, nowadays firms tend to increase the kinds of activities they outsource. For example, a lot of companies have begun to outsource their whole sales force, or at least, have begun to regard as "renting a sales force" rather than "owning" it.

Many firms already outsource a part of their marketing department: advertising. Alternatively, in recent years, many other marketing activities have been supposed to be outsourced such as market research, lead management and customer statistics. Firms expect a considerable benefit from outsourced processes or jobs that are related to marketing, by getting the service from external providers if the in-house personnel are lack of this kind of ability. Surprisingly, another procedure has been popular: firms deal with selling their products or services by using a provider.

Getting a product or service into the market can be provided efficiently and effectively with the use of independent sales representatives. In many industries, independent sales representatives are widely existed. The variety of products and services sold, independent sales options are available nearly all around the world. In general, independent sales representatives become qualified practicing directly with a specific employee before beginning to become self-employed. Independent sales representatives should have adequate information about brand, competitors, customer, production, selling process, technological knowledge, selling task properties, market fluctuations.

The current literature reveals that many benefits of sales outsourcing exist along with simple cost reductions. Upsizing and downsizing rapidly become possible with an outside sales force, which is crucial in the volatility of market and can be available for both small and large companies. For instance, in the pharmaceutical sector, the size of sales force must increase depending upon the number of drugs in the firm's product range (Rapp, 2009).

2.4.5. Logistics Outsourcing

The augmenting competitive pressure symbolizing main industries, where goods are seemed in a technical way, has dramatically increased the importance of the service which firms deliver to their customers (Bottani & Rizzi, 2006). Effective logistics service is an important component of firms' performance. Competition in markets and demands of customers' for ordered products force companies to continuously assess, enhance and reengineer their logistics activities. These activities have a significant contribution in firms' efforts to satisfy customer requirements (Gotzamani et al., 2010). Many logistics processes can be outsourced such as transportation, distribution, warehousing, packaging, reverse logistics. Likewise, the use of the third party logistics (3PL) provider can be based on assets, non-assets, geographic properties or workforce demographics. Hence, for specific circumstances, firms may tend to outsource their logistics processes to assed-based companies due to the necessity of superior control of the process. Alternatively, the 3PL vendor may be needed just for its managerial capabilities. Hence management-based providers may be preferred as well (Bottani & Rizzi, 2006).

Delivery time, waiting time, and distance are crucial to final customer and influence its purchasing behavior. Therefore, evaluating the role of 3PL and their competence in improving the customer-client relationship, by enhancing service quality and final-customer satisfaction become crucial. For that reason, firms should assess the performance of 3PL providers with regard to quality management methods in their logistics services. High performance of the quality management is anticipated to result in high quality in logistics services and hence, high satisfaction of the final-customer (Gotzamani et al., 2010).

Due to the complexity of the outsourcing provider selection process multi-criteria should be considered for 3PL vendor selection to avoid low service quality and then dissatisfaction of the final-customer. Bottani & Rizzi (2006) take into account wideness of the service, business experience, type of the service, compatibility, financial stability, flexibility, price, assets, information systems, quality, strategic thinking, reliability, while choosing the best performing 3PL vendor.

3. OUTSOURCING PERFORMANCE ASSESSMENT AND BUSINESS PROCESS OUTSOURCING

3.1. Performance Assessment of Outsourcing

Over the last few decades, outsourcing has been a widely utilized and practiced activity for organizations to improve their performance. Outsourcing is related to the market success of companies, especially market share. Market share may be increased via outsourcing while excessive level of outsourcing may cause the decrease of market share. The main strategy of outsourcing is likely to influence not only the cost related issues; but also market-focused performance structure including product, customer loyalty, product delivery, brand recognition and reliability, overall company reputation, etc. Organizations outsourced their minor activities or full functions so as to improve performance, however, their performance may be improved by different levels (Kotabe et al., 2012).

Outsourcing has become a prominent managerial practice which has essential effects on global value chain management of firms. In spite of its prevalence, some reports from multiple prestigious companies indicate that many outsourcing initiatives are failed. Therefore, customer could not reach the expected success and benefits from the outsourced activities. With regard to Deloitte Consulting survey study, 64% of respondents stated that they had got outsourcing services, 44% of them indicated that they did not obtain cost savings via outsourcing. Recently, a more extended survey study of 300 business managers of Deloitte declared that they require improved outsourcing services. Provider's innovation capabilities satisfied only 34% of respondents. Alternatively, 75% of outsourcing providers stated that their clients were not prepared well to manage the outsourcing process, develop a strategy and understand how outsourcing relationship works (Handley & Benton, 2009). In order to avoid the potential failure in the outsourcing process and transform the expectations to the reality, outsourcing performance assessment is necessary to the client as well as the provider, especially for providing a self-evaluation.

Financial performance indicators are generally utilized to assess the performance of strategic outsourcing outputs. Top executives are responsible to make strategic decisions and therefore, their job is directly related to financial issues such as profit, revenue, sales, etc. However, these issues have to be associated with long-term financial benefits (Gunasekaran et al., 2015).

Even though tangible financial performance criteria can be readily determined and measured, intangible financial performance factors require considering a subjective assessment. Non-financial performance criteria have begun to be widely considered over the last 10 years, and become equally crucial as financial performance factors. Hence, non-financial performance criteria are needed to be incorporated into decision framework of outsourcing performance assessment (Gunasekaran et al., 2015).

Over the last decade, scholars contributed to the literature of "outsourcing performance assessment" by carrying out academic studies and several approaches have been proposed. The table forms of the literature survey with selected papers on “outsourcing performance assessment” are given in Table 3.1 and Table 3.2. “Web of Science”, “Science Direct”, “Taylor & Francis”, “Springer” and “Emerald” databases are observed with the keywords “outsourcing performance” and “method”.

Several approaches have been proposed over the last decade for statistical analysis of outsourcing performance. Lee et al. (2008) analyzed statistically the trust relationship between client and provider to assess IT outsourcing performance by performing a case study consisting of organizations in Korea. Tiwana (2008) made an analysis of performance indicators for software outsourcing agreements by utilizing statistics. Krakovics et al. (2008) evaluated the performance indicators of fourth party logistics (4PL) provider that performs in the chemistry industry, in Brazil. Wüllenweber et al. (2008) also employed statistics to discuss the effect of process standardization on BPO performance. Bengtsson & Dabhilkar (2009) analyzed statistically the effect of manufacturing outsourcing on factory's performance by carrying out a survey study with Swedish plants. Dabhilkar et al. (2009) determined manufacturing outsourcing performance criteria which have both positive and negative effects on outsourcer's success by collecting data from Swedish plants. They applied multiple regression analysis. Handley et al. (2009) provided a statistical analysis for indicators which influence BPO performance. Bustinza et al. (2010) revealed the relationship between firm's performance and outsourcing decisions that is derived through the effect of outsourcing decisions on company's competence. They conducted an empirical study in service companies and benefited from statistics.

Hsiao et al. (2010) tested statistically the presence of a relationship between logistics outsourcing functions and company's logistics service performance by analyzing logistics through 4 different functions such as shipping, packaging, shipping management and distribution network management. Narayanan et al. (2011) studied the issue of BPO integration, both internally and externally, and indicated the performance indicators by the service provider perspective. They utilized statistical methods. Sharda & Chatterjee (2011) analyzed statistically organizational performance indicators from outsourcing firms' perspective through the data of Indian BPO companies. Solakivi et al. (2011) examined the connection between cost of logistics and financial performance of both manufacturing and trade industry in case of no-outsourcing, moderate outsourcing and heavy outsourcing. They used statistics by means of data from Finland firms. Kotabe et al. (2012) made a statistical analysis of the relation between outsourcing and manufacturing companies' performance, especially its effect on market share. Swar et al. (2012) accomplished a statistical application to analyze outsourcing relationship criteria influencing the performance of IT outsourcing projects. They performed a survey study in the public sector of Korea. Ee et al. (2013) employed statistics and analyzed outsourcing performance indicators with the use of banks' data through a survey in Malaysia banking sector. Ibrahim & Hanafi (2013) identified and reduced provider's opportunistic behavior in BPO by conducting a performance management. They applied a statistical analysis for offshore call centers, telecom industry.

Kim et al. (2013) proposed a statistical IT outsourcing management model in which supervision efficiency affects the contract control and relationship power on outsourcing performance. Meixell et al. (2014) made an analysis on core manufacturing functions outsourcing effects on cost of goods sold, financial performance of a plant by using data from US factories. They benefited from statistical technique. Raassens et al. (2014) utilized statistics and compared the success of customer service outsourcing to emerging versus established economies by measuring the stock market reaction. Sanchis-Pedregosa et al. (2014) provided a financial performance assessment for manufacturing companies which tend to outsource service activities totally/partially or which behave neutrally. They used statistics. Liu et al. (2015) analyzed statistically the factors affecting logistics outsourcing performance. They collected the data from Chinese companies.

Alternatively, a number of authors have employed the methods apart from statistics for outsourcing performance evaluation over the last decade. Kung et al. (2006) proposed a model for assessing the performance of companies' outsourcing activities by conducting a case study of avionics manufacturer in Taiwan. They integrated fuzzy set theory and grey decision making approaches. Paisittanand & Olson (2006) evaluated both financial performance and risk indicators for credit card operations outsourcing decisions of a major Thai bank by using Monte Carlo simulation method. Tjader et al. (2014) built a model to determine the outsourcing performance indicators with the use of balanced scorecard and to select the best outsourcing strategy through ANP (analytic network process) methodology. Gunasekaran et al. (2015) provided a review article on outsourcing performance in which they classified outsourcing decisions in pre-outsourcing, during outsourcing and post-outsourcing stages and discussed their performance measures.

The greater part of the studies mentioned above applied statistical methods and did not consider the complex decision framework to evaluate outsourcing performance. However, there are a lot of criteria for outsourcing performance evaluation and a complicated decision analysis should be provided. Hence, a multi-criteria decision-making (MCDM) tool is required to assess robustly outsourcing performance indicators.

Table 3.1: Reviewed academic studies which utilize statistical analysis for outsourcing performance assessment

Author(s)	**Year**	**Statistical Tool**
Krakovics et al.	2008	S-curve
Lee et al.	2008	Partial least squares
Tiwana et al.	2008	Least squares hierarchical regression
Wüllenweber et al.	2008	Partial least squares
Bengtsson & Dabhilkar	2009	ANOVA
Dabhilkar et al.	2009	Multiple regression analysis
Handley et al.	2009	Confimatory factor analysis
Bustinza et al.	2010	Confimatory factor analysis
Hsiao et al.	2010	Hierarchical regression analysis
Narayanan et al.	2011	Structual equation modeling
Sharda & Chatterjee	2011	Cluster analysis & ANOVA
Solakivi et al.	2011	ANOVA
Kotabe et al.	2012	Panel data regression analysis
Swar et al.	2012	Partial least squares
Ee et al.	2013	Partial least squares
Ibrahim & Hanafi	2013	ANOVA
Kim et al.	2013	Partial least squares
Meixell et al.	2014	Two-way panel model
Raassens et al.	2014	Event study
Sanchís-Pedregosa et al.	2014	ANOVA
Liu et al.	2015	Structural equation modeling

Table 3.2: Reviewed academic studies which utilize method(s) apart from statistics or provide literature survey for outsourcing performance assessment

Author(s)	**Year**	**Method(s)**
Kung et al.	2006	Fuzzy Set Theory & Grey Decision Making
Paisittanand & Olson	2006	Monte Carlo Simulation
Tjader et al.	2014	ANP
Gunasekaran et al.	2015	Review paper

3.2. Business Process Outsourcing

Nowadays, companies concentrate on their core business processes. They focus on their expertise activities in order to keep up with increasing market competition, and to obtain competitive advantage. Herewith, firms have to buy certain business process services from the external firms for performing the peripheral activities of their business processes. This is the definition of BPO, which helps organizations achieve their business goals.

IT outsourcing has been a crucial part of strategic management. BPO is an improved version of IT outsourcing, which is considered to be a new big current in information systems services. One of the leader firms in IT consulting, called as “The Gartner Group” describes BPO as the assignment of one or more IT-enabled business processes to an external firm, which holds and manages the related process by taking into consideration the key performance indicators (Yang et al., 2007).

The BPO theme goes back a long way. Outsourcing service providers in fields such as location operations, accounting & finance, logistics services, marketing & sales, customer relationships have been in existence for a long time. However, changing and developing technology, and IT-intensive activities force companies to BPO. Also the BPO market is supposed to be changed and improved all the time because of the motivation for using technology, the development of Web services, and more cost-aware clients (Yang et al., 2007).

Naturally, opportunities for service providers in BPO grow rapidly due to the increasing requirement of outsourcer firms for keeping up with changing technology. Therefore, providers need to make their job definition straightforwardly, and to select specific segments in the entire BPO market. In addition, they have to identify their brand value generated from their strengths and market needs, and finally, they should act in a strategic manner for realizing opportunities. Besides, outsourcer firms have to determine which business process has to be outsourced to an external provider by considering both advantages and disadvantages of BPO, and eventually, do not make mistakes in outsourcing decisions (Yang et al., 2007). The client should take into consideration both its requirements and expectations. Hence, positive and negative sides of BPO must be taken into account in the decision framework. Moreover, positive and negative aspects of BPO are not evaluated in the same way therefore different decision makers evaluate the decision process differently. Thus, the criteria related to BPO process are assessed subjectively. Since precise and crisp data are likely to fail to deal with this process, such problems should be solved by the use of fuzzy numbers (Perçin, 2008).

BPO is anticipated to provide a wide range benefits to clients and their end-users. These benefits, which involve expertise in the processes thought to be outsourced, are cost reduction via cheaper labor force, obtaining effectiveness, efficiency and flexibility (Grefen et al., 2006; Luo et al., 2010). BPO, being utilized by leader firms, focus on knowledge-based service activities in a wide spectrum sectors such as finance, banking, health, consulting, logistics, law, etc. In addition, offshore BPO is commonly used by large companies such as General Electric Corporation, Sony Corporation, Wal-Mart Stores. Offshore BPO has been a strategic tool for outsourcers to survive in market competition (Luo et al., 2010).

Notwithstanding many advantages that are thought to be offered from BPO, especially offshore BPO, outsourcers have to cope with important administrative and operational issues such as cultural and linguistic differences, problems that are related to contract signed between outsourcer and provider, risk of service quality reduction. Besides, when firms outsource more than one business process and work with multiple providers, managing all the BPO processes becomes more complicated because of the coordination difficulties and different locations (Luo et al., 2010).

Alternatively, BPO enables outsourcers for focusing on their core competencies while trusting in their overseas providers for specialized talents and capabilities. Due to the changing and developing technology, and then the pressure of the competitive dynamics of market, firms aim to build new enterprises, that are digitally allowed and extended, and that have access to specialized companies located in foreign countries. For instance, American Express Corporation has utilized India since 1990s to maintain its global BPO service activities, obtain yield from lower labor force and brain power costs, reach greater project management talents and develop IT services (Luo et al., 2010).

Conversely, BPO may cause several risk factors along with its potential benefits. These factors include four main criteria such as performance, finance, strategy and psychology. Performance risk refers to the fact that the vendor does not provide the anticipated level of service. Financial risk supposes that the outsourcer has to pay more to obtain the anticipated level of service than expected in the beginning of cooperation. The outsourcer is exposed to the strategic risk when the outsourcer faces with losing some resources and skills that are required to maintain the competitiveness. These resources and skills may involve functional talents along with know-how, which is necessary to be innovative. In addition, psychological risk is related to responsible manager's reputation and career when the business process is damaged because of the outsourcing (Gewald & Dibbern, 2009). The overall architecture of risk and benefit model related to BPO is reported in Figure 3.1.

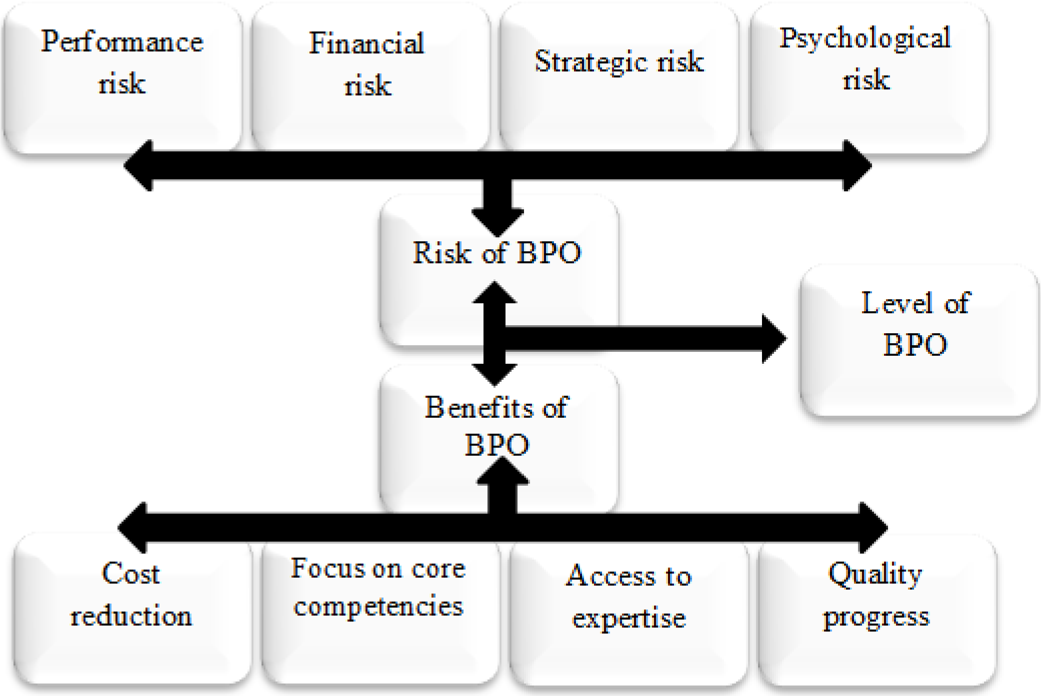


Figure 3.1: BPO risk & benefit model (adapted from Gewald & Dibbern, 2009).

BPO is an improved version of IT outsourcing, which is assumed to be a new big wave in information systems services. Several authors have made a contribution to the BPO literature over the last decade. Although BPO is crucial to outsourcers due to the risk and performance factors, which are mentioned in the previous part of this thesis, almost all the studies do not consider such a complex decision framework. In general, they do not provide any mathematical approach and evaluate BPO by social sciences perspective. A few studies employ statistical analysis, mathematical programming model or MCDM tool. However, these approaches do not consider the complexity of BPO decision framework. Hence, there is a gap in literature in the area of "evaluation of BPO process". The table form of reviewed and selected BPO papers is reported in Table 3.3. “Web of Science”, “Science Direct”, “Taylor & Francis”, “Springer” and “Emerald” databases are observed with the keywords “business process outsourcing” and “method”.

The research papers in which mathematical approaches are given for BPO are reported. Yang et al. (2007) determined the criteria affecting BPO and evaluated them with a

MCDM approach. They employed a numerical illustration by using analytic hierarchy process (AHP) in human resources management. Balakrishnan et al. (2008) implemented a mathematical programming model in order to identify the business processes that can be outsourced and the factors influencing the outsourcing decisions related to these processes. Gewald et al. (2009) developed a BPO implication model based on risk-benefit analysis and testing it statistically in German banking industry. Narayanan et al. (2011) focused on the issue of BPO integration and determined performance indicators by the service provider perspective. They used statistic. Chou et al. (2015) analyzed statistically commitment criteria of the client in BPO.

Table 3.3: Reviewed academic studies which use a mathematical approach for BPO evaluation

Author(s)	**Year**	**Method(s)**
Yang et al.	2007	AHP
Balakrishnan et al.	2008	Mathematical Programming Model
Gewald et al.	2009	Statistics
Narayanan et al.	2011	Statistics
Chou et al.	2015	Statistics

In this thesis, performance assessment for BPO is provided by employing FCM methodology. As mentioned in this section of the study, there has not been any other research in the literature that evaluates the performance of the BPO.

4. PROPOSED METHODOLOGY

4.1. Cognitive Maps

Cognitive maps (CMs) were originally proposed by Axelrod (1976) as a tool to model decision support systems in political and social sciences. CMs comprise directed edges which provide modeling causalities and interrelationships among concepts. There are multiple types of CMs, such as signed, weighted and functional graphs.

CMs may also be utilized for forecasting, research and development, strategic planning. The binary relations (i.e., increase and decrease) are used in crisp (conventional) CM. CMs are advantageous tools that are required in order to provide an engineering planning, by considering causal links, managing complexity, comparing the models with real cases, providing efficient assessments (Ross, 2010).

4.1.1. Concepts and Causalities

CMs graphically represent a system according to two main components: concepts and causal links (causal relations). Concepts are denoted by nodes, C_x, where $x = 1,2,\ldots,N$. A cause concept variable is defined as the variable which is located at the origin of an edge, while an influence concept variable is stated as the variable that is at the endpoint of an edge. For instance, an arrow from the node C_h to the node C_i, demonstrates that C_h is the cause variable that affects C_i, which is the influence variable. Figure 4.1 describes a simple CM which consists of four concepts.

The edges refer to the causalities between concepts, which can be negative or positive. For instance, an arrow from the node C_h to the node C_i, and that is negatively signed, indicates that C_h has a negative causal relation on C_i. Hence, a decrease in C_h results in an increase in C_i. Likewise, an increase C_h causes a decrease in C_i (Ross, 2010).

4.1.2. Cycles and Paths

A path from a concept to another concept, from C_h to C_k, which is identified as $P(h,k)$, is an array of all the nodes that are linked by edges from the first node (C_h) to the last node (C_k). A cycle is a path which has an edge from the endpoint of the path to the origin of the first point (Ross, 2010).

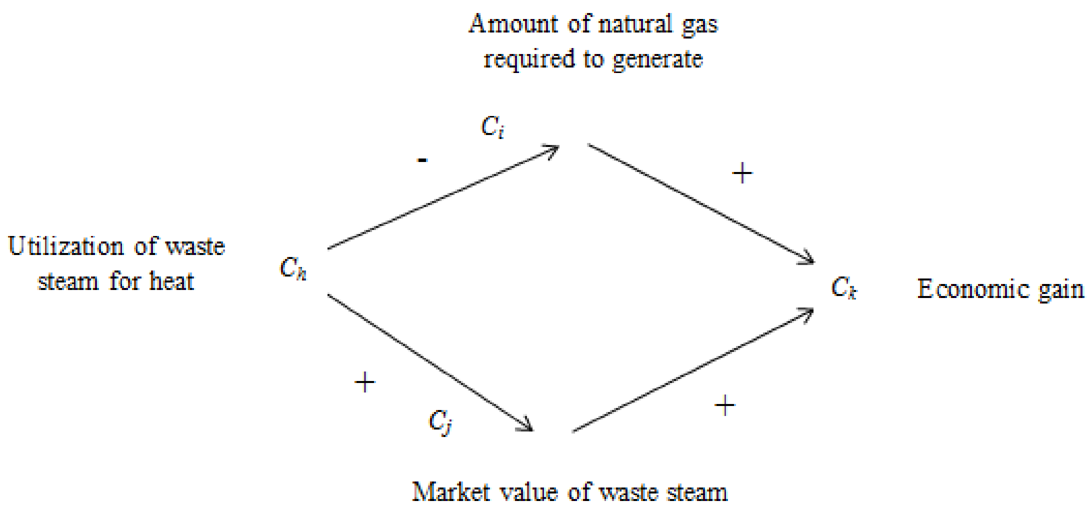


Figure 4.1: An example of a crisp cognitive map for the waste steam usage (Kosko, 1986)

4.1.3. Indirect Influence

$I(h,k)$, which represents the indirect influence of a path from the cause variable C_h to the influence variable C_k, is the product of the causal links that construct the path from the cause variable to the influence variable (Axelrod, 1976). If a path has even several negative edges, then the indirect influence is positive. However, if the path has both negative and positive edges, then the indirect influence is negative. Figure 4.1 indicates that the indirect influence of cause variable C_h on the influence variable C_k through path $P(h,i,k)$ is negative and the indirect influence of the cause variable C_h on the influence variable C_k through path $P(h,j,k)$ is positive (Ross, 2010).

4.1.4. Total Influence

$T(h,k)$, which denotes the total influence of the cause variable C_h on the influence variable C_k, is the sum of all indirect influences of all the paths from the cause variable to the influence variable (Axelrod, 1976). If all the indirect influences are positive, then the total influence is positive. Likewise, if all the indirect influences are negative, then the total influence is negative. Besides, if some indirect influences are positive and some are negative, then the sum is indeterminate (Kosko, 1986). A complex CM, which has a great number of concepts and paths, will be probably a candidate to be indeterminate. Figure 4.1 indicates that the total influence of cause variable C_h to influence variable C_k is the summation of the indirect influence of C_h to C_k through the paths $P(h,i,k)$ and $P(h,j,k)$. Since there are positive as well as negative influences along these paths, the total influence is indeterminate (Ross, 2010).

4.2. Basic Notions of Fuzzy Logic

4.2.1. Uncertainty and Information

Certain or deterministic information can be available only in a small portion of real world problems. The knowledge with no ignorance, vagueness, imprecision or chance, is not accessible in real life. Uncertain information, which can take a lot of different forms, arises due to the complexity of problems, and the inability to measure adequately or lack of knowledge.

The type of uncertainty in a specific problem is crucial for scholars to select a suitable method to imply the uncertainty. Fuzzy sets are appropriate to provide a mathematical way in order to represent vagueness and fuzziness in systems (Ross, 2010).

4.2.2. Fuzzy Sets and Membership

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).

The membership function involves the mathematical representation of membership in a set. The interval of the degree of membership of an element in a fuzzy set is as follows.

$$\mu_{\tilde{A}}(x) \in [0,1] \tag{4.1}$$

where $\mu_{\tilde{A}}(x)$ refers to the degree of membership of element x in fuzzy set $\tilde{A}$ (Ross, 2010).

Two example membership functions for a crisp set and a fuzzy set are given in Figure 4.2 and Figure 4.3, respectively.

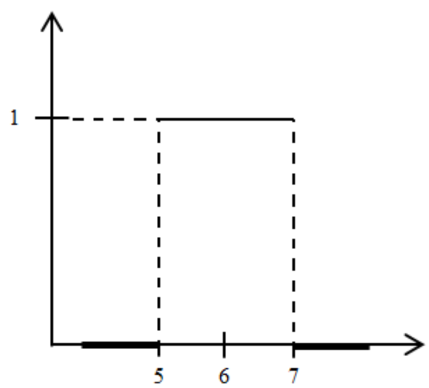


Figure 4.2: An example membership function for a crisp set (Ross, 2010)

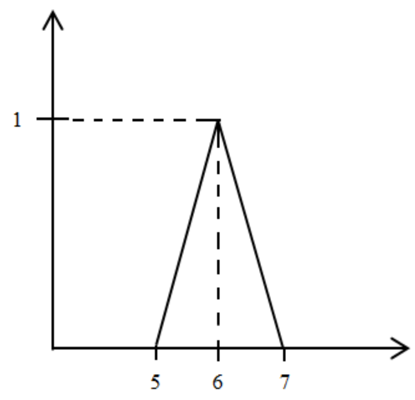


Figure 4.3: An example membership function for a fuzzy set (Ross, 2010)

4.2.2.1. Fuzzy Sets

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

$$\tilde{A} = \left\{ \frac{\mu_{\tilde{A}}(x_1)}{x_1} + \frac{\mu_{\tilde{A}}(x_2)}{x_2} + \ldots \right\} = \left\{ \sum_i \frac{\mu_{\tilde{A}}(x_i)}{x_i} \right\} \tag{4.2}$$

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

$$\tilde{A} = \left\{ \int \frac{\mu_{\tilde{A}}(x)}{x} \right\} \tag{4.3}$$

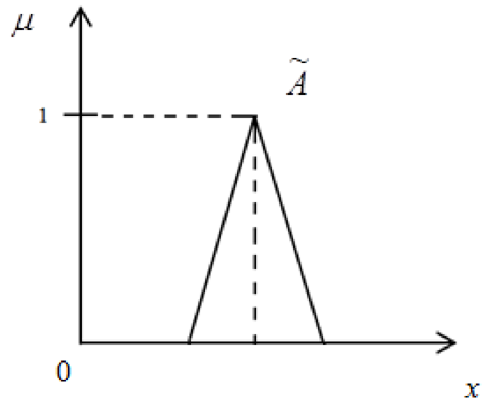


Figure 4.4: Membership function for fuzzy set $\tilde{A}$ (Ross, 2010)

4.2.2.1.1. Definitions of the Fuzzy Set

Definition 1:

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

Definition 2:

A fuzzy set, whose membership function has no element *x* in the universe with a membership value that is equal to unity, is called as a **subnormal fuzzy set** (Ross, 2010).

Definition 3:

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

Definition 4:

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

$$hgt(\tilde{A}) = \max\{\mu_{\tilde{A}}(x)\} \tag{4.4}$$

If $\tilde{A}$ is a convex normal fuzzy set described on the real line, then $\tilde{A}$ is said to be a fuzzy number (Ross, 2010).

4.2.2.2. Definitions of the Membership Function

Definition 1:

The **core** of a membership function contains elements x of the universe such that $\mu_{\tilde{A}}(x) = 1$ (Ross, 2010).

Definition 2:

The **support** of a membership function involves elements x of the universe such that $\mu_{\tilde{A}}(x) > 0$ (Ross, 2010).

Definition 3:

The **boundaries** of a membership function consists of elements x of the universe such that $0 < \mu_{\tilde{A}}(x) < 1$ (Ross, 2010).

Definition 4:

The **crossover points** of a membership function includes elements x of the universe such that $\mu_{\tilde{A}}(x) = 0.5$ (Ross, 2010).

4.2.3. Defuzzification

Defuzzification is the transformation of a fuzzy quantity to a crisp quantity (Ross, 2010).

4.2.3.1. Defuzzification to Crisp Sets

Let $\tilde{A}$ is a fuzzy set, A_λ is a lambda-cut set, where $0 \le \lambda \le 1$. A_λ, which is called as the *lambda*(λ)*-cut* (or *alpha-cut*), is a crisp set of the fuzzy set $\tilde{A}$, where $A_\lambda = \{x \mid \mu_{\tilde{A}}(x) \ge \lambda\}$ (Ross, 2010).

4.2.3.2. Defuzzification to Scalars

There exist various defuzzification methods that are proposed in the literature. Ross (2010) considers four main methods whose formulations are given as follows.

- ***Max membership principle:***

$$\mu_{\tilde{A}}(z^*) \ge \mu_{\tilde{A}}(z), \qquad \text{for all } z \in Z, \tag{4.5}$$

where z^* is the defuzzified value.

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

$$z^* = \frac{\int \mu_{\tilde{A}}(z).z \quad dz}{\int \mu_{\tilde{A}}(z)\, dz}, \tag{4.6}$$

where $\int$ refers to an algebraic integration.

- ***Weighted average method:***

$$z^* = \frac{\sum \mu_{\tilde{A}}(\bar{z}).\bar{z}}{\sum \mu_{\tilde{A}}(\bar{z})}, \tag{4.7}$$

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

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

$$z^* = \frac{a+b}{2} \tag{4.8}$$

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.

4.3. Fuzzy Cognitive Maps

4.3.1. Indeterminacy

A crisp CM, which is indeterminate, can be solved by providing a numerical weighting, however, it requires computational and conceptual efforts (Kosko, 1986). If the causal arrows are positively or negatively weighted, the indirect influence is the product of the weights in the corresponding path, and the total influence is the summation of the products. This weighting framework not also eliminates the problem of indeterminacy from the total influence computation; yet also requires a more sensitive causal discrimination. This sensitivity may not be possible for decision makers who are supposed to construct the CM. Forcing decision makers to create CM with crisp numbers causes insufficient decision information, different numbers from different decision makers or different numbers from the same decision maker on different days. However, causal links can be stated by linguistic variables rather than numerical terms by proposing FCM methodology (Ross, 2010).

4.3.2. Methodology of FCM

FCM, helping model complex decision systems, is a causal knowledge-based method which is originated from the combination of fuzzy logic and neural networks (Kosko, 1986). Hereafter, Taber and Kosko (Kosko, 1986; Taber, 1994). extended the method and included fuzzy numbers or linguistic variables for revealing the causal relationships among concepts in FCM. These concepts stand for an entity, a state, a variable or a characteristic of a system, a behavior of a knowledge-based system is represented by concepts in FCM. Concept nodes and weighted edges are the elements of FCM which can be graphically showed with feedback. Edges are signed to understand the direction of causality: whether the causal relationship is positive, negative or null, and connect the nodes through which causal relationships among concepts are produced (Büyükavcu et al., 2016).

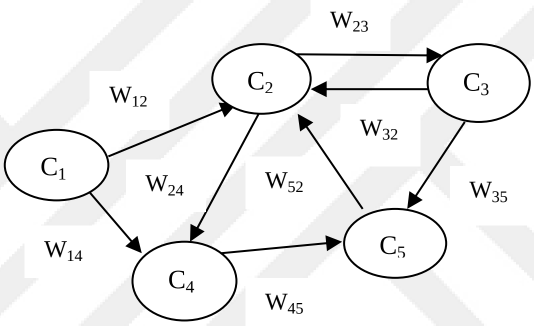


Figure 4.5: Graphical representation of FCM (Büyükavcu et al., 2016)

$C = \{C_1, C_2, ..., C_n\}$ is the representation of concepts set, edges (C_j, C_i) demonstrate how concept C_j causes concept C_i, and are utilized for causal relationships between concepts. The weights of causality links range in the interval [-1,1] or can be represented with linguistic variables such as “negatively weak”, “zero”, “positively weak”, etc. Figure 4.5 and Figure 4.6 indicate the graphical presentation and application steps of a FCM, respectively.

Figure 4.6: Application steps of FCM (Büyükavcu et al., 2016)

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. In order to determine the power of these causal relations, a value has to be assigned to weight w_{ji}. For instance, in Figure 4.5, concept C_2 causes an increase or a decrease in C_3 with a degree of w_{23}. The value of each concept is calculated, considering the effect of the other concepts on the under-evaluation concept, by running the following iterative formulation.

$$A_i^{(k+1)} = f\left(A_i^{(k)} + \sum_{\substack{j \neq i \\ j=1}}^{N} A_j^{(k)} w_{ji} \right) \qquad (4.9)$$

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

The activation levels of all the concepts are synchronously updated in FCM, which represents a discrete time system. Hence, the system is to be updated in a simultaneous way. The activation level of concept C_i is denoted by A_i^t, t is the time step. The vector $A^t = \left[A_1^t, A_2^t, ..., A_n^t\right]$ indicates 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 indicate a state for the system at the initial and the last time step, respectively. The objective of FCM method is to identify the final vector, which provides determining the value of each concept (Büyükavcu et al., 2016).

4.3.3. Literature Review on FCM

For the last 5 years, scholars focused on FCM methodology and applied it in several different research areas and sectors. The table form of the FCM literature survey, which is completed by observing the selected research papers published in “Web of Science”, “Science Direct”, “Taylor & Francis”, “Springer”, and “Emerald” databases, is given in

Table 4.1. “Fuzzy cognitive map” and “multi-criteria decision making” are utilized as keywords, reviewed papers are classified with regard to research areas.

FCM has been applied to quite complex problems in manufacturing sector. Chen et al. (2015) used FCM to deal with causal networks of reverse engineering. Zhao et al. (2014) constructed a model for a flexible operating mechanism in wind power industry via FCM methodology. Azadeh et al. (2015) utilized FCM to reveal the causal relationships among the leanness factors by carrying out a case study in Iran. Vidal et al. (2015) applied FCM method for eco-friendly product forecasting in ceramic industry.

Agriculture sector has also been an area for FCM applications. Papageorgiou et al. (2011) and Papageorgiou et al. (2013) used FCM in crop management for yield forecasting of cotton and apples, respectively. Jayashree et al. (2015) classified the coconut production levels in climatic conditions for agriculture through FCM.

Besides, FCM methodology was applied a few times to information management systems. Irani et al. (2014) integrated FCM to the evaluation process of information systems in investment decisions. Baykasoglu & Golcuk (2015) preferred FCM to construct the causal relationships of a SWOT-based strategy selection problem for an industrial engineering department. Ahmadi et al. (2015) adapted FCM to the problem of predicting readiness of an organization to implement a new enterprise resource planning (ERP) system. Büyüközkan & Vardaloğlu (2012) put account FCM to reveal and analyze the concepts which provide better integration of collaborative planning forecasting and replenishment strategy in retail sector. Sharif et al. (2012) developed a model for risk and cost mitigation of reverse third-party logistics operations centered upon information technologies and resource commitment factors. They validated the proposed model via FCM. Dias et al. (2015) used FCM to model the behavior of learning management systems’ users to interact with it and Maio et al. (2011) modeled emergency management systems through FCM. Ahmadi et al. (2015a) revealed causal relationships among activities which are required to implement new ERP system and determined the effects and feedback between activities by using FCM methodology.

Apart from these, in the literature, FCM was utilized to model tourism problems such as decision support systems for travelling alternatives, choosing a specific travel type, prioritizing the services properties that are mostly chosen by the customer and integrating mass media (Kardaras et al., 2013; Leon et al., 2014), to model transportation problems like structuring of transport collaboration, causal relationships of a car accident (Kayikci & Stix, 2014; Lee & Lee, 2015).

Energy sector was also preferred by researchers in which some problems such as anticipating the minimum number of needed elevators to provide electricity consumption or planning local renewable energy sources were thought to be solved by means of FCM methodology (Kyriakarakos et al., 2014; Chen et al., 2015a).

In addition, it has been widely used in many medical research areas because of the complexity of medical decision process: collecting the data and interpreting them are tough, integration of these data is uncertain and ambiguous (Büyükavcu et al., 2016). Papageorgiou (2011), Papageorgiou (2012), Papageorgiou et al.(2012) made use of FCM for radiotherapy treatment planning selection, for dealing with uncertainty and imprecise data about treatment of urinary tract infection, for modeling clinical practice guidelines by implementing experts' knowledge, respectively. Lee et al. (2012) proposed FCM approach that takes into account experts' knowledge about criteria which influence dental implant process by considering cause & effect relationship among factors. Giabbanelli et al. (2012) observed psychosocial factors of obesity via FCM. Froelich et al. (2012) researched oncologic area and utilized FCM to forecast prostate cancer in long-term periods. Büyükavcu et al. (2016) assessed breast cancer risk factors by combining FCM and fuzzy inference system, they employed several scenario analyses.

Table 4.1: Literature survey of FCM with regard to research area

Year	Author(s)	Research Area
2014	Zhao et al.	Manufacturing
2015	Azadeh et al.	
2015	Chen et al.	
2015	Vidal et al.	
2013	Papageorgiou et al.	Agriculture
2015	Jayashree et al.	
2011	Maio et al.	Management Systems
2012	Büyüközkan & Vardaloğlu	
2012	Sharif et al.	
2014	Irani et al.	
2015	Ahmadi et al.	
2015	Ahmadi et al.	
2015	Baykasoglu & Golcuk	
2015	Dias et al.	
2013	Kardaras et al.	Tourism
2014	Leon et al.	
2014	Kayikci & Stix	Transportation
2015	Lee & Lee	
2014	Kyriakarakos et al.	Energy
2015	Chen et al.	
2011	Papageorgiou	Medicine
2012	Froelich et al.	
2012	Giabbanelli et al.	
2012	Lee et al.	
2012	Papageorgiou	
2012	Papageorgiou et al.	
2016	Büyükavcu et al.	

5. APPLICATION

In this section of the thesis, a FCM approach is employed in order to provide a performance assessment for BPO. FCM methodology is preferred to be applied due to the lack of crisp numbers and consequently the requirement of the use of linguistic variables or fuzzy numbers, and the presence of cause-effect relationships among concepts in performance assessment of BPO.

Unlike classical MCDM approaches, which consider interrelationships among criteria such as ANP and DEMATEL (Decision-Making Trial and Evaluation Laboratory), CMs provide taking into account negative relationships. Moreover, FCMs enable incorporating linguistic variables or fuzzy numbers into decision framework, therefore decision makers evaluate the decision process in a robust manner when crisp numbers are not available.

The application steps are given in Figure 5.1.

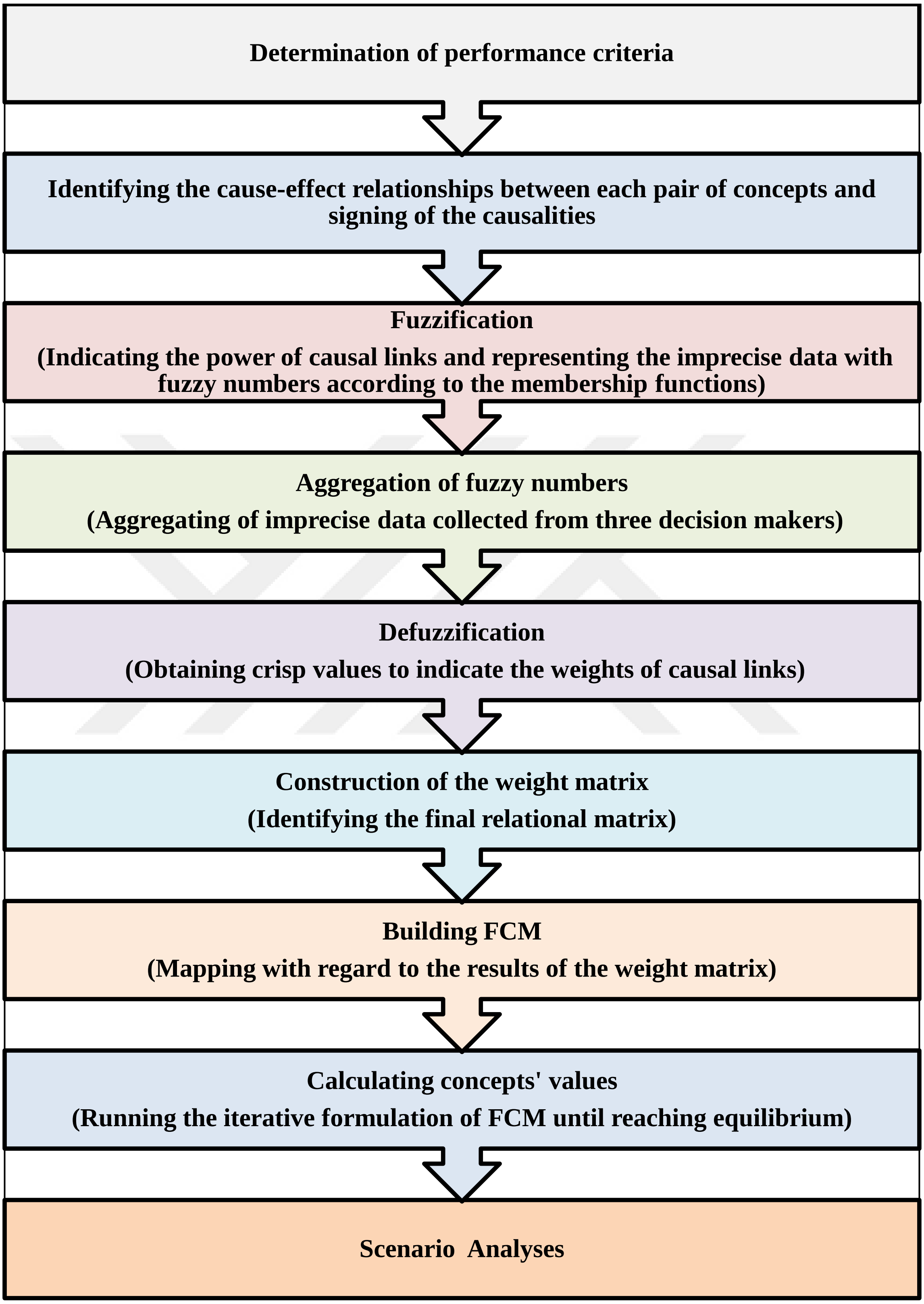


Figure 5.1: Application steps of the study

5.1. Determination of Performance Criteria

Performance criteria for BPO are listed in order to provide a decision framework to be evaluated. Academic studies which are related to outsourcing performance evaluation are reviewed, and the performance criteria that are appropriate as well as the most selected for BPO performance assessment are identified. Thereafter, selected criteria are sent to three different decision makers, whose jobs are associated with BPO in large companies, which are located in Turkey. Experts' opinions are incorporated in order to obtain the final performance criteria and 20 factors are included to the study as listed in Table 5.1. These criteria are classified into 2 groups such as "tangible" and "intangible" factors.

Table 5.1: Performance criteria for BPO

Label	Concept	Reference
Tangible Factors		
C_1	Cost reduction	Rhodes et al., 2016
C_2	Firm size	Sharda & Chattaerjee, 2011; Raassens et al., 2014
C_3	Firm age	Sharda & Chattaerjee, 2011
C_4	Age of relationship	Ee et al., 2013
C_5	Operational efficiency	Krakovics et al., 2008
C_6	Overall financial position	Gilley et al., 2004
C_7	Contract schedule	Kung et al., 2006
C_8	Responsiveness	Kung et al., 2006
Intangible Factors		
C_9	Employee productivity	Kung et al., 2006
C_{10}	Service quality	Ibrahim & Hanafi, 2013
C_{11}	Reliability	Kung et al., 2006
C_{12}	Process innovation	Gilley et al., 2004
C_{13}	IT capability	Narayanan et al., 2011
C_{14}	Task complexity	Narayanan et al., 2011
C_{15}	Information accessibility	Sharda & Chattaerjee, 2011
C_{16}	Coordination	Sharda & Chattaerjee, 2011
C_{17}	Commitment	Sharda & Chattaerjee, 2011; Ee et al., 2013
C_{18}	Communication capability	Swar et al., 2012; Ee et al., 2013
C_{19}	Flexibility	Swar et al., 2012
C_{20}	Degree of outsourcing	Meixell et al., 2014

5.1.1. Definitions of Tangible Factors

- **Cost reduction**

It refers to the reduced cost amount obtained by the client, through outsourcing provider performance in the specific outsourced process.

- **Firm size**

It denotes to the size of the service provider company (small-scale, midsize or a large company).

- **Firm age**

It represents to the number of years which have been passed since the outsourcing provider company had been established.

- **Age of relationship**

It signifies the number of years that have been passed since the client has initially outsourced the specific process to its provider.

- **Operational Efficiency**

It refers to the operational efficiency of the external service provider while performing outsourced process by the vendor firm.

- **Overall Financial Position**

It denotes the entire financial status outsourcing provider firm.

- **Contract Schedule**

It represents the strictness of the contract that is signed between client and service provider. The increase of the contract schedule is considered as the increase of the strictness of the contract. Likewise, the decrease of the contract schedule is thought as the decrease of the strictness of the contract.

- **Responsiveness**

It signifies the frequency of feedbacks of the outsourcing provider when the client requests something which is related to the corresponding outsourced process.

5.1.2. Definitions of Intangible Factors

- **Employee Productivity**

It refers to the productiveness as well as the overall performance of the personnel who work for the outsourced process in the provider company.

- **Service Quality**

It denotes the level of service which is offered from the outsourcing provider to the client.

- **Reliability**

It represents the reliability of the service provider for keeping the private and confidential information of the client firm.

- **Process Innovation**

It signifies the innovative capabilities of the service provider in order to keep up with changing and improving technology, and increasing innovation demands of the market in various business processes.

- **IT Capability**

It refers to equipment of both hardware and software of outsourcing provider firm, and the usage capability of this equipment in information technologies.

- **Task Complexity**

It denotes the complexity level of the task to be outsourced.

- **Information Accessibility**

It represents the power of service provider to access required digital information while performing BPO.

- **Coordination**

It signifies how much outsourcing provider team can be coordinated when they try to deal with the issues associated with outsourced process.

- **Commitment**

It refers to the loyalty degree of the vendor to the client firm.

- **Communication Capability**

It denotes the ability of the outsourcing provider in order to communicate with the client.

- **Flexibility**

It represents the capability of being flexible of the provider in case of exceptional demands of the client. For instance, working at weekends, out of office or out of working hours may be some flexibility indicators.

- **Degree of Outsourcing**

It signifies how many parts of a specific process are outsourced to an external service provider. Client firms may prefer to outsource just a little part of an activity or the entire process. The increase of the degree of outsourcing is considered as the increase of the number of the parts of a process to be outsourced. Likewise, the decrease of the outsourcing degree is supposed to be the decrease the number of the parts of the outsourced process.

5.2. Identifying the Cause-Effect Relationships between Each Pair of Concepts, and Signing of the Causalities

The performance criteria, which are indicated through a literature survey and experts' knowledge, are sent to the three decision makers whose job description is directly related to BPO, and who are from different large companies, which are located in Turkey. The decision makers have deep knowledge about outsourcing processes, solid background and market experience. Hence, each decision maker is able to indicate the effect of one concept on another.

At the initial step, they determine whether there is a causal relationship between each pair of concepts, or not. If there is no relation, they skip the associated pair of concepts, but if there is a causal link, they indicate the direction (sign) of the relation such as positive or negative. The copy of the matrix that the experts are supposed to fill is provided in Table 5.2, and the matrices of sign of three decision makers are given in Table 5.3, Table 5.4, Table 5.5, respectively.

Table 5.2: The copy of the matrix that is sent to experts

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
C1																				
C2																				
C3																				
C4																				
C5																				
C6																				
C7																				
C8																				
C9																				
C10																				
C11																				
C12																				
C13																				
C14																				
C15																				
C16																				
C17																				
C18																				
C19																				
C20																				

Table 5.3: The matrix of sign according to the Expert 1

	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_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}
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_{14}	-				-		+	-	-	-					-					
C_{15}	+				+				+	+		+	+							+
C_{16}					+				+	+								+		
C_{17}							-	+			+							+	+	
C_{18}							-	+	+	+	+					+	+			
C_{19}							-	+	+									+		
C_{20}							+										+		+	

Table 5.4: The matrix of sign according to the Expert 2

	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_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}
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_{14}	-				-		+	-	-	-					-	-				
C_{15}	+				+				+	+		+	+							+
C_{16}					+			+	+	+		+			+			+		
C_{17}							-				+							+	+	
C_{18}								+		+	+					+	+		-	
C_{19}							-	+								+		+		
C_{20}						+	+										+		+	

Table 5.5: The matrix of sign according to the Expert 3

	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_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}
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_{14}	-				-		+	-	-	-			+		-	-			+	
C_{15}	+				+					+		+	+							+
C_{16}					+			+	+	+		+			+			+		
C_{17}							-	+			+							+		
C_{18}							-	+		+	+					+	+			
C_{19}					+		-	+												
C_{20}							+										+		+	

5.3. Fuzzification

In this section, imprecise data are represented as fuzzy sets according the associated membership functions. After determining the sign of the causal links, second step is to indicate the degree (power) of influence by use of linguistic variables such as "few", "some", "very", etc. The third step is to transform linguistic variables to numerical values, which are defined as triangular fuzzy numbers in this study.

Experts decide initially the power of causalities by using linguistic variables; subsequently linguistic variables are mapped to fuzzy numbers. In this study, nine 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). The corresponding membership functions for these linguistic variables are reported in Figure 5.2. They are referred as $\mu_{nvs}, \mu_{ns}, \mu_{nm}, \mu_{nw}, \mu_{z}, \mu_{pw}, \mu_{pm}, \mu_{pm}, \mu_{ps}, \mu_{pvs}$.

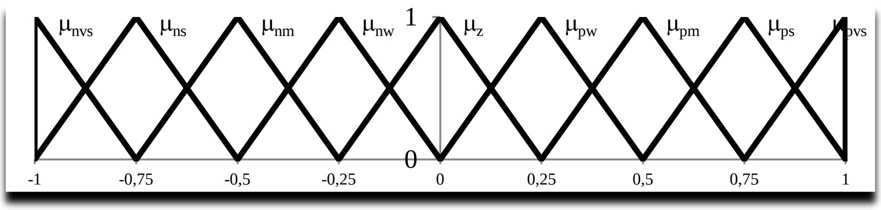


Figure 5.2: The nine membership functions corresponding to each fuzzy term of influence

The matrices of power of causalities by using linguistic variables are reported in Table 5.6, Table 5.7 and Table 5.8; the matrices of power of causalities that are transformed to triangular fuzzy numbers are given in Table 5.9, Table 5.10 and Table 5.11, respectively.

Table 5.6: The matrix of power of causalities by using linguistic variables according to the Expert 1

	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_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}
C_1	z	z	z	z	z	z	z	z	z	z	ps	z	z	z	z	z	z	z	z	pvs
C_2	pw	z	z	z	pw	pm	nw	nw	z	pw	pw	pw	ps	z	pw	pw	nw	z	nw	z
C_3	z	z	z	z	z	z	z	z	z	z	z	z	z	z	z	z	z	z	nw	z
C_4	pm	z	z	z	z	z	nvs	pm	z	pm	pm	z	z	z	z	z	pm	pm	pm	z
C_5	pvs	ps	z	z	z	ps	z	z	z	z	ps	z	z	z	z	z	z	z	z	ps
C_6	z	pvs	z	z	z	z	z	z	z	z	pw	pw	z	z	z	z	nm	z	nm	z
C_7	pw	z	z	z	pm	z	z	pm	pw	z	z	z	z	z	z	pw	nw	z	nm	z
C_8	z	z	z	z	z	z	nw	z	z	z	pw	z	z	z	z	z	z	z	z	z
C_9	pm	z	z	z	pvs	ps	z	z	z	ps	ps	z	z	z	z	z	z	z	z	z
C_{10}	pm	z	z	z	z	z	z	z	z	z	ps	z	z	z	z	z	z	z	z	z
C_{11}	z	z	z	z	z	z	nm	z	z	z	z	z	z	z	z	z	z	z	z	pm
C_{12}	ps	z	z	z	ps	z	z	z	pw	pm	z	z	z	z	z	z	z	z	z	pw
C_{13}	ps	pm	z	z	ps	pm	z	z	pw	pm	pw	pm	z	z	pm	z	z	z	z	pw
C_{14}	ns	z	z	z	nm	z	ps	nm	nw	nw	z	z	z	z	nm	z	z	z	z	z
C_{15}	pm	z	z	z	ps	z	z	z	pw	ps	z	ps	pw	z	z	z	z	z	z	pm
C_{16}	z	z	z	z	pm	z	z	z	pm	pm	z	z	z	z	z	z	z	pw	z	z
C_{17}	z	z	z	z	z	z	nm	pm	z	z	pm	z	z	z	z	z	z	ps	ps	z
C_{18}	z	z	z	z	z	z	nw	pm	pw	pm	pm	z	z	z	z	pm	pw	z	z	z
C_{19}	z	z	z	z	z	z	nw	pw	pw	z	z	z	z	z	z	z	z	pm	z	z
C_{20}	z	z	z	z	z	z	pw	z	z	z	z	z	z	z	z	z	ps	z	pvs	z

Table 5.7: The matrix of power of causalities by using linguistic variables according to the Expert 2

	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_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}
C_1	z	z	z	z	z	z	nw	z	z	z	pw	z	z	z	z	z	z	z	z	pvs
C_2	pw	z	z	z	ps	ps	nw	z	z	pm	ps	pw	ps	z	pm	pm	nm	z	nm	z
C_3	z	pw	z	z	z	z	z	z	z	z	z	z	z	z	z	z	nw	z	nw	z
C_4	pw	z	z	z	z	z	nm	ps	z	pm	pvs	z	z	z	z	z	pvs	pvs	ps	z
C_5	pw	pw	z	z	z	pw	z	pw	z	z	pm	z	z	z	pw	z	z	z	z	pw
C_6	z	ps	z	z	pm	z	nw	z	z	z	pm	z	z	z	z	z	nw	z	nw	z
C_7	z	z	z	z	pm	z	z	pm	z	z	z	z	z	z	z	z	nw	pw	ns	z
C_8	z	z	z	z	z	z	z	z	z	pw	ps	z	z	z	pw	z	z	ps	pm	z
C_9	pm	z	z	z	pm	pw	z	pw	z	pm	pw	z	z	z	z	pm	z	z	z	z
C_{10}	pm	z	z	z	z	z	pm	z	z	z	ps	z	z	z	z	z	z	z	z	z
C_{11}	z	z	z	z	z	z	nw	z	z	z	z	z	z	z	z	z	z	z	z	pvs
C_{12}	pm	z	z	z	pm	z	z	z	pm	pm	z	z	pw	z	pm	z	z	z	z	pw
C_{13}	pm	pw	z	z	pm	pm	z	z	pm	pm	pw	pw	z	z	pvs	z	z	z	z	pw
C_{14}	nvs	z	z	z	nw	z	pm	nw	nw	nw	z	z	z	z	ns	nw	z	z	z	z
C_{15}	pw	z	z	z	pm	z	z	z	pm	pm	z	pm	pw	z	z	z	z	z	z	ps
C_{16}	z	z	z	z	ps	z	z	pw	ps	pw	z	pw	z	z	pw	z	z	pw	z	z
C_{17}	z	z	z	z	z	z	nm	z	z	z	pvs	z	z	z	z	z	z	ps	pm	z
C_{18}	z	z	z	z	z	z	z	pw	z	pw	pw	z	z	z	z	pm	pm	z	nw	z
C_{19}	z	z	z	z	z	z	nm	pm	z	z	z	z	z	z	z	pw	z	pw	z	z
C_{20}	z	z	z	z	z	pw	pw	z	z	z	z	z	z	z	z	z	pvs	z	ps	z

Table 5.8: The matrix of power of causalities by using linguistic variables according to the Expert 3

	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_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}
C_1	z	z	z	z	z	z	nw	z	z	z	pm	z	z	z	z	z	z	z	z	ps
C_2	z	z	z	z	pw	ps	z	nm	z	pw	pw	z	pvs	z	z	pw	z	z	ns	z
C_3	z	z	z	z	z	z	z	z	z	z	z	z	z	z	z	z	z	z	z	z
C_4	pw	z	z	z	z	z	nm	ps	z	pm	ps	z	z	z	z	z	pm	ps	pm	z
C_5	pw	pw	z	z	z	pm	z	pw	z	z	pw	z	z	z	z	z	z	z	pw	z
C_6	z	pm	z	z	pm	z	z	z	z	z	ps	pw	z	z	z	z	z	z	z	z
C_7	z	z	z	z	z	z	z	pw	z	z	z	z	z	z	z	z	nw	pw	nm	z
C_8	z	z	z	z	z	z	z	z	z	pm	pm	z	z	z	pm	z	z	pm	z	z
C_9	z	z	z	z	ps	pm	z	pm	z	pm	ps	z	z	z	z	pw	z	z	z	z
C_{10}	z	z	z	z	z	z	pw	z	z	z	pm	z	z	z	z	z	z	z	z	z
C_{11}	z	z	z	z	z	z	nw	z	z	z	z	z	z	z	z	z	z	z	z	ps
C_{12}	pw	z	z	z	pw	z	z	z	pw	pw	z	z	z	z	z	z	z	z	z	pw
C_{13}	pm	z	z	z	pw	z	z	z	z	pm	z	z	z	z	pm	z	z	z	z	z
C_{14}	ns	z	z	z	nw	z	pw	nw	nm	nw	z	z	pw	z	nw	nw	z	z	pw	z
C_{15}	pw	z	z	z	pw	z	z	z	z	pw	z	pm	pw	z	z	z	z	z	z	pw
C_{16}	z	z	z	z	pw	z	z	pw	pm	pm	z	pw	z	z	pw	z	z	pw	z	z
C_{17}	z	z	z	z	z	z	ns	pm	z	z	pvs	z	z	z	z	z	z	pw	z	z
C_{18}	z	z	z	z	z	z	nw	pm	z	pm	pm	z	z	z	z	ps	pw	z	z	z
C_{19}	z	z	z	z	pm	z	nw	pm	z	z	z	z	z	z	z	z	z	z	z	z
C_{20}	z	z	z	z	z	z	pm	z	z	z	z	z	z	z	z	z	ps	z	pw	z

Table 5.9: The matrix of power of causalities that are transformed to triangular fuzzy numbers according to the Expert 1 (from C_1 to C_{10})

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
C_1	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_2	(0,0.25,0.5)	(-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)	(-0.5,-0.25,0)	(-0.5,-0.25,0)	(-0.25,0,0.25)	(0,0.25,0.5)
C_3	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_4	(0.25,0.5,0.75)	(-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)	(-1,-1,-0.75)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(0.25,0.5,0.75)
C_5	(0.75,1,1)	(0.5,0.75,1)	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_6	(-0.25,0,0.25)	(0.75,1,1)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_7	(0,0.25,0.5)	(-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)	(0.25,0.5,0.75)	(0,0.25,0.5)	(-0.25,0,0.25)
C_8	(-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)
C_9	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.75,1,1)	(0.5,0.75,1)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.5,0.75,1)
C_{10}	(0.25,0.5,0.75)	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{11}	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{12}	(0.5,0.75,1)	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)	(0.25,0.5,0.75)
C_{13}	(0.5,0.75,1)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.5,0.75,1)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)	(0.25,0.5,0.75)
C_{14}	(-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)	(-0.25,0,0.25)	(0.5,0.75,1)	(-0.75,-0.5,-0.25)	(-0.5,-0.25,0)	(-0.5,-0.25,0)
C_{15}	(0.25,0.5,0.75)	(-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)	(0,0.25,0.5)	(0.5,0.75,1)
C_{16}	(-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)	(0.25,0.5,0.75)	(0.25,0.5,0.75)
C_{17}	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{18}	(-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)	(0.25,0.5,0.75)	(0,0.25,0.5)	(0.25,0.5,0.75)
C_{19}	(-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)	(0,0.25,0.5)	(0,0.25,0.5)	(-0.25,0,0.25)
C_{20}	(-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)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)

Table 5.10: The matrix of power of causalities that are transformed to triangular fuzzy numbers according to the Expert 1 (from C_{11} to C_{20})

	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}
C_1	(0.5,0.75,1)	(-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)	(-0.25,0,0.25)	(0.75,1,1)
C_2	(0,0.25,0.5)	(0,0.25,0.5)	(0.5,0.75,1)	(-0.25,0,0.25)	(0,0.25,0.5)	(0,0.25,0.5)	(-0.5,-0.25,0)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(-0.25,0,0.25)
C_3	(-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)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(-0.25,0,0.25)
C_4	(0.25,0.5,0.75)	(-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)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(-0.25,0,0.25)
C_5	(0.5,0.75,1)	(-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)	(-0.25,0,0.25)	(0.5,0.75,1)
C_6	(0,0.25,0.5)	(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)	(-0.75,-0.5,-0.25)	(-0.25,0,0.25)	(-0.75,-0.5,-0.25)	(-0.25,0,0.25)
C_7	(-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)	(0,0.25,0.5)	(-0.5,-0.25,0)	(-0.25,0,0.25)	(-0.75,-0.5,-0.25)	(-0.25,0,0.25)
C_8	(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)	(-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)
C_9	(0.5,0.75,1)	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{10}	(0.5,0.75,1)	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{11}	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.25,0.5,0.75)
C_{12}	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)
C_{13}	(0,0.25,0.5)	(0.25,0.5,0.75)	(-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)	(-0.25,0,0.25)	(0,0.25,0.5)
C_{14}	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{15}	(-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)	(-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)
C_{16}	(-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)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{17}	(0.25,0.5,0.75)	(-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)	(0.5,0.75,1)	(0.5,0.75,1)	(-0.25,0,0.25)
C_{18}	(0.25,0.5,0.75)	(-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)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{19}	(-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)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{20}	(-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)	(0.5,0.75,1)	(-0.25,0,0.25)	(0.75,1,1)	(-0.25,0,0.25)

Table 5.11: The matrix of power of causalities that are transformed to triangular fuzzy numbers according to the Expert 2 (from C_1 to C_{10})

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
C_1	(-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)
C_2	(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)	(0.5,0.75,1)	(-0.5,-0.25,0)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.25,0.5,0.75)
C_3	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_4	(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)	(-0.25,0,0.25)	(-0.75,-0.5,-0.25)	(0.5,0.75,1)	(-0.25,0,0.25)	(0.25,0.5,0.75)
C_5	(0,0.25,0.5)	(0,0.25,0.5)	(-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)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_6	(-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)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_7	(-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)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_8	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)
C_9	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-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)	(0,0.25,0.5)	(-0.25,0,0.25)	(0.25,0.5,0.75)
C_{10}	(0.25,0.5,0.75)	(-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)
C_{11}	(-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)
C_{12}	(0.25,0.5,0.75)	(-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)	(0.25,0.5,0.75)	(0.25,0.5,0.75)
C_{13}	(0.25,0.5,0.75)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.25,0.5,0.75)	(0.25,0.5,0.75)
C_{14}	(-1,-1,-0.75)	(-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)	(0.25,0.5,0.75)	(-0.5,-0.25,0)	(-0.5,-0.25,0)	(-0.5,-0.25,0)
C_{15}	(0,0.25,0.5)	(-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)	(0.25,0.5,0.75)	(0.25,0.5,0.75)
C_{16}	(-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)	(0,0.25,0.5)	(0.5,0.75,1)	(0,0.25,0.5)
C_{17}	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{18}	(-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)	(0,0.25,0.5)	(-0.25,0,0.25)	(0,0.25,0.5)
C_{19}	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{20}	(-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)	(0,0.25,0.5)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)

Table 5.12: The matrix of power of causalities that are transformed to triangular fuzzy numbers according to the Expert 2 (from C_{11} to C_{20})

	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}
C_1	(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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.75,1,1)
C_2	(0.5,0.75,1)	(0,0.25,0.5)	(0.5,0.75,1)	(-0.25,0,0.25)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(-0.75,-0.5,-0.25)	(-0.25,0,0.25)	(-0.75,-0.5,-0.25)	(-0.25,0,0.25)
C_3	(-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,-0.25,0)	(-0.25,0,0.25)
C_4	(0.75,1,1)	(-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)	(0.75,1,1)	(0.75,1,1)	(0.5,0.75,1)	(-0.25,0,0.25)
C_5	(0.25,0.5,0.75)	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)
C_6	(0.25,0.5,0.75)	(-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,-0.25,0)	(-0.25,0,0.25)
C_7	(-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)	(0,0.25,0.5)	(-1,-0.75,-0.5)	(-0.25,0,0.25)
C_8	(0.5,0.75,1)	(-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)	(0.5,0.75,1)	(0.25,0.5,0.75)	(-0.25,0,0.25)
C_9	(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)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{10}	(0.5,0.75,1)	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{11}	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.75,1,1)
C_{12}	(-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)	(-0.25,0,0.25)	(0,0.25,0.5)
C_{13}	(0,0.25,0.5)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.75,1,1)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)
C_{14}	(-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)	(-0.5,-0.25,0)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{15}	(-0.25,0,0.25)	(0.25,0.5,0.75)	(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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.5,0.75,1)
C_{16}	(-0.25,0,0.25)	(0,0.25,0.5)	(-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)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{17}	(0.75,1,1)	(-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)	(0.5,0.75,1)	(0.25,0.5,0.75)	(-0.25,0,0.25)
C_{18}	(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)	(0.25,0.5,0.75)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(-0.25,0,0.25)
C_{19}	(-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)	(0,0.25,0.5)	(-0.25,0,0.25)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{20}	(-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)	(0.75,1,1)	(-0.25,0,0.25)	(0.5,0.75,1)	(-0.25,0,0.25)

Table 5.13: The matrix of power of causalities that are transformed to triangular fuzzy numbers according to the Expert 3 (from C_1 to C_{10})

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
C_1	(-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)
C_2	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)	(0.5,0.75,1)	(-0.25,0,0.25)	(-0.75,-0.5,-0.25)	(-0.25,0,0.25)	(0,0.25,0.5)
C_3	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_4	(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)	(-0.25,0,0.25)	(-0.75,-0.5,-0.25)	(0.5,0.75,1)	(-0.25,0,0.25)	(0.25,0.5,0.75)
C_5	(0,0.25,0.5)	(0,0.25,0.5)	(-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)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_6	(-0.25,0,0.25)	(0.25,0.5,0.75)	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_7	(-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)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_8	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.25,0.5,0.75)
C_9	(-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)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(0.25,0.5,0.75)
C_{10}	(-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)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{11}	(-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)
C_{12}	(0,0.25,0.5)	(-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)	(-0.25,0,0.25)	(0,0.25,0.5)	(0,0.25,0.5)
C_{13}	(0.25,0.5,0.75)	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.25,0.5,0.75)
C_{14}	(-1,-0.75,-0.5)	(-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)	(0,0.25,0.5)	(-0.5,-0.25,0)	(-0.75,-0.5,-0.25)	(-0.5,-0.25,0)
C_{15}	(0,0.25,0.5)	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)
C_{16}	(-0.25,0,0.25)	(-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)	(0,0.25,0.5)	(0.25,0.5,0.75)	(0.25,0.5,0.75)
C_{17}	(-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)	(-1,-0.75,-0.5)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{18}	(-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)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(0.25,0.5,0.75)
C_{19}	(-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)	(-0.5,-0.25,0)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{20}	(-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)

Table 5.14: The matrix of power of causalities that are transformed to triangular fuzzy numbers according to the Expert 3 (from C_{11} to C_{20})

	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}
C_1	(0.25,0.5,0.75)	(-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)	(-0.25,0,0.25)	(0.5,0.75,1)
C_2	(0,0.25,0.5)	(-0.25,0,0.25)	(0.75,1,1)	(-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)	(-1,-0.75,-0.5)	(-0.25,0,0.25)
C_3	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_4	(0.5,0.75,1)	(-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)	(0.5,0.75,1)	(0.25,0.5,0.75)	(-0.25,0,0.25)
C_5	(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)	(-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)
C_6	(0.5,0.75,1)	(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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_7	(-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)	(0,0.25,0.5)	(-0.75,-0.5,-0.25)	(-0.25,0,0.25)
C_8	(0.25,0.5,0.75)	(-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)	(0.25,0.5,0.75)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_9	(0.5,0.75,1)	(-0.25,0,0.25)	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{10}	(0.25,0.5,0.75)	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{11}	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0.5,0.75,1)
C_{12}	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)
C_{13}	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{14}	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.5,-0.25,0)	(-0.5,-0.25,0)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)	(-0.25,0,0.25)
C_{15}	(-0.25,0,0.25)	(0.25,0.5,0.75)	(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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(0,0.25,0.5)
C_{16}	(-0.25,0,0.25)	(0,0.25,0.5)	(-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)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{17}	(0.75,1,1)	(-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)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{18}	(0.25,0.5,0.75)	(-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)	(0,0.25,0.5)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{19}	(-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)	(-0.25,0,0.25)	(-0.25,0,0.25)	(-0.25,0,0.25)
C_{20}	(-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)	(0.5,0.75,1)	(-0.25,0,0.25)	(0,0.25,0.5)	(-0.25,0,0.25)

5.4. Aggregation of Fuzzy Numbers

Experts initially determine each interrelationship, and then the causal links for the same interrelation are indicated, the fuzzy numbers from the three decision makers for the associated interrelation are transformed into a single fuzzy set via MAX method, which is coded in MATLAB Fuzzy Toolbox.

5.5. Defuzzification Process

The single fuzzy set, which is obtained from MAX aggregation method, is converted into numerical value, w_{ji}, with the defuzzification method of COG, which is coded in MATLAB Fuzzy Toolbox. The formulation of this method is given in the following formulation (Ross, 2010).

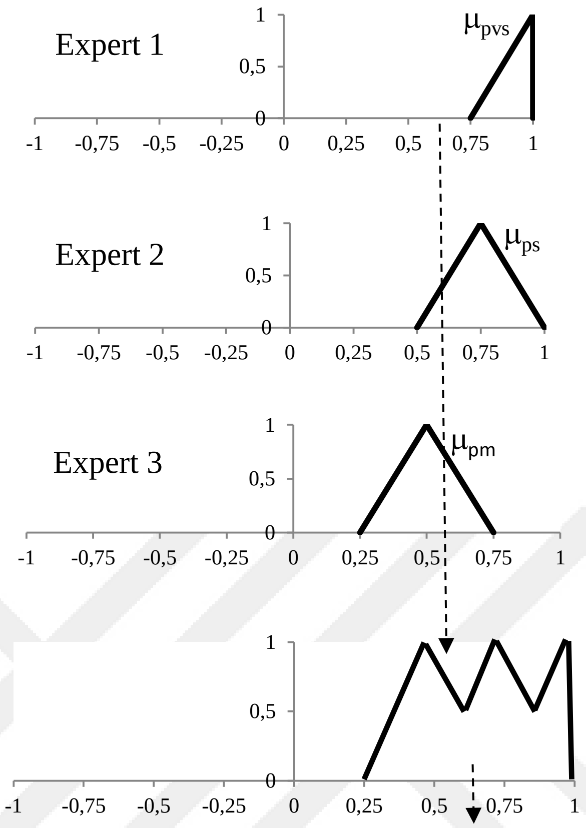
$$z^{*} = \frac{\int \mu_{\tilde{A}}(z).z \quad dz}{\int \mu_{\tilde{A}}(z)\, dz} \qquad (5.1)$$

Figure 5.3 illustrates the three linguistic variables for a particular interrelation. These linguistic variables are aggregated using MAX method, and a single numerical weight is produced by using COG method. The expert opinions for this particular example are as follows.

Expert 1: Overall financial position of the service provider influences firm size with a *positive very strong* degree of causation.

Expert 2: Overall financial position of the service provider influences firm size with a *positive strong* degree of causation.

Expert 3: Overall financial position of the service provider influences firm size with a *positive medium* degree of causation.



Result of defuzzification: 0.673

Figure 5.3: Aggregation and defuzzification of three linguistic variables

In brief, overall financial position of the service provider influences firm size with a degree of causation of 0.673 (e_{62}).

5.6. Construction of the Weight Matrix

The weight matrix for performance indicators of BPO is generated by employing aggregation and defuzzification processes, which are mentioned before, for every relation between each pair of (132) connected concepts, and given in Table 5.12. Indices are reported in Table 5.13, and FCM that is created with regard to the results of the weight matrix is provided in Figure 5.4.

Table 5.15: 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_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}
C_1	0.00	0.00	0.00	0.00	0.00	0.00	-0.13	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80
C_2	0.13	0.00	0.00	0.00	0.50	0.63	-0.13	-0.25	0.00	0.38	0.50	0.13	0.80	0.00	0.25	0.38	-0.25	0.00	-0.50	0.00
C_3	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.13	0.00	-0.13	0.00
C_4	0.38	0.00	0.00	0.00	0.00	0.00	-0.65	0.63	0.00	0.50	0.67	0.00	0.00	0.00	0.00	0.00	0.65	0.67	0.63	0.00
C_5	0.49	0.50	0.00	0.00	0.00	0.50	0.00	0.13	0.00	0.00	0.50	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.13	0.35
C_6	0.00	0.67	0.00	0.00	0.25	0.00	-0.13	0.00	0.00	0.00	0.50	0.13	0.00	0.00	0.00	0.00	-0.25	0.00	-0.13	0.00
C_7	0.13	0.00	0.00	0.00	0.25	0.00	0.00	0.38	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.13	-0.25	0.13	-0.63	0.00
C_8	0.00	0.00	0.00	0.00	0.00	0.00	-0.13	0.00	0.00	0.25	0.50	0.00	0.00	0.00	0.25	0.00	0.00	0.40	0.25	0.00
C_9	0.25	0.00	0.00	0.00	0.67	0.50	0.00	0.25	0.00	0.63	0.50	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00
C_{10}	0.25	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C_{11}	0.00	0.00	0.00	0.00	0.00	0.00	-0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67
C_{12}	0.50	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.13	0.00	0.25	0.00	0.00	0.00	0.00	0.25
C_{13}	0.63	0.25	0.00	0.00	0.50	0.25	0.00	0.00	0.25	0.50	0.13	0.25	0.00	0.00	0.65	0.00	0.00	0.00	0.00	0.13
C_{14}	-0.80	0.00	0.00	0.00	-0.38	0.00	0.50	-0.38	-0.38	-0.25	0.00	0.00	0.13	0.00	-0.50	-0.13	0.00	0.00	0.13	0.00
C_{15}	0.38	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.25	0.50	0.00	0.63	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.50
C_{16}	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.13	0.63	0.38	0.00	0.13	0.00	0.00	0.13	0.00	0.00	0.25	0.00	0.00
C_{17}	0.00	0.00	0.00	0.00	0.00	0.00	-0.63	0.25	0.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.40	0.00
C_{18}	0.00	0.00	0.00	0.00	0.00	0.00	-0.13	0.38	0.13	0.38	0.38	0.00	0.00	0.00	0.00	0.63	0.38	0.00	-0.13	0.00
C_{19}	0.00	0.00	0.00	0.00	0.25	0.00	-0.38	0.38	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.25	0.00	0.00
C_{20}	0.00	0.00	0.00	0.00	0.00	0.13	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.56	0.00

Table 5.16: Indices

Label	Concept	Outdegree	Indegree	Centrality
C_1	Cost reduction	1.42	3.91	5.33
C_2	Firm size	4.80	1.55	6.35
C_3	Firm age	0.38	0.00	0.38
C_4	Age of relationship	4.77	0.00	4.77
C_5	Operational efficiency	2.71	4.30	7.01
C_6	Overall financial position	2.05	2.00	4.05
C_7	Contract schedule	2.00	3.77	5.77
C_8	Responsiveness	1.77	3.13	4.90
C_9	Employee productivity	3.05	2.25	5.30
C_{10}	Service quality	1.13	4.13	5.25
C_{11}	Reliability	1.05	5.45	6.49
C_{12}	Process innovation	2.38	1.25	3.63
C_{13}	IT capability	3.52	1.30	4.82
C_{14}	Task complexity	3.55	0.00	3.55
C_{15}	Information accessibility	3.00	2.15	5.15
C_{16}	Coordination	2.13	1.63	3.75
C_{17}	Commitment	2.42	2.70	5.12
C_{18}	Communication capability	2.50	2.20	4.70
C_{19}	Flexibility	1.50	3.58	5.08
C_{20}	Degree of outsourcing	1.86	2.70	4.55

Outdegree values represent the sum of absolute values for row elements of the weight matrix, indegree values denotes the sum of absolute values for column elements of the same matrix and centrality refers to the sum of the outdegree and indegree values. For instance, 1.42 represents the sum of absolute values for the 1st row; 3.91 indicates the sum of absolute values for the 1st row column, and 5.33 states the sum of 1.42 and 3.91. 1.42 expresses the total influence of C_1 on the other concepts, 3.91 signifies the total effect of the concepts on C_1.

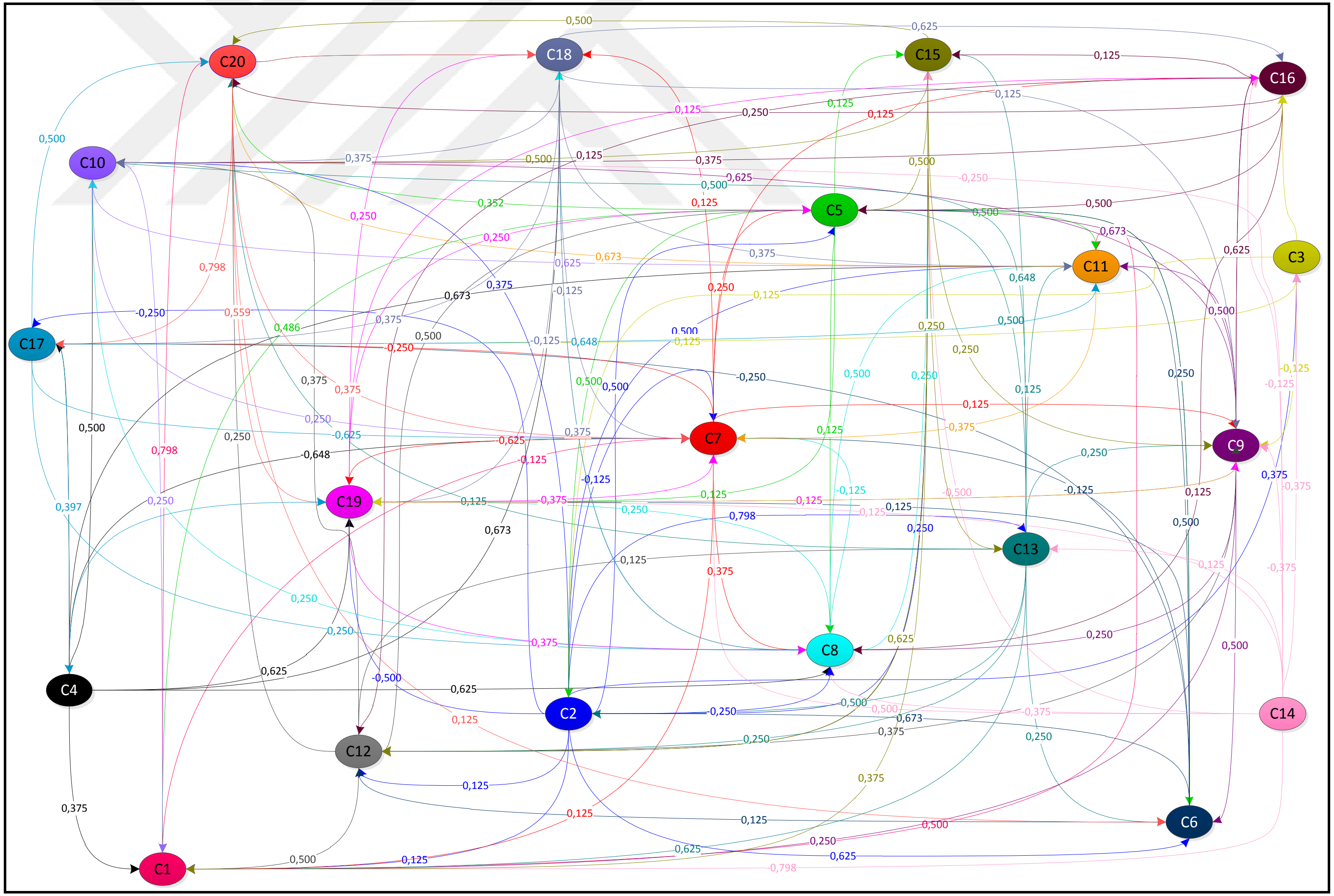


Figure 5.4: FCM

5.7. Calculating concepts' values

In this section of the application, FCMapper software is utilized to obtain concepts' values to employ performance assessment for BPO by running Formulation (4.8). The value A_i of a concept C_i is computed by considering the effect of the interrelated concepts (C_j) on the particular concept C_i. Each concept C_i is represented by A_i^t that denotes the activation level of concept C_i at time step t. The vector $A^t = [A_1^t, A_2^t, \ldots, A_n^t]$ provides the state of the FCM at time step t.

In this thesis, the Formulation (4.8) starts to be activated with the initial vector $A^0 = [1,1,\ldots,1]$. The values of this vector finalized by utilizing Formulation (4.8) and a threshold function. $f(x) = \tanh(x)$ is the appropriate threshold function since the values of A_i can be negative and the interval that these values belong to is [-1,1]. The new vector, which is obtained by running the iterative formulation with this threshold function, is considered as the initial vector for the next iteration. These vectors are updated by using Formulation (4.8) until positive as well as negative interrelations between the concepts have acquired equilibrium. In other words, the process continues till $|vector(t) - vector(t+1)| \leq \varepsilon$, where $\varepsilon > 0$, and small enough (Büyükavcu et al., 2016). After 1572 iterations, the system reaches the equilibrium and the stabilization is provided. The concepts' values of BPO performance are listed in Table 5.14.

Table 5.17: The concepts' values of BPO performance

Label	Concept	Concept's value
Tangible Factors		
C_1	Cost reduction	0.99792
C_2	Firm size	0.98367
C_3	Firm age	0.03087
C_4	Age of relationship	0.03087
C_5	Operational efficiency	0.99967
C_6	Overall financial position	0.99476
C_7	Contract schedule	-0.98050
C_8	Responsiveness	0.94739
Intangible Factors		
C_9	Employee productivity	0.98821
C_{10}	Service quality	0.99964
C_{11}	Reliability	0.99998
C_{12}	Process innovation	0.97604
C_{13}	IT capability	0.97216
C_{14}	Task complexity	0.03087
C_{15}	Information accessibility	0.98851
C_{16}	Coordination	0.97561
C_{17}	Commitment	0.95491
C_{18}	Communication capability	0.97648
C_{19}	Flexibility	0.97412
C_{20}	Degree of outsourcing	0.99873

Table 5.14 indicates that the firm age and the age of relationship are not powerful tangible factors, and the power of task complexity, which is an intangible factor, is observed to be low, because the concept values of these three factors are small enough. Apart from these three criteria, the others are quite powerful on performance assessment of business process outsourcing. These relative importance degrees demonstrate that those factors have all strong power on the occurrence of performance degree of business process outsourcing. In these work, criteria are initially determined in a detailed way by both reviewing the literature and making use of experts' opinions. Criteria are discriminatingly indicated in order to decrease the total number of factors therefore the criteria whose necessity is uncertain are not incorporated into decision framework. The employed filtration leads to result in such high concept values of criteria.

5.8. Scenario Analyses

Scenario 1:

If a cost reduction is not provided via outsourcing, in other words, if the value of the cost reduction concept is equal to zero, minor changes on the other concepts' values occur; however the most significant change occurs on the contract schedule's importance degree. The power of the contract schedule decreases negatively; because if the provider does not provide a financial benefit to the client, the contract schedule is expected to be more flexible. Hence, the performance of an outsourced service, which is not financially attractive, can be conducted by signing a contract that is less strict. The results of Scenario 1 are listed in Table 5.15.

Scenario 2:

If the service provider is unable to compete in the increasing technology, the power of the IT capability of this firm decreases. However, this decrease leads to an increase on the relative importance of responsiveness and flexibility. Especially, small-scale companies cannot easily access to the information due to the lower level of IT. On the other hand, these small enterprises have an improved maneuverability therefore they respond rapidly and behave flexibly to their clients. The resulting concepts' values according to the Scenario 2 are given in Table 5.15.

Scenario 3:

For provider firms, a decrease of the power of employee productivity as a factor leads to a decrease of the power of responsiveness and coordination. The results of this scenario analysis are provided in Table 5.15.

Scenario 4:

When the service provider has a lot of clients, commitment can be possible just for few number of client firms. Provider gives priority to these clients, makes expense for them. In addition, being loyal necessitates an additional budget. Hence, the provider is committed to its preferred customers, however, has a professional relationship with the other clients. Therefore, contract schedule becomes more flexible when the commitment is ignored. Besides, lack of commitment leads to a decrease on the communication between provider and the client, this decrease affects flexibility in a negative way. The results of Scenario 4 are listed in Table 5.15.

Table 5.18: The results of scenario analyses

	No change	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Cost reduction	0.99792	**0**	0.99741	0.99777	0.99795
Firm size	0.98367	0.98367	0.98215	0.98365	0.98367
Firm age	0.03087	0.03087	0.03087	0.03087	0.03087
Age of relationship	0.03087	0.03087	0.03087	0.03087	0.03087
Operational efficiency	0.99967	0.99967	0.99960	0.99960	0.99967
Overall financial position	0.99476	0.99476	0.99427	0.99398	0.99476
Contract schedule	-0.98050	-0.97483	-0.98049	-0.98047	-0.92683
Responsiveness	0.94739	0.94760	0.94740	0.94325	0.90821
Employee productivity	0.98821	0.98823	0.98709	**0.85000**	0.98810
Service quality	0.99964	0.99964	0.99957	0.99957	0.99962
Reliability	0.99998	0.99994	0.99998	0.99997	0.99992
Process innovation	0.97604	0.97604	0.97368	0.97602	0.97602
IT capability	0.97216	0.97216	**0.80000**	0.97215	0.97215
Task complexity	0.03087	0.03087	0.03087	0.03087	0.03087
Information accessibility	0.98851	0.98851	0.98554	0.98848	0.98827
Coordination	0.97561	0.97564	0.97556	0.97379	0.97428
Commitment	0.95491	0.95438	0.95496	0.95493	**0**
Communication capability	0.97648	0.97651	0.97649	0.97638	0.93229
Flexibility	0.97412	0.97377	0.97416	0.97407	0.93704
Degree of outsourcing	0.99873	0.99370	0.99866	0.99873	0.99873

6. CONCLUSION

Globalization, competitive environment and developing technology in the market force firms to cope with every kind of change in order to maintain their competitive advantages. Organizations must consider performance measures such as cost reduction, quality, reliability, flexibility, efficiency and innovation for surviving in the market. Outsourcing is the strategic component, thanks to which firms are able to disintegrate peripheral business process activities and to focus on their core competencies. It has many advantages, as well as potential disadvantages and risks, hence performance evaluation of outsourced processes is required for clients to handle with market competition, for providers to understand their performance measures in order to assess themselves.

This thesis introduces FCM methodology to provide a performance assessment in BPO, which is an advanced type of IT outsourcing. Business processes are associated with IT, and BPO may contain various business processes of main fields, which involve IT-enabled activities such as marketing, sales, logistics, accounting, finance, customer relations, etc.

FCM, which is a causal knowledge-based method, combines fuzzy logic and neural networks in order to model complex decision systems, by collecting data from experts. It takes into consideration the direction, the sign and the power of the interrelationships among criteria, and obtains concepts' values by employing its iterative formulation with a threshold function to be decided for obtaining significant results. In addition, when exact data are not available, FCM methodology enables decision makers to utilize fuzzy numbers or linguistic variables to indicate the power of relationships between pair of concepts.

In this study, performance criteria of BPO were initially determined by reviewing the literature and using experts' opinions. Afterwards, twenty factors were indicated and sent to three different decision makers, whose job description is directly related to BPO. Experts determined firstly whether there is causality between each pair of concept, and the sign of the relationship if there exists. Then, the power of causal links for each relationship was determined by using linguistic variables. These linguistic variables are converted into fuzzy numbers according to the associated membership function. By means of MATLAB Fuzzy Toolbox, obtained fuzzy numbers from three decision makers were aggregated and then defuzzified by using MAX and center of gravity methods, respectively. The final weight matrix and FCM were constructed; outdegree, indegree and centrality values were calculated. By running the iterative formulation of FCM, concepts' values were computed. Scenario analyses are employed to understand the influence of an increase or a decrease of the power of specific concept(s) on other concepts.

The weight matrix indicates that there are 132 connections in total. Firm age, age of relationship and task complexity are the transmitters. The other 17 factors are seen as ordinary concepts, hence there is no receiver. Therefore, 15% of the criteria are transmitter, 85% of them are ordinary. The results of FCM shows that three criteria, which are firm age, age of relationship and task complexity have a low degree of power. Besides, the other factors are quite significant on performance evaluation of business process outsourcing because of the fact that criteria are initially determined in a detailed way by both reviewing the literature and making use of experts' opinions.

In addition, this thesis contributes to the literature by being the first study which incorporates FCM methodology into performance assessment of outsourcing, and considers the complexity of the decision model of the outsourced processes. Moreover, this study provides an evaluation for outsourcer to evaluate their service providers, and a self-evaluation for providers to assess themselves, hence this thesis introduces a mutual assessment. Future research will focus on incorporating a performance domain as a criterion into the assessment of BPO, beside this adding outsourcing provider alternatives to the decision framework and selecting the most appropriate service provider by employing TOPSIS (technique for order preference by similarity to ideal solution) methodology or proposing an integrated model called as FCM-TOPSIS.

REFERENCES

Agrawal, M., Kishore, R., Rao, H.R. (2006). Market reactions to e-business outsourcing announcements: An event study., *Information&Management* 43 : 861-873.

Ahmadi, S., Yeh, C.H., Martin, R., Papageorgiou, E. (2015). Optimizing ERP readiness improvements under budgetary constraints., *International Journal of Production Economics* 161 : 105-115.

Ahmadi, S., Yeh, C.H., Papageorgiou, E.I., Martin, R. (2015a). An FCM-FAHP approach for managing readiness-relevant activities for ERP implementation., *Computers&Industrial Engineering* 88 : 501-517.

Apak, S., Gümüş, S., Kurban, Z. (2012). Strategic dimension of outsourcing in the information technologies intensified businesses., *Procedia – Social and Behavioral Sciences* 58 : 783-791.

Axelrod, R. (1976). Structure of decision, Princeton University Press, Princeton, New York.

Aydin, M.N., Bakker, M.E. (2008). Analyzing IT maintenance outsourcing decision from a knowledge management perspective., *Information Systems Frontiers* 10 : 293-305.

Azadeh, A., Zarrin, M., Abdollahi, M., Noury, S., Farahmand, S. (2015). Leanness assessment and optimization by fuzzy cognitive map and multivariate analysis., *Expert Systems with Applications* 42 : 6050-6064.

Balakrishnan, K., Mohan, U., Seshadri, S. (2008). Outsourcing of front-end business processes: Quality, information, and customer contact., *Journal of Operations Management* 26 : 288-302.

Baykasoğlu, A., Gölcük, İ. (2015). Development of a novel multiple-attribute decision making model via fuzzy cognitive maps and hierarchical fuzzy TOPSIS., *Information Sciences* 301 : 75-98.

Bengtsson, L., Dabhilkar, M. (2009). Manufacturing outsourcing and its effect on plant performance-lessons for KIBS outsourcing., *Journal of Evolutionary Economics* 19 : 231-257.

Bottani, E., Rizzi, A. (2006) A fuzzy TOPSIS methodology to support outsourcing of logistics services., *Supply Chain Management: An International Journal* 11(4) : 294-308.

Bustinza, O.F., Arias-Aranda, D., Gutierrez-Gutierrez, L. (2010). Outsourcing, competitive capabilities and performance: an empirical study in service firms., *International Journal of Production Economics* 126 : 276-288.

Butler, M.G., Callahan, C.M. (2014). Human resource outsourcing: Market and operating performance effects of administrative HR functions., *Journal of Business Research* 67 : 218-224.

Büyükavcu, A., Albayrak, Y.E., Göker, N. (2016). A fuzzy information-based approach for breast cancer risk factors assessment., *Applied Soft Computing* 38 : 437-452.

Büyüközkan, G., Vardaloğlu, Z. (2012). Analyzing of CPFR success factors using fuzzy cognitive maps in retail industry., *Expert Systems with Applications* 10438-10455.

Chen, Y., Mazlack, L.J., Minai, A.A., Lu, L.J. (2015). Inferring causal networks using fuzzy cognitive maps and evolutionary algorithms with application to gene regulatory network reconstruction., *Applied Soft Computing* 37 : 667-679.

Chen, T.C., Lee, A.C., Huang, S.H. (2015a). FCM based hybrid evolutionary computation approach for optimization power consumption by varying cars in EGCS., *Applied Mathematical Modelling* 39 : 5917-5924.

Chen, Y.H., Wang, T.C., Wu, C.Y. (2011). Strategic decisions using the fuzzy PROMETHEE for IS outsourcing., *Expert Systems with Applications* 38 : 13216-13222.

Chou, T.C., Chen, J.R., Pan, S.L. (2006). The impacts of social capital on information technology outsourcing decisions: A case study of a Taiwanese high-tech firm., *International Journal of Information Management* 26 : 249-256.

Chou, S.W., Techatassanasoontorn, A.A., Hung, I.H. (2015). Understanding commitment in BPO., *Information & Management* 52 : 30-43.

Dabhilkar, M., Bengsston, L., Haartman, R., Ahlström, P. (2009). Supplier selection or collaboration? Determining factors of performance improvement when outsourcing manufacturing., *Journal of Purchasing & Supply Management* 15 : 143-153.

Dias, S.B., Hadjileontiadou, S.J., Hadjileontiadou, L.J., Diniz, J.A. (2015). Fuzzy cognitive mapping of LMS users' Quality of Interaction within higher education blended-learning environment., *Expert Systems with Applications* 42 : 7399-7423.

Ee, O., Halim, H.A., Ramayah, T. (2013). The effects of partnership quality on BPO success in Malaysia: key users perspective., *Service Business* 7 : 227-253.

Froelich, W., Papageorgiou, E.I., Samarinas, M., Skriapas, K. (2012). Application of evolutionary fuzzy cognitive maps to the long-term prediction of prostate cancer., *Applied Soft Computing* 12 : 3810-3817.

Gewald, H., Dibbern, J. (2009). Risks and benefits of BPO: A study of transaction services in the German banking industry., *Information & Management* 46 : 249-257.

Giabbanelli, P.J., Torsney-Weir, T., Mago, V.K. (2012). A fuzzy cognitive map of the psychological determinants of obesity., *Applied Soft Computing* 12 : 3711-3724.

Gilley, K.M., Greer, C.R., Rasheed, A.A. (2004). Human resource outsourcing and organizational performance in manufacturing firms., *Journal of Business Research* 57 : 232-240.

Gotzamani, K., Longinidis, P., Vouzas, F. (2010). The logistics services outsourcing dilemma quality management and financial performance perspectives., *Supply Chain Management: An International Journal* 15(6) : 438-453.

Grefen, P., Ludwig, H., Dan, A., Angelov, S. (2006). An analysis of web services support for dynamic BPO., *Information and Software Technology* 48 : 1115-1134.

Gunasekaran, A., Irani, Z., Choy, K.L., Filippi, L., Papadopoulos, T. (2015). Performance measures and metrics in outsourcing decisions: A review for research and applications., *International Journal of Production Economics* 161 : 153-166.

Handley, S.M., Benton Jr., W.C. (2009). Unlocking the BPO process model., *Journal of Operations Management* 27 : 344-361.

Hsiao, H.I., Kemp, R.G.M., van der Vorst, J.G.A.J, Omta, S.W.F. (2010). A classification of logistics outsourcing levels and their impact on service performance: Evidence from the food processing industry., *International Journal of Production Economics* 124 : 75-86.

Ibrahim, S.E., Hanafi, A. (2013). Call center offshoring performance management., *Strategic Outsourcing: An International Journal* 6(3) : 292-312.

Irani, Z., Sharif, A., Kamal, M.M., Love, P.E.D. (2014). Visualising a knowledge mapping of information systems investment evaluation., *Expert Systems with Applications* 41 : 105-125.

Jayashree, L.S., Palakkal, N., Papageorgiou, E.I., Papageorgioui K. (2015). Application of fuzzy cognitive maps in precision agriculture: a case study on coconut yield management of southern India’s Malabar region., *Neural Computing and Applications* 26 : 1963-1978.

Kalaignanam, K., Varadarajan, R. (2012). Offshore outsourcing of customer relationship management: conceptual model and propositions., *Journal of the Academy of Marketing Science* 40 : 347-363.

Kardaras, D.K., Karakostas, B., Mamakou, X.J. (2013). Content presentation personalization and media adaptation in tourism web sites using Fuzzy Delphi Method and Fuzzy Cognitive Maps., *Expert Systems with Applications* 40 : 2331-2342.

Kayikci, Y., Stix, V. (2014). Causal mechanism in transport collaboration., *Expert Systems with Applications* 41 : 1561-1575.

Kim, Y.J., Lee, J.M., Koo, C., Nam, K. (2013). The role of governance effectiveness in explaining IT outsourcing performance., *International Journal of Information Management* 33 : 850-860.

Kinange, U., V, M. (2011). Human Resource Outsourcing: A New Mantra for Business Sustenance., *Procedia-Social and Behavioral Sciences* 25 : 227-232.

Kosko, B. (1986). Fuzzy cognitive maps., *International Journal of Man-Machine Studies* 24 : 65-75.

Kotabe, M., Mol, M.J., Murray, J.Y., Parente, R. (2012). Outsourcing and its implications for market success: negative curvilinearity, firm resources, and competition., *Journal of the Academy of Marketing Science* 40 : 329-346.

Krakovics, F., Leal, J.E., Mendes Jr, P., Santos, R.L. (2008). Defining and calibrating performance indicators of a 4PL in the chemical industry in Brazil., *International Journal of Production Economics* 115 : 502-514.

Kung, C.Y. (2006). Using fuzzy sets and grey decision-making to construct the performance evaluation model of firm's outsourcing management – A case study of avionics manufacturer in Taiwan., *Quality & Quantity* 40 : 577-593.

Kyriakarakos, G., Patlitzianas, K., Damasiotis, M., Papastefanakis, D. (2014). A fuzzy cognitive maps decision support system for renewables local planning., *Renewable and Sustainable Energy Reviews* 39 : 209-222.

Lee, J.N., Huynh, M.Q., Hirschheim, R. (2008). An integrative model of trust on IT outsourcing: Examining a bilateral perspective., *Information Systems Frontiers* 10 : 145-163.

Lee, S., Yang, J., Han, J. (2012). Development of a decision making system for selection of dental implant abutments based on the fuzzy cognitive map., *Expert Systems with Applications* 39 : 11564-11575.

Lee, D.H., Lee, H. (2015). Construction of holistic Fuzzy Cognitive Maps using ontology matching method., *Expert Systems with Applications* 42 : 5954-5962.

Leng, J., Jiang, P., Ding, K. (2014). Implementing of a three-phase integrated decision support model for parts machining outsourcing., *International Journal of Production Research* 52(12) : 3614-3636.

Leon, M., Mkrtchyan, L., Depaire, B., Ruan, D. Vanhoof, K. (2014). Learning and clustering of fuzzy cognitive maps for travel behavior analysis., *Knowledge and Information Systems* 39 : 435-462.

Li, D.F., Wan, S.P. (2014). A fuzzy inhomogeneous multiattribute group decision making approach to solve outsourcing provider selection problems., *Knowledge-Based Systems* 67 : 71-89.

Liu, L.B., Berger, P., Zeng, A., Gerstenfeld, A. (2008). Applying the analytic hierarchy process to outsourcing location decision., *Supply Chain Management: An International Journal* 13(6) : 435-449.

Liu, C., Huo, B., Liu, S., Zhao, X. (2015). Effect of information sharing and process coordination on logistics outsourcing., *Industrial Management & Data Systems* 115(1) : 41-63.

Luo, Y., Zheng, Q., Jayaraman, V. (2010). Managing BPO., *Organizational Dynamics* 39(3) : 205-217.

Maio, C.D., Fenza, G., Gaeta, M., Loia, V., Orciuoli, F. (2011). A knowledge-based framework for emergency DSS., *Knowledge-Based Systems* 24 : 1372-1379.

Meixell, M.J., Kenyon, G.N., Westfall, P. (2014). The effects of production outsourcing on factory cost performance: an empirical study., *Journal of Manufacturing Technology Management* 25(6) : 750-774.

Mohanty, R.P., Mishra, D., Mishra, T. (2009). Comparative study of production outsourcing models., *Journal of Advances in Management Research* 6(1) : 41-69.

Mojsilovic, A., Ray, B., Lawrence, R., Takriti, S. (2007). A logistic regression framework for information technology outsourcing lifecycle management., *Computers & Operations Research* 34 : 3609-3627.

Narayanan, S., Jayaraman, V., Luo, Y., Swaminathan, J.M. (2011). The antecedents of process integration in BPO and its effect on firm performance., *Journal of Operations Management* 29 : 3-16.

Paisittanand, S., Olson, D.L. (2006). A simulation study of IT outsourcing in the credit card business., *European Journal of Operational Research* 175 : 1248-1261.

Papageorgiou, E.I. (2011). A new methodology for decisions in medical informatics using fuzzy cognitive maps based on fuzzy rule-extraction techniques., *Applied Soft Computing* 11 : 500-513.

Papageorgiou, E.I., Markinos, A.T., Gemtos, T.A. (2011). Fuzzy cognitive map based approach for predicting yield in cotton crop production as a basis for decision support system in precision agriculture application., *Applied Soft Computing* 11 : 3643-3657.

Papageorgiou, E.I. (2012). Fuzzy cognitive map software tool for treatment management of uncomplicated urinary tract infection., *Computer Methods and Programs in Biomedicine* 105 : 233-245.

Papageorgiou, E.I., Roo, J.D., Huszka, C., Colaert, D. (2012). Formalization of treatment guidelines using fuzzy cognitive maps., *Journal of Biomedical Informatics* 45 : 45-60.

Papageorgiou, E.I., Aggelopoulou, K.D., Gemtos, T.A., Nanos, G.D. (2013). Yield prediction in apples using Fuzzy Cognitive Map learning approach., *Computers and Electronics in Agriculture* 91 : 19-29.

Perçin, S. (2008). Fuzzy multi-criteria risk-benefit analysis of BPO (BPO)., *Information Management & Computer Security* 16(3) : 213-234.

Raassens, N., Wuyts, S., Geyskens, I. (2014). Performance implications of outsourcing customer support to service providers in emerging versus established economies., *International Journal of Research in Marketing* 31 : 280-292.

Rapp, A. (2009). Outsourcing the sales process: Hiring a mercenary sales force., *Industrial Marketing Management* 38 : 411-418.

Ray, A., Sarkar, B., Sanyal, S. (2008). A holistic approach for production outsourcing., *Strategic Outsourcing: An International Journal* 1(2) : 142-153.

Rhodes, J., Lok, P., Loh, W., Cheng, V. (2016). Critical success factors in relationship management for services outsourcing., *Service Business* 10 : 59-86.

Ross, T.J. (2010). Fuzzy logic with engineering applications, third edn, Wiley.

Sanchis-Pedregosa, C., Palacin-Sanchez, M.J., Gonzalez-Zamora, M.M. (2014). Exploring the financial impact of outsourcing services strategy on manufacturing firms., *Operations Management Researh* 7 : 77-85.

Sharda, K., Chatterjee, L. (2011). Configurations of outsourcing firms and organizational performance: A study of outsourcing industry in India., *Strategic Outsourcing: An International Journal* 4(2) : 152-178.

Sharif, A.M., Irani, Z., Love, P.E.D., Kamal, M.M. (2012). Evaluating reverse third-party logistics operations using a semi-fuzzy approach., *International Journal of Production Research* 50(9) : 2515-2532.

Solakivi, T., Töyli, J., Engblom, J., Ojala, L. (2011). Logistics outsourcing and company performance of SMEs., *Strategic Outsourcing: An International Journal* 4(2) : 131-151.

Swar, B., Moon, J., Oh, J., Rhee, C. (2012). Determinants of relationship quality for IS/IT outsourcing success in public sector., *Information Systems Frontiers* 14 : 457-475.

Taber, R. (1994). Fuzzy cognitive maps., *Al Expert* 9 : 19-23.

Tiwana, A. (2008). Does technological modularity substitute for control? A study of alliance performance in software outsourcing., *Strategic Management Journal* 29 : 769-780.

Tjader, Y., May, J.H., Shang, J., Vargas, L.G., Gao, N. (2014). Firm-level outsourcing decision making: A balanced scorecard-based analytic network process model., *International Journal of Production Economics* 147 : 614-623.

Tsai, W.H., Leu, J.D., Liu, J.Y., Lin, S.J., Shaw, M.J. (2010). A MCDM approach for sourcing strategy mix decision in IT projects., *Expert Systems with Applications* 37 : 3870-3886.

Vidal, R., Salmeron, J.L., Mena, A., Chulvi, V. (2015). Fuzzy cognitive map-based selection of TRIZ (Theory of inventive problem solving) trends for eco-innovation of ceramic industry., *Journal of Cleaner Production* 107 : 202-214.

Wang, E.J., Chen, Y.C., Wang, W.S., Su, T.S. (2010). Analysis of outsourcing cost-effectiveness using a linear programming model with fuzzy multiple goals., *International Journal of Production Research* 48(2) : 501-523.

Wüllenweber, K., Beimborn, D., Weitzel, T., König, W. (2008). The impact of process standardization on BPO success., *Information Systems Frontiers* 10 : 211-224.

Yang, D.H., Kim, S., Nam, C., Min, J.W. (2007). Developing a decision model for BPO., *Computers & Operations Research* 34 : 3769-3778.

Zadeh, L.A. (1965). Fuzzy sets., *Information and Control* 8 : 338-353.

Zhao, Z.Y., Zhu, J., Zuo, J. (2014). Sustainable development of the wind power industry in a complex environment: a flexibility study., *Energy Policy* 75 : 392-397.

BIOGRAPHICAL SKETCH

Nazlı GÖKER was born in Istanbul on March 24, 1991. She studied at Galatasaray High School where she was graduated in 2010. She started her undergraduate studies at the Industrial Engineering Department of Galatasaray University in 2010. In 2014, she obtained the B.S. degree in Industrial Engineering as a second ranking graduate. Since December 2014, she has been working as a research assistant in Industrial Engineering Department of Galatasaray University. Currently, she is working towards master's degree in Industrial Engineering under the supervision of Prof. Dr. Y. Esra ALBAYRAK at the Institute of Science and Engineering, Galatasaray University.

She is the co-author of the research paper entitled "A Fuzzy Information-Based Approach for Breast Cancer Risk Factors Assessment", which is published in Applied Soft Computing, on January, 2016. She is also co-author of the papers whose titles are "Mağaza Yeri Seçimi Kriterlerinin Belirlenmesi ve Değerlendirilmesi: Çok Kriterli Karar Verme Yaklaşımı Uygulaması" and "An Application of Hybrid Multi Criteria Decision Making Approach for Personnel Selection in the Logistics Industry" which were presented at the Yöneylem Araştırması ve Endüstri Mühendisliği 35. Ulusal Kongresi, YAEM 2015, and 13th International Logistics & Supply Chain Congress, LMSCM 2015, respectively.