MARMARA UNIVERSITY

INSTITUTE FOR GRADUATE STUDIES
IN PURE AND APPLIED SCIENCES

MULTI-CRITERIA HOSPITAL SERVICE QUALITY EVALUATION AND ITS APPLICATION

MELTEM MUTLU

MASTER THESIS

Department of Industrial Engineering

Thesis Supervisor

Assoc. Prof. Dr. Gülfem TUZKAYA

Thesis CO- Supervisor

Assoc. Prof. Dr. Bahar SENNAROĞLU

ISTANBUL, 2018

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ACKNOWLEDGEMENT

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CONTENTS

ÖZET

ÇOK KRİTERLİ HASTANE HİZMET KALİTESİ DEĞERLENDİRME VE UYGULAMASI

Hizmet kalitesi ve müşteri memnuniyeti, işletmelere hizmet sektöründe sürdürülebilir rekabet avantajı sağlaması açısından önemli kavramlardır. Rekabetçi bir sektörde, şirketler hayatta kalabilmek için müşterilerine en iyi hizmeti sunmak zorundadırlar. Günümüzün küresel dünyasındaki şiddetli rekabet koşulları, sanayi kuruluşlarını olduğu gibi sağlık kuruluşlarını da derinden etkilemektedir. Hastane yönetimi, daha kaliteli hizmet sağlamak için hangi alanlarda eksiklikleri olduğunu tespit etmelidir.

Hastane yönetimi için hizmet kalitesinin doğru ölçülmesi önemli bir unsurdur. Bu nedenle hastanelerin hizmet kalitesinin, hastaların bakış açısından değerlendirilerek analiz edilmesi, kalite iyileştirmelerinde strateji geliştirmede yarar sağlar. Hizmet kalitesi ve müşteri memnuniyeti ölçümü belirsizlikler içerir. Fakat diğer metotlara göre bulanık metotları uygulamak insan düşüncesine daha yakındır. Bu nedenle bu çalışmanın amacı, bulanık çok kriterli karar verme kullanarak bir hastanenin beş polikliniğinin hizmet kalitesini değerlendiren ve karşılaştıran etkili bir yaklaşımı kalite iyileştirme faaliyetleri için hastane yönetimine yol göstermektir.

Anahtar Kelimeler: Çok Kriterli Karar Verme, Hizmet Kalitesi, IVIF-PROMETHEE, Hastane Hizmet Kalitesi

ABSTRACT

MULTI-CRITERIA HOSPITAL SERVICE QUALITY EVALUATION AND ITS APPLICATION

Service quality and customer satisfaction are very important concepts that provide companies sustainable competitive advantage in the service sector. In a competitive environment, companies have to deliver the best quality of service to its customers in order to survive. Fierce competition circumstances in today's global world influence industrial companies as well as the health care establishments deeply. Hospital management should determine in which area they have deficiencies in order to ensure better service quality.

Precise measurement of service quality is an important concern for hospital management. Therefore, analyzing the quality of health care services from patients' point of view provide benefits for a hospital. Measuring service quality and customer satisfaction is ambiguous. However, applying fuzzy methods rather than other methods are intimate for human thinking. Therefore, objective of this study is to propose an effective approach for evaluating and confronting service quality of five divisions in a hospital by fuzzy Multi-Criteria Decision Making in order to provide a guide to the hospital management for quality improvement activities.

Key Words: Multi-Criteria Decision Making, Service Quality, IVIF-PROMETHEE, Hospital Service Quality

SYMBOLS

$\tilde{A}$: Fuzzy Set

X : Criterion Set

X_b : Benefit Criteria

X_c : Cost Criteria

Z : Set of Decision Alternatives

M_A : Degree of membership of an element x to A

M_L : Lower Bound of Membership

M_U : Upper Bound of Membership

N_A : Degree of nonmembership of an element x to A

N_{AL} : Lower bound of non-membership

N_{AU} : Upper bound of non-membership

$\tilde{A}_{ij}$: Evaluative rating of alternative $z_i \in Z$ with respect to criterion $x_j \in X$

$\tilde{W}_j$: Importance weight of criterion x_j

$\tilde{A}_{\rho j}$: Evaluation value of the alternative z_p with respect to criterion $x_j \in X$

$h(\tilde{A}_{\rho j}, \tilde{A}_{\beta j})$: Intensity of the preference of $\tilde{A}_{\rho j}$ over $\tilde{A}_{\beta j}$

D : Difference between $p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j})$ and 0.5

$\Phi^+(z_i)$: Leaving flow of alternative $z_i \in Z$

$\Phi^-(z_i)$: Entering flow of alternative $z_i \in Z$

$S(\Phi^+(z_i))$: Score function of the leaving flow $\Phi^+(z_i)$

$S(\Phi^-(z_i))$: Score function of the entering flow $\Phi^-(z_i)$

$H(\Phi^{+}(z_i))$: The accuracy function of the leaving flow $\Phi^{+}(z_i)$

$H(\Phi^{-}(z_i))$: The accuracy function of the entering flow $\Phi^{-}(z_i)$

μ_{ij} : Interval of the membership degree

v_{ij} : Interval of non-membership degree

w_j : Interval of importance degree of criterion x_j

ABBREVIATIONS

MCDM : Multi-Criteria Decision Making

QFD : Quality Function Deployment

AHP : Analytic Hierarchy Process

TOPSIS : Technique for Order Preference by Similarity to Ideal Solution

VIKOR : Vısekriterijumska Optimizacija i Kompromisno Resenje

PROMETHEE : Preference Ranking Organisation Method for Enrichment Evaluation

ELECTRE : Elimination and Choice Translating Reality

SQ : Service Quality

TQM : Total Quality Management

EFA : Exploratory Factor Analysis

ICT : Information and Communication

DEA : Data Envelopment Analysis

DEMATEL : Decision-Making Trial and Evaluation Laboratory

MUSA : Multi-Criteria Satisfaction Analysis

FAHP : Fuzzy Analytical Hierarchy Process

ANP : Analytic Network Process

BSC : Balanced Score Card

PEM : Performance Evaluation Matrix

HFMEA : Healthcare Failure Mode and Effects Analysis

FMEA : Failure Mode and Effects Analysis

NCPS : National Center for Patient Safety

IFS : Intuitionistic Fuzzy Sets

FSs : Fuzzy Sets

IVFS : Interval-Valued Fuzzy Sets

MCDA : Multiple-Criteria Decision Analysis

IVIFN : Interval-Valued Intuitionistic Fuzzy Numbers

GAIA : Geometrical Analysis for Interactive Aid

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1. INTRODUCTION

In a globalizing world with increasing competitive conditions, companies make an intensive effort to gain competitive advantage against each other and to increase their efficiency in the service sector. In order to be efficient in the service sector companies have to provide qualified service and to enhance the satisfaction of services received. The increasing of service sector share in the world - wide production and understanding the importance of customer satisfaction effect on customer loyalty cause companies to attempt improving service quality.

Nowadays, the importance of cost, changing customer attitudes and tight competition has increased the importance of service quality in healthcare enterprises as in other businesses. In today's competitive and cost-effective market, it is very important for healthcare institution to gain competitive advantage and to measure and evaluate the service quality for their continuity. The most important indicator of service quality is patient satisfaction for healthcare institutions. It is important to provide patients with service that meet or exceed their expectation to be successful in healthcare industry. Healthcare institutions have to consider determining factors related to patient satisfaction such as how the service quality is perceived by patients, how and when service quality should be improved. Hospital managers and employees should use the information they will obtain by measuring the perceptions of patients while protecting and improving the service quality they provide. The information gained from the patients' perceptions and opinions allow to determine the strentgs and weaknesses of the hospitals, the level of satisfaction of the patients' needs. Continuous control on patient perceptions and improvements based on patient feedback will enhance the quality of health care and patient satisfaction degree.

Evaluation of hospital service quality evaluation process is complex and contains multiple criteria, qualitative and uncertain factors that are difficult to evaluate. There is major association between service quality dimensions and patient satisfaction. In order to cope with and solve vagueness related to human judgements, Multi-criteria Decision Making Models (MCDM) have been presented. Due to its several qualitative and quantitative criteria, The Multi-Criteria Decision Making (MCDM) methodologies are applicable for evaluating the hospital service quality. Service quality could be evaluated by different approaches such as statistical approaches, Quality Function Deployment(QFD), Analytic Hierarchy Process, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), VIKOR (Vısekriterijumska Optimizacija i Kompromisno Resenje), Preference Ranking Organisation Method for Enrichment Evaluation (PROMETHEE), Elimination and Choice Translating Reality (ELECTRE) and AnalyticNetwork Process (AHP). In this study, a systematic review of MCDM techniques used in the evaluation of healthcare service quality is presented. This literature review identified a substantial body of literature on the implementation of MCDM approaches and approaches used to address service quality problems. Several studies in literature evaluate service quality of different industries.

This thesis focuses on proposing a ranking method for five divisions of a selected hospital in İstanbul using IVIF-PROMETHEE and service quality evaluation. Considering the behavioral, technical, time dependent and physical conditions criteria, hospital quality of five divisions of a public hospital in Istanbul are evaluated. In order to measure service quality of divisions, patients fill a questionnaire for each divisions. According to survey results, preference functions results and the global preference indices are obtained. Finally, the scores of each division are found.

2. LITERATURE REVIEW

2.1. Methodology of Literature Review

This section describes the methodology to identify, and clarify the literature on healthcare service quality evaluation by using MCDM methodology. 42 papers are reviewed in proceedings and journals. The classification of the reviewed papers is made with respect to some characteristics such as year of publication, method, country of origin, aim of the study and evaluation area. A literature search in the SCOPUS, ScienceDirect, Taylor&Francis, Ebsco, Web of Knowledge, and Google Scholar databases was implemented between 2005 and 2016 using the following search terms: ("multi-criteria" and "healthcare service quality"), ("fuzzy" and "multi-criteria" and "healthcare service quality”), ("hospital service quality" and "multi-criteria decision making") and ("SERVQUAL" and "multi-criteria" and "healthcare"). In order to gather all relevant papers, a seven-step selection procedure was implemented in this review as shown in Figure 2.1.

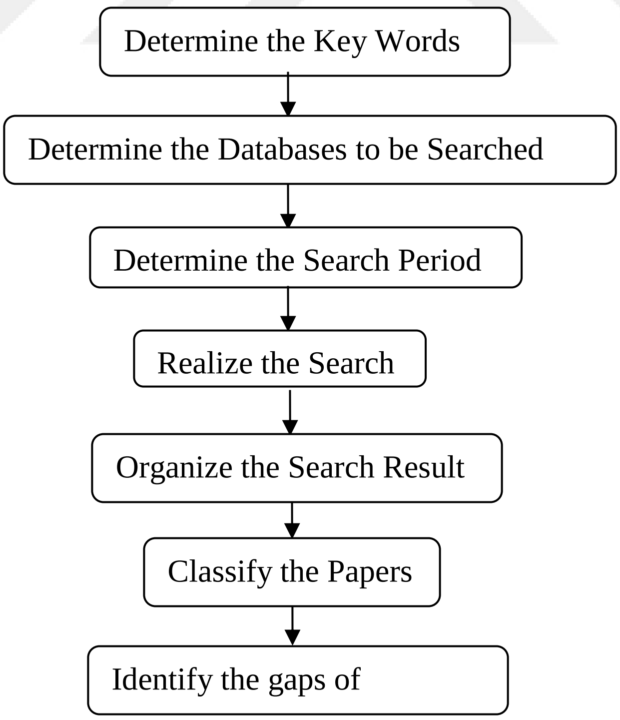


Figure 2.1. Literature Review Process

The first step of literature process is to determine the keywords for the search in the databases. After identifying the keywords, next step is to determine the databases to be searched. The number of papers found relevant is presented in Table 2.1. The last part of this process is the classification of the papers.

Table 2.1. The number of papers

	"multi-criteria" and "healthcare service quality"	"fuzzy" and "multi-criteria" and "healthcare service quality”	"hospital service quality" and "multi-criteria decision making"	"SERVQUAL" and "multi-criteria" and "healthcare"
Science Direct	6	5	6	12
Taylor&Francis	7	140	0	28
Ebsco	17	17	183	17
Web of Knowledge	0	1	2	0
Scopus	1	0	3	1
Google Scholar	163	144	145	257

An extensive search for appropriate English-language literature was applied using six popular publication databases and indexing services. Table 2.1. indicates the keywords and the number of papers that are searched in several databases. After the search of papers in databases, papers are examined and eliminated by checking whether it is related with the subject or not. Papers are excluded that are not based on the evaluation of healthcare service quality.

The steadily growing amount of literature on service quality in healthcare covers a variety of interpretations and implementations. This study is composed of the literature that has papers with MCDM techniques. There exists several papers which includes different techniques except of MCDM for the healthcare service quality evaluation. Womack et al. (2005) suggest how to implement lean thinking to health care along with case example of Seattle’s Virginia Mason Medical Center. Zidel (2006) introduces lean principles, basic lean tools and implementations of these tools for health care industry. Grove et al. (2010) provide challenges faces during lean implementation from UK hospitals. Torres and Guo (2004) state three approaches to make healthcare quality improvement to provide patient satisfaction. These approaches are measuring patient perspective, evolving patient outcomes and using Six Sigma approach.

According to our knowledge, for healthcare quality literature, there exists two literature review studies. Talib and Rahman (2015) present a literature review that contains various aspects belongs to healthcare quality. Classification is applied for different categories such as quality of healthcare, studies on Indian healthcare system, service quality in healthcare, improvement and application of SERVQUAL. The review focuses on the papers that includes methods of SERVQUAL, total quality management (TQM), MCDM, and exploratory factor analysis (EFA). Mardani et al. (2015) investigate the papers that applied MCDM in different industries such as tourism and hospitality, airline, healthcare, transportation, manufacturing, banking and education. In the study, articles classified into the titles of author, year, application area, the nationality of the author, technique, the number of criteria, research purpose, gap and research problem, results and outcome. Considering only the service quality evaluation in healthcare industry, according to their findings, previously used techniques are statistical approaches, multi-criteria satisfaction analysis for benchmarking analysis, AHP, VIKOR, fuzzy AHP, PROMETHEE, and TOPSIS.

The MCDM papers in literature are classified into three categories. These categories are individual techniques with crisp data, fuzzy individual techniques with fuzzy data and integrated techniques.

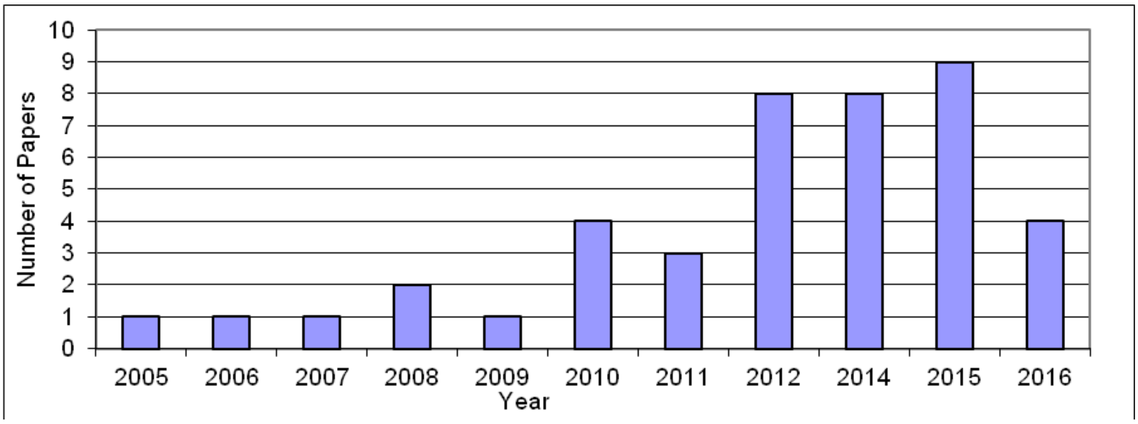


Figure 2.2. Distribution of Healthcare Service Quality Evaluation Papers by Publication Year

Figure 2.2. presents the number of papers reviewed on MCDM in hospital service quality between 2005 and 2016. In 2015, the number of published papers reaches their highest level with nine papers. On the other hand, in 2005, 2006, 2007 and 2009 they are at the minimum with one paper.

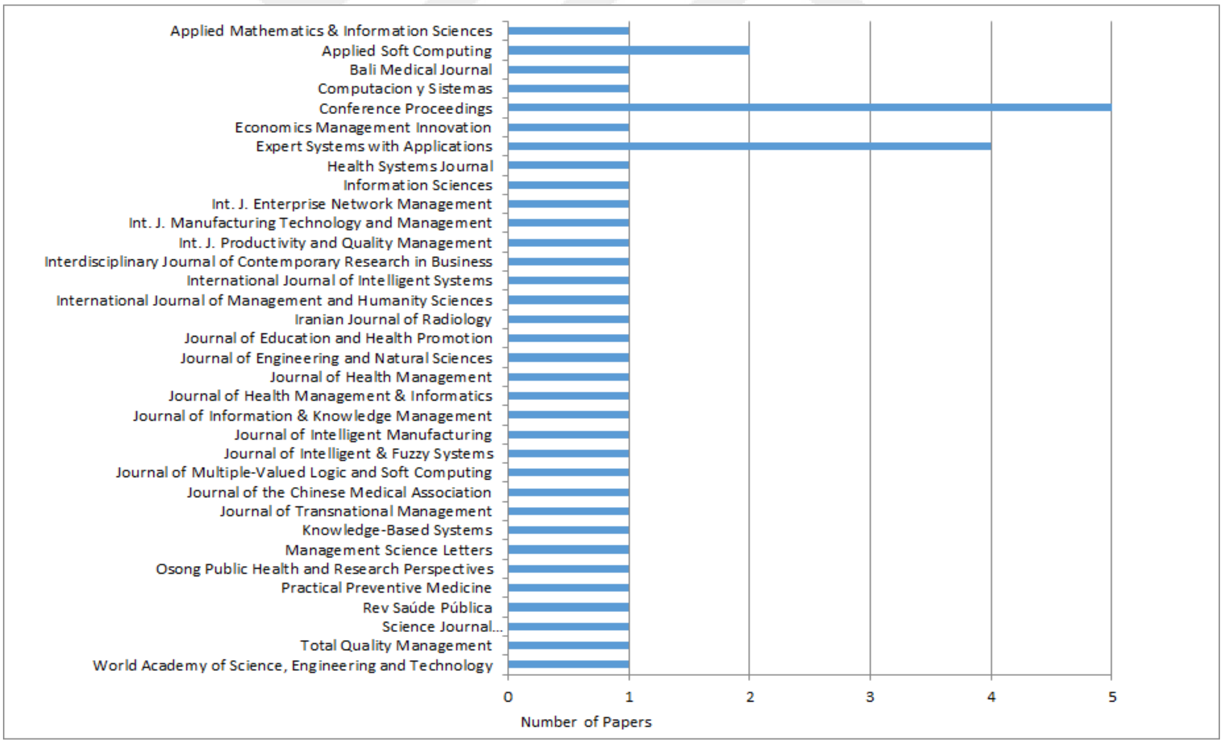


Figure 2.3. Distribution of Healthcare Service Quality Evaluation Papers by Publication Name

The number of papers reviewed about healthcare service quality evaluation in different sources are shown in Figure 2.3. As it can be observed there is not a specific journal which focuses on this subject.

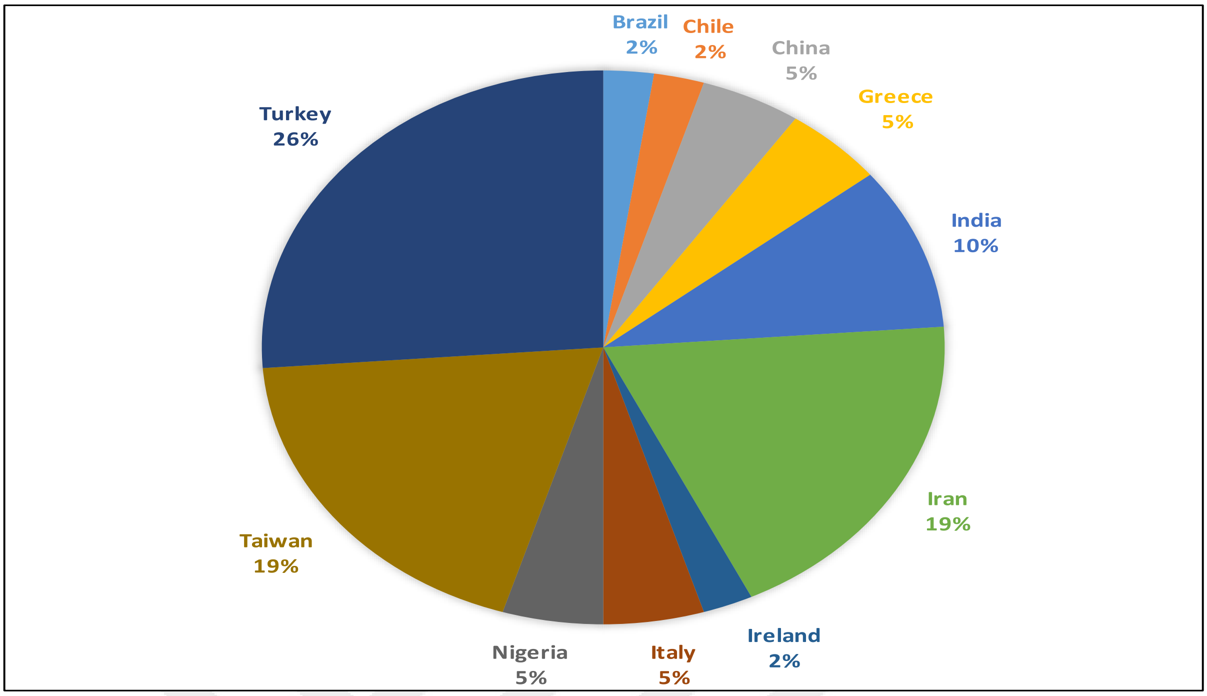


Figure 2.4. Percentage of Papers by Country of Origin

The percentages of papers by country of origin are shown in Figure 2.4. The highest percentage of 26% belongs to Turkey followed by Iran with and Taiwan with 19%.

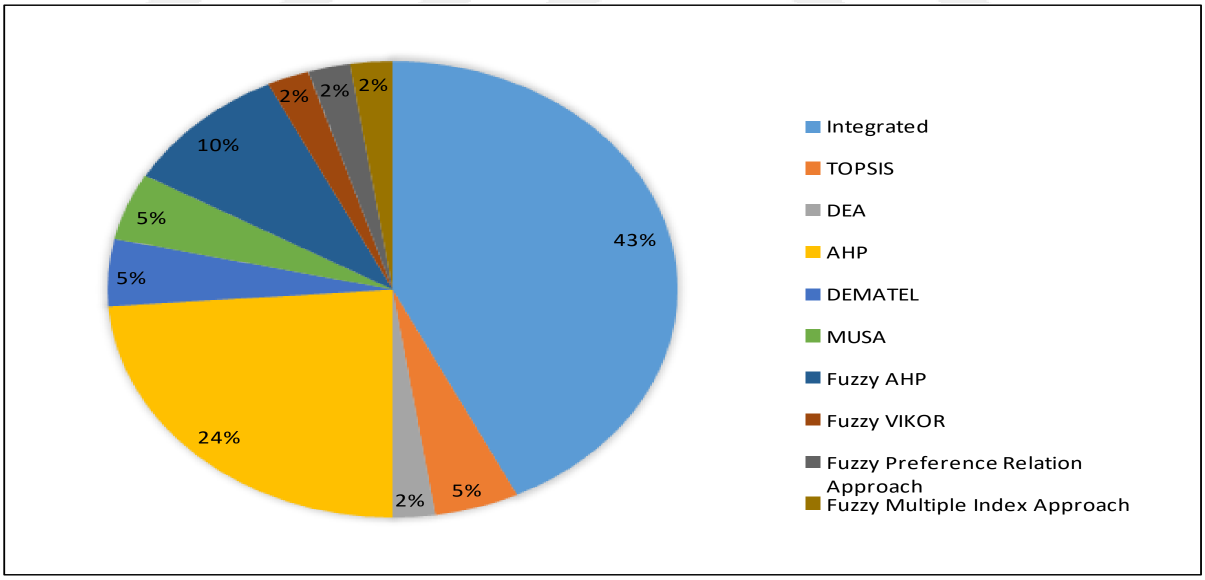


Figure 2.5. Distribution of Healthcare Service Quality Evaluation Papers by MCDM Methods

Figure 2.5. shows the percentage of MCDM methods used in reviewed papers. It is noted that AHP (24%) and fuzzy AHP (10%) receive more interests than the other methods.

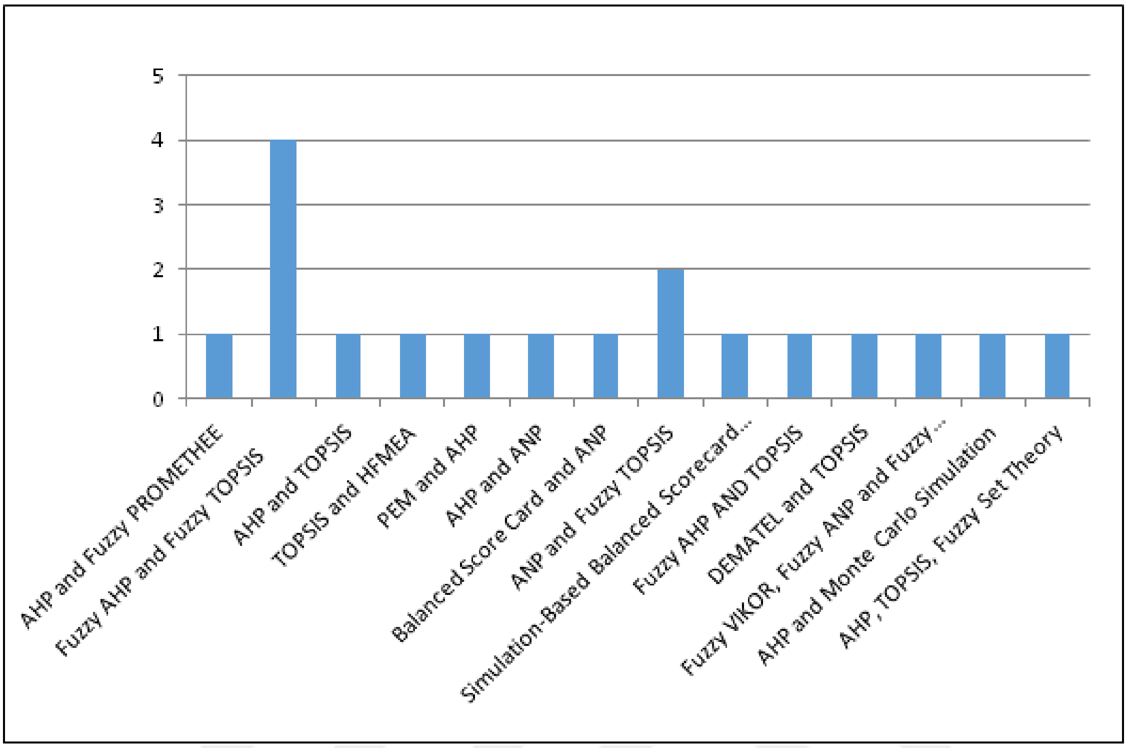


Figure 2.6. Integrated Techniques with Fuzzy Data

Integrated techniques with fuzzy data are shown in Figure 2.6. It is observed that the number of articles containing integration of fuzzy AHP and fuzzy TOPSIS is greater than the others.

2.2. Individual Techniques with Crisp Data

AHP is used for estimation of patients' satisfaction towards service delivery in six public teaching hospitals by applying cross-sectional survey research design (Zhang et al., 2007). Standards of departments are compared to each other by using comparison matrix and they are ranked by AHP. Herrera et al. (2008). Zaim et al. (2008) propose a study to evaluate the efficiency of twelve hospitals in Turkey by applying DEA technique. Additionally, DEMATEL is applied for demonstrating the degree of influence of factors and observing the relationship among the factors based on a cause-effect diagram. Khan et al. (2010) evaluate three hospitals from the southern region of India by using SERVQUAL. As a decision making methodology, AHP is used for evaluating the three hospitals based on the selected criteria and subcriteria. Shieh et al. (2010) implement

SERVQUAL model to identify seven main criteria from the viewpoints of patients in a hospital in Taiwan. DEMATEL method is applied to the management of hospital to prioritize the importance of criteria. Chang (2011) determines service quality of four public hospitals by fuzzy preference relation approach using the criteria of hospital environment, service attitude, pharmacy treatment, professional capability, administrative policy. AHP method is used for the analyzing the quality of services offered by healthcare service providers (Wollman et al., 2012). Khan et al. (2012) use AHP and SERVQUAL methodologies based on the selected criteria ans sub-criteria in order to rank the best service quality offered by the five corporate hospitals. TOPSIS method was conducted to evaluate the quality of hospital medical services including 18 departments of hospital. Bahadori et al. (2014) rank military hospitals in Iran according to the Joint Commission International (JCI) standards by using AHP. SERVQUAL criteria are used for evaluating the quality of hospital services in their study. Basu and Bhola (2014) evaluate the service quality dimensions in IT healthcare ventures from Indian context. As a linear programming based technique, Data Envelopment Analysis (DEA) method is implemented to measure the relative efficiency and relative performance of organizational units. Patients satisfaction is evaluated and solutions are proposed by Manolitzas et al. (2014). Multi-criteria Satisfaction Analysis (MUSA) methodology is used to measure and analyze the customer satisfaction and this methodology reveals the level of the patient satisfaction.

Alimohammadzadeh et al. (2015) propose a methodology to rank radiology departments in 6 hospitals in Tehran city by applying (AHP). Aktas et al. (2015) used AHP in order to provide a scientific basis for classification of three Turkish hospitals.

2.3. Fuzzy Individual Techniques with Fuzzy Data

The fuzzy AHP approach is implemented in various MCDM techniques for evaluation of service quality in healthcare. Buyukozkan et al. (2011) apply fuzzy AHP to evaluate the proposed service quality structure of four hospitals in Turkey. This study finds out the best healthcare service quality performance among the alternatives by using SERVQUAL. Ho (2012) adopted Fuzzy Analytic Hierarchy Process (FAHP) approach to make weight assessment on evaluation indexes of Health Management Center. The research investigates the health examination institutions and demands of their customers for Health Management Center and provides recommendation concerning progress and future operating of Health Management Center in the current market. Sinimole (2012) develops a fuzzy AHP model to evaluate service quality of four hospitals in India. SERVQUAL scale is used for the evaluation of hospitals. In addition to these studies, Lupo (2016) applies fuzzy AHP method to assess service quality of nine relevant public hospitals by focusing on the criteria of healthcare staff, responsiveness, relationships and support services. Another method that is used to evaluate service quality under a fuzzy environment is VIKOR. Chang (2014) evaluates hospital service by means of VIKOR where uncertainty, subjectivity and ambiguity are addressed with linguistic variables. The aim of this study is to use a combined multi-criteria technique which includes fuzzy set theory and VIKOR to evaluate a set of feasible hospitals in an attempt to obtain the best hospital that satisfies the expectations of patients. Taskin et al. (2015) use fuzzy DEMATEL approach for deriving interaction among the main criteria, fuzzy ANP for finding weights of the sub-criteria and VIKOR method for evaluating service quality performance of hospitals. Patient satisfaction, education and research, institution, administrative policy, financial aspects and infrastructure are considered as main criteria.

2.4. Integrated Techniques

Altuntas et al. (2012) apply AHP and ANP with SERVQUAL technique to analyze perceived service quality in Turkish hospitals. The most important service quality dimensions are empathy, knowledge of personnel, trustworthy of personnel, services provided at the required time and safe feeling of patients with hospital personnel. Hojati et al. (2012) prioritize the dimensions of surgery department service quality of a hospital by using ANP with the method of Balanced Score Card (BSC) which is one of the main performance measurement frameworks that operate strategy-linked leading performance measures. The Performance Evaluation Matrix (PEM) is proposed by Lambert & Sharma, (1990) which as applied as a strategy to make performance measurement and to establish best strategy for improving service quality. Chen and Yeh (2015) aim to integrate the PEM and AHP methods in order to identify and prioritize areas of improvement in service quality. The aim of the research is to propose the methods to evaluate service quality, and then identify hospitals to state the elements that require service improvement. Khanjankhani et al. (2016) apply DEMATEL technique to determine cause and effect relationships between identified service quality aspects of three hospitals and TOPSIS to rank these hospitals. The Healthcare Failure Mode and Effects Analysis HFMEA methodology is an adaptation of the Failure Mode and Effects Analysis (FMEA) method developed by the Department of Veterans Affairs' National Center for Patient Safety (NCPS) to identify and avoid the potential errors in healthcare. Kuo et al. (2012) apply TOPSIS to rank the severity of failure modes and HFMEA to find the effect of geriatric outpatient service process failures on elderly patients.

Buyukozkan and Cifci (2010) study electronic service quality analysis of healthcare industry in Turkey by implementing an integrated multi-criteria decision making technique. SERVQUAL methodology is applied for the electronic service quality concept. Combined fuzzy AHP and fuzzy TOPSIS methods are included in the study in order to measure electronic service quality of thirteen hospital web sites. Buyukozkan and Cifci (2012) consider healthcare service quality evaluation as a multi-criteria decision making problem and provide a new approach based on an integrated multi-criteria decision making approach consist of AHP to calculate criteria weights and TOPSIS to rank alternatives in an uncertain environment. The model is implemented in Turkish hospitals and accuracy of proposed framework is evaluated. Hamidi et al. (2014) apply the fuzzy MCDM techniques to evaluate electronic service quality of hospitals like AHP, TOPSIS, etc. Afkham et al. (2011) evaluate and compare service quality of four hospitals in Iran by applying methodologies of AHP and fuzzy TOPSIS. SERVQUAL and DEMATEL methods are used to display the most significant service quality dimension by means of patients' perspective and to decide on which criteria to be focused in accomplishing the service quality, respectively (Gul et al., 2014). Lee et al. (2010) evaluate the four online auctions service quality to offer a solution with multiple criteria evaluation by the methods of AHP, Fuzzy set theory and TOPSIS. Mirbargkar and Zadmehr (2015) integrate the methods of ANP and fuzzy TOPSIS to select the most convenient hospital in terms of electronic services. Criteria of the study are designed based on the six dimensions of SERVQUAL which are tangibility, responsiveness, reliability, quality of information, assurance and empathy.

3. MATHEMATICAL BACKGROUND

3.1. Fuzzy Sets

The fuzzy sets theory was proposed by Zadeh (1965) in order to handle different problems related with vagueness to originate more from actual ambiguity than probability theory. The fuzzy sets theory is the source for the development of the linguistic approach (Zadeh, 1975).

A Fuzzy Set $\tilde{A}$ in X can be mathematically expressed as in Eq (1):

$$\tilde{A} = \{(x, \mu_{\tilde{A}}(x) \mid x \in X)\} \quad (1)$$

Where $\mu_A : X \rightarrow [0,1]$ is the membership function of Fuzzy Set A Membership degree of the element x to the set $\tilde{A}$ is $\mu_{\tilde{A}}(x) \in [0,1]$.

3.2. Intuitionistic Fuzzy Sets

Intuitionistic fuzzy sets (IFS) was initially presented by Atanassov which is an advanced adaptation of fuzzy sets (FSs) in 1986 (Atanassov, 1986). Fuzzy set theory states uncertainty with the contribution of a membership function (Zadeh, 1965). Distinct from the standard FSs, in the IFSs, a membership degree, a nonmembership degree, and also a hesitancy degree is applied to express it (Atanassov, 1986). IFSs are convenient for solving the problem of deficient information. They are useful to elaborate uncertainty and vagueness. Some researches which can be referenced for IFSs are proposed by Chen (2009), Liu and Wang (2007) and Zhang and Xu (2012). Because of its aspect, there exits many studies that interested in IFS theory and applied to the decision making area. In the extended version, Atanassov (1986) inserted a second degree (a degree of non-membership) to the fuzzy set to establish IFSs.

An Intuitionistic Fuzzy Set $\tilde{A}$ in X can be mathematically symbolized as in Eq (2):

$$\tilde{A} = \{(x, \mu_{\tilde{A}}(x), v_{\tilde{A}}(x)) \mid x \in X)\} \quad (2)$$

Where the functions $\mu_A : X \rightarrow [0,1]$ and $v_A : X \rightarrow [0,1]$

with the condition $0 \leq \mu_A(x) + \nu_A(x) \leq 1, \forall x \in X$. For each *x*, the degree of membership is denoted by $\mu_A(x) \in [0,1]$ and degree of non-membership is denoted by $\nu_A(x) \in [0,1]$. The hesitancy degree in intuitionistic fuzzy sets is indicated by Eq (3), which displays the hesitance to the membership of *x* to *A*.

$$\pi_A(x) = 1 - (\mu_A(x) + \nu_A(x)) \quad (3)$$

3.3. Interval Valued Fuzzy Sets

Interval-valued fuzzy sets were proposed by Zadeh (1975) as extensions of Zadeh (1965)'s fuzzy set theory. IVFSs can be considered as a form of type-2 fuzzy sets (Mendel and John, 2002; John, 1998). In interval-valued fuzzy sets (IVFSs), membership degree of each element is represented by a closed subinterval of the interval [0, 1]. It is convenient to display the degree of membership by an interval rather than a single number. IVFSs provide more sufficient definition of uncertainty than traditional fuzzy sets. Since it is useful to handle uncertainty, many studies are created. Guijun and Xiaoping (1998) establish interval-valued fuzzy numbers and interval-distributed numbers. Method for interval-valued fuzzy reasoning is presented based on compatibility measure (Gorzalczany, 1987). Deschrijver (2007) present some arithmetic operators for IVFSs. Vlachos and Sergiadis (2007) build a combined structure that contains the notions of subsets, entropy, and cardinality for IVFSs.

An Interval Valued Fuzzy Set $\tilde{A}$ in *X* can be mathematically symbolized by Eq (4):

$$\tilde{A} = \{(x, M_A(x)) \mid x \in X\} \quad (4)$$

where the function $M_A : X \rightarrow D[0,1]$ represents the degree of membership of an element *x* to *A*.

Let $M = [M_L, M_U] \in D[0,1]$ where M_L indicates lower bound and M_U indicates upper bound.

3.4. Interval Valued Intuitionistic Fuzzy Sets

Atanassov and Gargov (1989) presented the IVIFSs approach which contains closed interval for membership and non-membership because of identifying the membership degree and the non-membership degree as exact values, and estimating their ranges is not easy for IFSs. They define a membership function and non-membership function by applying interval values instead of exact numbers. IVIFSs are a further generalized version of IFSs (Atanassov and Gargov, 1989). IVIFSs are more precision and certain in displaying vagueness of things. They can better deal with hesitancy and vagueness in describing membership functions. Xu (2007) presented the concept of IVIF numbers and proposed some procedures to be applied with IVIF numbers. IVIF sets are better than conventional fuzzy sets at dealing with vagueness. Chai and Liu (2010) applied a ranking method, which is an extention of the PROMETHEE technique, and intuitionistic fuzzy aggregation operators to analyze ambiguity MCDA issues. In a similar manner, Chai et al. (2012) proposed an intuitionistic fuzzy superiority and inferiority ranking method and paid attention on its implementation to supplier selection. Nevertheless, little attention has been paid to the improvement of PROMETHEE approaches in the IVIFS term. In this respect, this thesis aims to evolve IVIF-PROMETHEE outranking models and methods for addressing vagueness and evaluating presedence orders of alternatives. Eq (5) represents Interval-Valued Intuitionistic Fuzzy Set A.

$$\tilde{A} = \{(x, M_A(x), N_A(x)) \mid x \in X\} \tag{5}$$

where the functions $M_A : X$ and $N_A : X$ represents the degree of membership and the degree of non-membership respectively,

$$0 \le \sup(M_A(x)) + \sup(N_A(x)) \le 1, \forall x \in X.$$

$M_A(x) = [M_{AL}(x), M_{AU}(x)]$ and $N_A(x) = [N_{AL}(x), N_{AU}(x)]$ for all $x \in X$. Therefore, $A = ([M_{AL}(x), M_{AU}(x)], [N_{AL}(x), N_{AU}(x)])$.

3.5. IVIF-PROMETHEE Method

PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) method is developed in order to implement easily and effectively in the solution of MCDM problems. PROMETHEE is a type of MCDM method improved by Brans

(1982), further extended by Brans and Vincke (1985) and Brans and Mareschal (1994). PROMETHEE is an outranking method that applies partial aggregation. It is convenient when the number of alternative to rank is finite. Because of the various criteria, chosing the alternatives is very difficult during the decision-making process. Therefore, it is possible to use the PROMETHEE method which is an easy and understandable method in the decision making process. In the literature, PROMETHEE method seems to be mainly used to solve the problems in various fields such as environmental management, hydrology and water management, business and financial management, chemistry, logistics and transportation, production, energy management and social sciences. Araz and Ozkarahan (2005) presented a main framework based on the PROMETHEE method for financial classification problems. PROMETHEE method was used to evaluate the companies in the agricultural sector based on financial criteria (Baourakis et al., 2002). Maragoudaki and Tsakiri (2005) suggested the PROMETHEE method to simplify the selection process of flood problems and alternative practices of reducing as much as possible damages caused by these problems. Amponsah et al. (2012) determined a preference function for performance data in their work. With this preference function, national telecommunication data is used. They determine the PROMETHEE method and the Gaussian preference function is also in the same order. Queiruga et al. (2008) apply this method to rank Spanish municipalities with respect to their suitability with the installation of waste recycling plants. Ni et al. (2002) applied PROMETHEE and geometrical analysis for interactive aid (GAIA) together with Chemometricsmethods, to rank various calibration models in food samples. Lim et al. (2007) performed PROMETHEE II ranking of the emissions from the cars in terms of the types of the fuels. PROMETHEE method is also extended by fuzzy set like other MCDM methods to overcome the uncertainty established by vague situations. Ho (2006) integrates the fuzzy set theory and PROMETHEE method and proposes the Fuzzy PROMETHEE. Chen et al. (2011) use fuzzy PROMETHEE to rank alternative suppliers for information systems outsourcing by adopting triangular fuzzy number. Elevli (2014) uses fuzzy PROMETHEE to represent uncertain information in order to select logistics center location. Dadzie et al. (2015) use fuzzy PROMETHEE for the selection of start-up businesses in a highly uncertain field such as venture capital schemes. PROMETHEE includes outranking methods of PROMETHEE I for partial ranking of alternatives and

PROMETHEE II for complete ranking of alternatives. PROMETHEE I can be used to get the partial rankings by computing the positive and negative outranking flow; the two flow values do not generally give the same rankings. In the PROMETHEE II method, alternatives are ranked completely based on pairwise comparisons, however PROMETHEE can only give partial ranking of alternatives. Since the decision maker constantly requests full

ranking, PROMETHEE II can be appropriately utilized for the evaluation. In the following, this study improves the IVIF PROMETHEE I and IVIF-PROMETHEE II ranking operations to define the partial and full rankings, respectively, of the alternatives for MCDA.

Steps of IVIF-PROMETHEE I can be summarized as following steps (Chen, 2015):

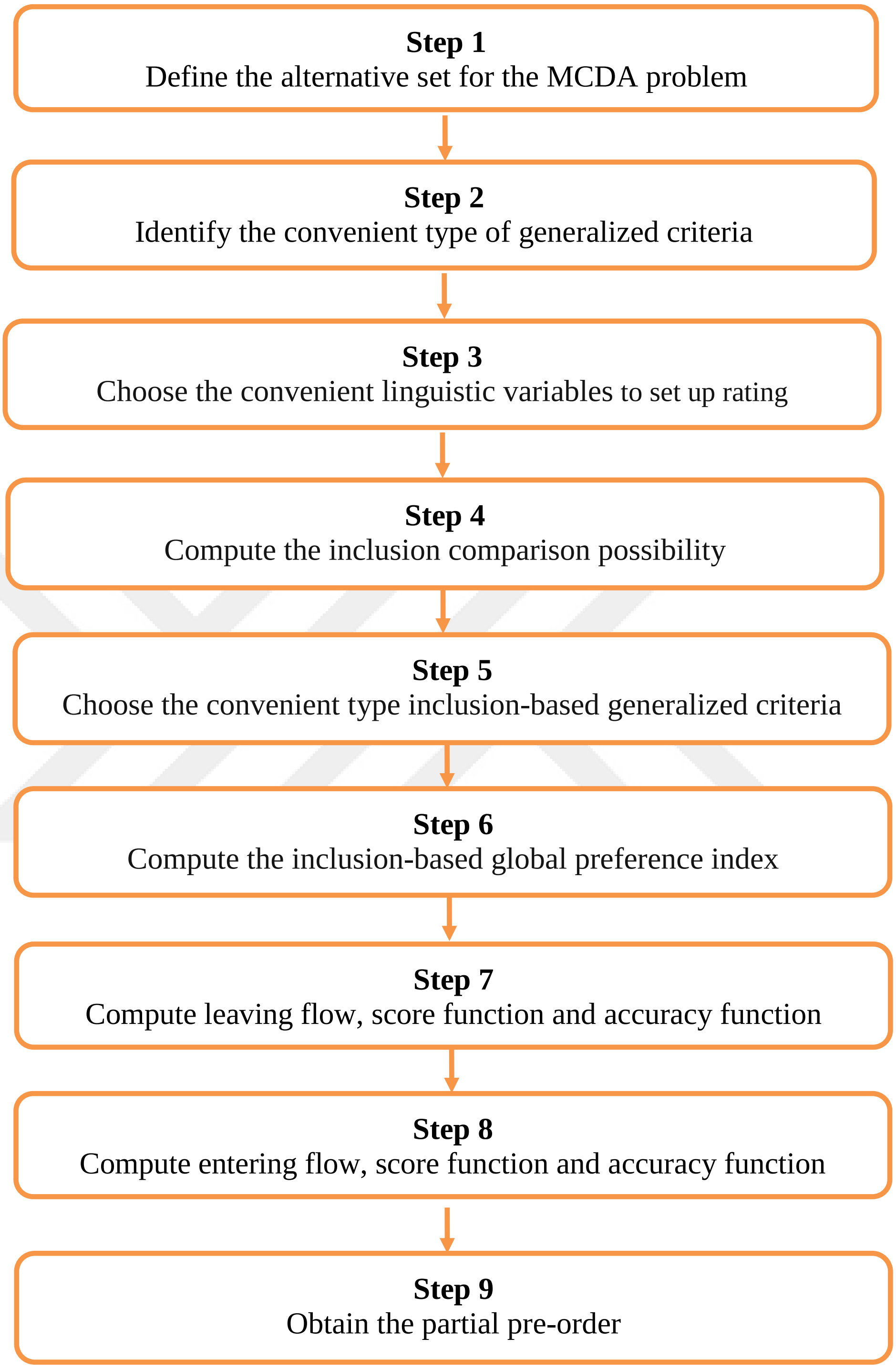


Figure 3.1. IVIF-PROMETHEE I Steps

The alternative set $Z=\{z_1, z_2,\ldots,z_m\}$ is defined for the MCDA problem and the criterion set $X=\{x_1, x_2,\ldots,x_n\}$ which is divided into (X_b) and (X_c). (X_b) and (X_c) represents benefit criteria set and cost criteria set respectively (Step1). The convenient type of common criteria is defined for each $x_j \in X$. Then, the decision maker is informed to identify suitable parameters such as indifference threshold *q*, preference threshold *p*, standard deviation σ of a normal distribution. In order to set up IVIFS rating $\tilde{A}_{ij}$ for criterion $xj \in X$ (Eq.6). the convenient linguistic variables or other data collection tools are selected and weigh $\tilde{W}_j$ is assigned for criterion $x_j \in X$ for alternative $zi \in Z$ (Eq.7).

$$\tilde{A}_{ij} = (\mu_{ij}, \nu_{ij}) = ([\mu_{ij}^-, \mu_{ij}^+], [\nu_{ij}^-, \nu_{ij}^+]) \tag{6}$$

$$\tilde{W}_j(\omega_j, \varpi_j) = ([\omega_j^-, \omega_j^+], [\varpi_j^-, \varpi_j^+]) \tag{7}$$

Next, for each criterion $x_j \in X$ and for each pair of alternatives (z_ρ, z_β) where $z_\rho, z_\beta \in Z$ the inclusion comparison possibility $p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j})$ is computed (Eq.8).

$$\begin{aligned}
&\boldsymbol{p}(\tilde{\boldsymbol{A}}_{\rho j} \supseteq \tilde{\boldsymbol{A}}_{\beta j}) = \frac{1}{2}\left(\boldsymbol{p}^-(\tilde{\boldsymbol{A}}_{\rho j} \supseteq \tilde{\boldsymbol{A}}_{\beta j}) + \boldsymbol{p}^+(\tilde{\boldsymbol{A}}_{\rho j} \supseteq \tilde{\boldsymbol{A}}_{\beta j})\right)\\
&\boldsymbol{p}^-(\tilde{\boldsymbol{A}}_{\rho j} \supseteq \tilde{\boldsymbol{A}}_{\beta j}) = \max\left\{1 - \max\left\{\frac{(1-\nu_{\beta j}^-) - \mu_{\rho j}^-}{(1-\mu_{\rho j}^- - \nu_{\rho j}^+) + (1-\mu_{\beta j}^+ - \nu_{\beta j}^-)}, 0\right\}, 0\right\}\\
&\boldsymbol{p}^+(\tilde{\boldsymbol{A}}_{\rho j} \supseteq \tilde{\boldsymbol{A}}_{\beta j}) = \max\left\{1 - \max\left\{\frac{(1-\nu_{\beta j}^+) - \mu_{\rho j}^+}{(1-\mu_{\rho j}^+ - \nu_{\rho j}^-) + (1-\mu_{\beta j}^- - \nu_{\beta j}^+)}, 0\right\}, 0\right\}
\end{aligned} \tag{8}$$

The convenient type inclusion-based generalized criterion type is chosen to compute the preference function $h(\tilde{A}_{\rho j}, \tilde{A}_{\beta j})$ for each alternative pair (z_ρ, z_β) for each criterion $x_j \in X$ (Eq.9).

The preference function $h(\tilde{A}_{\rho j}, \tilde{A}_{\beta j})$ can be found as a function of difference between $p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j})$ and 0.5. Let,

$$D = \begin{cases} p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) - 0.5 \text{ if } x_j \in X_b, \\ 0.5 - p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) \text{ if } x_j \in X_c, \end{cases} \tag{9}$$

$$h(\tilde{A}_{\rho j}, \tilde{A}_{\beta j}) = \begin{cases} \Psi(D) & \text{if } D \geq 0, \\ 0 & \text{if } D < 0. \end{cases} \tag{10}$$

Next step is to calculate the inclusion-based global preference index $\hbar((z_\rho, z_\beta)$ for each alternative pair (z_ρ, z_β) considering criterion importance $\tilde{W}_j$ of each criterion $x_j \in X$ (Eq.11).

$$\hbar(z_\rho, z_\beta) = \sum_{j=1}^{n} h(\tilde{A}_{\rho j}, \tilde{A}_{\beta j}) \cdot \left([\omega_j^-, \omega_j^+], [\varpi_j^-, \varpi_j^+]\right) = \left([\bar{h}_{\rho\beta}^-, \bar{h}_{\rho\beta}^+], [\underline{h}_{\rho\beta}^-, \underline{h}_{\rho\beta}^+]\right) \tag{11}$$

where $\bar{h}_{\rho\beta}^- = 1 - \prod_{j=1}^{n} (1-\omega_j^-)^{h(\tilde{A}_{\rho j}, \tilde{A}_{\beta j})}$, $\bar{h}_{\rho\beta}^+ = 1 - \prod_{j=1}^{n} (1-\omega_j^+)^{h(\tilde{A}_{\rho j}, \tilde{A}_{\beta j})}$, $\underline{h}_{\rho\beta}^- = \prod_{j=1}^{n} (\varpi_j^-)^{h(\tilde{A}_{\rho j}, \tilde{A}_{\beta j})}$ (12)

and $\underline{h}_{\rho\beta}^+ = \prod_{j=1}^{n} (\varpi_j^+)^{h(\tilde{A}_{\rho j}, \tilde{A}_{\beta j})}$ (13)

In order to compute the leaving flow $\Phi^+(z_i)$ for alternative $z_i \in Z$, apply (Eq.14). After that, calculate the score function $S(\Phi^+(z_i))$ (Eq.15) and the accuracy function $H(\Phi^+(z_i))$ (Eq.16) for $z_i \in Z$.

$$\boldsymbol{\Phi^+(z_i) = \sum_{\beta=1,\beta\neq i}^{m} \eta(z_i, z_\beta) = \left(\left[1 - \prod_{\beta=1,\beta\neq i}^{m} (1-\bar{h}_{i\beta}^-), 1 - \prod_{\beta=1,\beta\neq i}^{m} (1-\bar{h}_{i\beta}^+)\right], \left[\prod_{\beta=1,\beta\neq i}^{m} \underline{h}_{i\beta}^-, \prod_{\beta=1,\beta\neq i}^{m} \underline{h}_{i\beta}^+\right]\right)} \tag{14}$$

$$S(\Phi^+(z_i)) = 1 - \frac{1}{2}\left(\prod_{\beta=1,\beta\neq i}^{m} (1-\bar{h}_{i\beta}^-) + \prod_{\beta=1,\beta\neq i}^{m} (1-\bar{h}_{i\beta}^+) + \prod_{\beta=1,\beta\neq i}^{m} \underline{h}_{i\beta}^- + \prod_{\beta=1,\beta\neq i}^{m} \underline{h}_{i\beta}^+\right) \tag{15}$$

$$\boldsymbol{H(\Phi^+(z_i)) = 1 - \frac{1}{2}\left(\prod_{\beta=1,\beta\neq i}^{m} (1-\bar{h}_{i\beta}^-) + \prod_{\beta=1,\beta\neq i}^{m} (1-\bar{h}_{i\beta}^+) - \prod_{\beta=1,\beta\neq i}^{m} \underline{h}_{i\beta}^- - \prod_{\beta=1,\beta\neq i}^{m} \underline{h}_{i\beta}^+\right)} \tag{16}$$

Entering flow $\Phi^-(z_i)$ is computed for alternative $z_i \in Z$ (Eq.17). After that, the score function $S(\Phi^-(z_i))$ (Eq.18) and the accuracy function $H(\Phi^-(z_i))$ (Eq.19) are calculated for $z_i \in Z$.

$$\Phi^{-}(z_i)=\sum_{\rho=1,\rho\neq i}^{m}\eta(z_\rho,z_i)=\left(\left[1-\prod_{\rho=1,\rho\neq i}^{m}(1-\bar{h}_{\rho i}^{-}),1-\prod_{\rho=1,\rho\neq i}^{m}(1-\bar{h}_{\rho i}^{+})\right],\left[\prod_{\rho=1,\rho\neq i}^{m}\underline{h}_{\rho i}^{-},\prod_{\rho=1,\rho\neq i}^{m}\underline{h}_{\rho i}^{+}\right]\right) \tag{17}$$

$$\boldsymbol{S(\Phi^{-}(z_i))=1-\frac{1}{2}\left(\prod_{\rho=1,\rho\neq i}^{m}(1-\bar{h}_{\rho i}^{-})+\prod_{\rho=1,\rho\neq i}^{m}(1-\bar{h}_{\rho i}^{+})+\prod_{\rho=1,\rho\neq i}^{m}\underline{h}_{\rho i}^{-}+\prod_{\rho=1,\rho\neq i}^{m}\underline{h}_{\rho i}^{+}\right)} \tag{18}$$

$$H(\Phi^{-}(z_i))=1-\frac{1}{2}\left(\prod_{\rho=1,\rho\neq i}^{m}(1-\bar{h}_{\rho i}^{-})+\prod_{\rho=1,\rho\neq i}^{m}(1-\bar{h}_{\rho i}^{+})-\prod_{\rho=1,\rho\neq i}^{m}\underline{h}_{\rho i}^{-}-\prod_{\rho=1,\rho\neq i}^{m}\underline{h}_{\rho i}^{+}\right) \tag{19}$$

The procedures in IVIF-PROMETHEE I partial preorder ($\succ^{I},\sim^{I},\mathbb{R}$) are obtained in (Eq. 20) after considering the intersection of the two preorders ((Eq.21),(Eq.22)).

$$\begin{cases} z_i \succ^{I} z_j \ (z_i \text{ outranks } z_j) & \text{if } z_i \succ^{+} z_j \text{ and } z_i \succ^{-} z_j, \\ & \text{or } z_i \succ^{+} z_j \text{ and } z_i \sim^{-} z_j, \\ & \text{or } z_i \sim^{+} z_j \text{ and } z_i \succ^{-} z_j; \\ z_i \sim^{I} z_j \ (z_i \text{ is indifferent to } z_j) & \text{if and only if } z_i \sim^{+} z_j \text{ and } z_i \sim^{-} z_j; \\ z_i \mathbb{R} z_j \ (z_i \text{ and } z_j \text{ are incomparable}) & \text{otherwise.} \end{cases} \tag{20}$$

$$\begin{cases} z_i \succ^{+} z_j & \text{if and only if } S(\Phi^{+}(z_i)) > S(\Phi^{+}(z_j)) \\ & \quad \text{or } S(\Phi^{+}(z_i)) = S(\Phi^{+}(z_j)) \text{ and } H(\Phi^{+}(z_i)) > H(\Phi^{+}(z_j)), \\ z_i \sim^{+} z_j & \text{if and only if } S(\Phi^{+}(z_i)) = S(\Phi^{+}(z_j)) \text{ and } H(\Phi^{+}(z_i)) = H(\Phi^{+}(z_j)); \end{cases} \tag{21}$$

$$\begin{cases} z_i \succ^{-} z_j & \text{if and only if } S(\Phi^{-}(z_i)) < S(\Phi^{-}(z_j)) \\ & \quad \text{or } S(\Phi^{-}(z_i)) = S(\Phi^{-}(z_j)) \text{ and } H(\Phi^{-}(z_i)) > H(\Phi^{-}(z_j)), \\ z_i \sim^{-} z_j & \text{if and only if } S(\Phi^{-}(z_i)) = S(\Phi^{-}(z_j)) \text{ and } H(\Phi^{-}(z_i)) = H(\Phi^{-}(z_j)); \end{cases} \tag{22}$$

Steps of IVIF-PROMETHEE II can be summarized as following steps (Chen, 2015):

Step 1-6. Perform the step 1-6 of IVIF-PROMETHEE I.

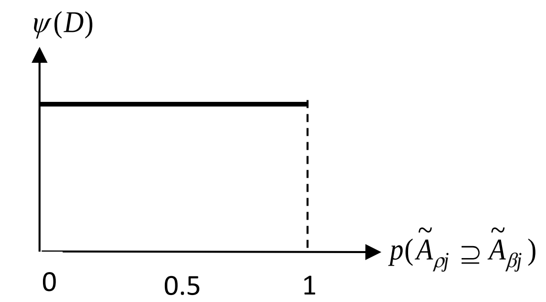
Calculate the score $S(\Phi(z_i))$ of the net flow $\Phi(z_i)$ for alternative $z_i \in Z$ (Eq.23) is calculated. The complete preorder for the alternative set Z is determined by using ($\succ^{II},\sim^{II}$) in Eq. (24).

$$S(\Phi(z_i)) = S(\Phi^+(z_i)) - S(\Phi^-(z_i)) \quad (23)$$

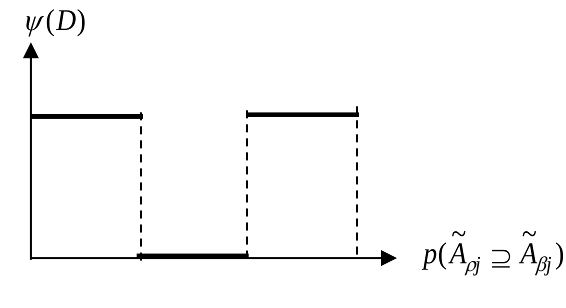
$$\begin{cases} z_i \succ^{\mathrm{II}} z_j \quad (z_i \text{ outranks } z_j) & \text{if and only if } S(\Phi(z_i)) > S(\Phi(z_j)), \\ z_i \sim^{\mathrm{II}} z_j \quad (z_i \text{ is indifferent to } z_j) & \text{if and only if } S(\Phi(z_i)) = S(\Phi(z_j)). \end{cases} \quad (24)$$

When the score $S(\Phi(z_i))$ of the net flow fails to differentiate between two alternatives, the degree of accuracy $H(\Phi(z_i))$ of the net flow $\Phi(z_i)$ is calculated for alternative $z_i \in Z$ (Eq.25). The higher the value of $H(\Phi(z_i))$ is, the higher the degree of accuracy for the alternative z_i.

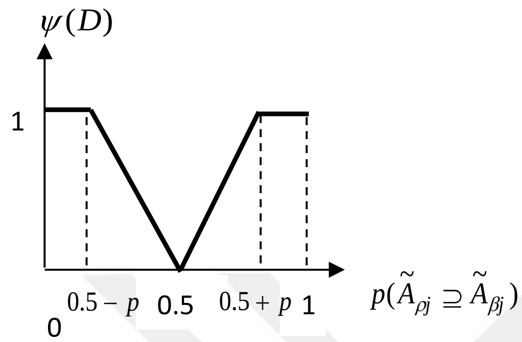
$$H(\Phi(z_i)) = H(\Phi^+(z_i)) - H(\Phi^-(z_i)) \quad (25)$$



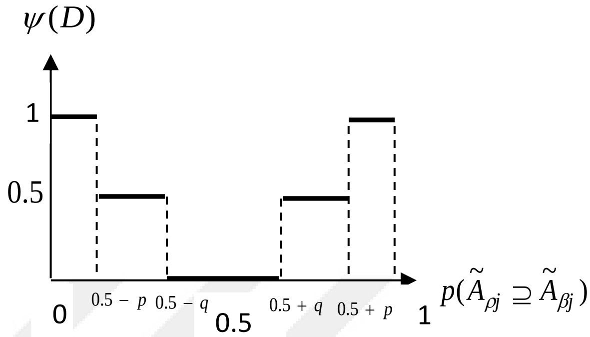
Type I: Inclusion-based usual criterion



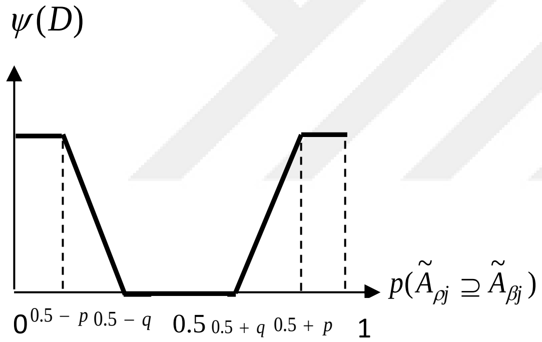
Type II: Inclusion-based ∪-shaped criterion



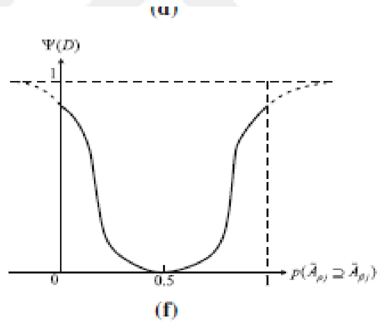
Type III: Inclusion-based V-shaped criterion



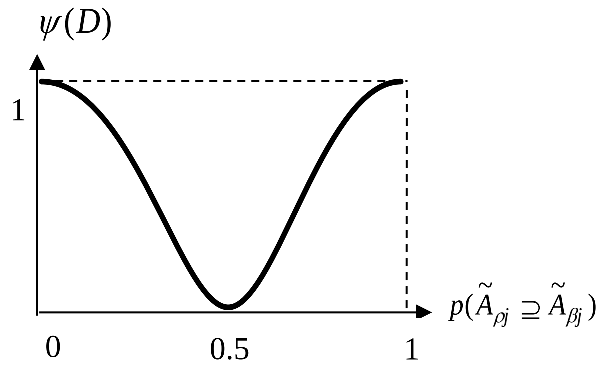
Type IV: Inclusion-based level criterion



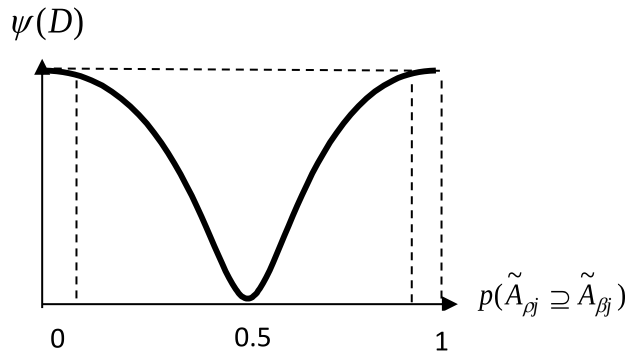
Type V: Inclusion-based V-shaped with indifference criterion



Type VI: Inclusion-based Gaussian criterion (example 1)



Type VI: Inclusion-based Gaussian criterion (example 2)



Type VI: Inclusion-based Gaussian criterion (example 3)

Figure 3.2. Functions of Inclusion-based generalized criteria

Figure 3.2. shows the functions of inclusion-based generalized criteria. When $p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j})$ = 0.5, there exits indifference between $\tilde{A}_{pj}$ and $\tilde{A}_{\beta j}$. There is exact preference for the situation when $p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) \geq 0.5$ for $x_j \in X_b$ or $p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) < 0.5$ (Eq.26).

$$\Psi(D) = \begin{cases} 0 & \text{if } p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) = 0.5 \\ 1 & \text{otherwise} \end{cases} \tag{26}$$

For the Type 2 function, the two alternative z_p and z_β with respect to x_j are indifferent to decide if and only if the absolute value of the difference between $p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j})$ and 0.5 does not exceed the indifference threshold q. Strict preference occurs when $|p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) - 0.5|$ is greater than q (Eq.27).

$$\Psi(D) = \begin{cases} 0 & \text{if } \left|p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) - 0.5\right| \leq q \\ 1 & \text{otherwise} \end{cases} \tag{27}$$

When the p value is greater than $|p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) - 0.5|$ decision maker preference increases linearly. If p value is smaller than $|p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) - 0.5|$ there also exists strict preference (Eq.28).

$$\Psi(D) = \begin{cases} \dfrac{\left|p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) - 0.5\right|}{p} & \text{if } \left|p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) - 0.5\right| \leq p \\ 1 & \text{otherwise} \end{cases} \tag{28}$$

In Type IV, indifference threshold q and preference threshold p are operated at the same time. If the value of $|p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) - 0.5|$ is less than q then $\psi(D)$ = 0. If the $|p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) - 0.5|$ is between q and p then the value of $\psi(D)$ becomes 0.5 (Eq.29).

$$\Psi(D) = \begin{cases} 0 & \text{if } \left|p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) - 0.5\right| \leq q \\ 0.5 & \text{if } q < \left|p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) - 0.5\right| \leq p, \\ 1 & \text{otherwise} \end{cases} \tag{29}$$

In Type V case, if the value of $|p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) - 0.5|$ is less than q, then $\psi(D) = 0$. If $\left|p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) - 0.5\right|$ is less than p and larger than q, then $\psi(D)$ value will be $\frac{\left|p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) - 0.5\right| - q}{p - q}$ (Eq.30).

$$\Psi(D) = \begin{cases} 0 & \text{if } \left|p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) - 0.5\right| \le q \\ \frac{\left|p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) - 0.5\right| - q}{p - q} & \text{if } q < \left|p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) - 0.5\right| \le p, \\ 1 & \text{otherwise} \end{cases} \tag{30}$$

The Type VI Gaussian criterion establishes the parameter σ, which is standard deviation of a normal distribution in statistics (Eq.31).

$$\Psi(D) = 1 - \exp\left\{-\frac{\left(p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j}) - 0.5\right)^2}{2\sigma^2}\right\} \tag{31}$$

4. HOSPITAL SERVICE QUALITY EVALUATION

The most well-known definition of service is that it is an activity or utility that does not result in ownership of anything presented from one group to another. Service production may or may not be linked to a physical product (Rust et al., 1993). Service is an intangible product that is produced to satisfy the expectations of the customers (Garland et al., 1989). Kotler and Armstrong (1996) define the service as an activity or a benefit whether it is related with a physical product or not. While Goetsch and Davis (1997) define service as a performing business for someone else, a work or action that is consumed in the place where it is produced services have various characteristics that differ from the goods. Related characteristics are; inseparability of production and consumption, intangibility of service, perishability of services and heterogeneity of services (Ghobadian et al., 1994). Service is the whole of the benefits provided to the customer. Every element that creates the service satisfies the need of the customer. In case one of the elements is missing, customer will be unsatisfied from the whole service.

Parasuraman (1985) propose that services could be explained by three characteristics, namely intangibility, heterogeneity, and inseparability. Intangibility of services includes inability to measure value of it before sales occur comparing to products. Heterogeneity is defined in the way that quality of a service delivery could vary from one day to another. Inseparability means that services emerge during an interaction between customers and personnel. (Parasuraman et al., 1985).

The American Marketing Association defines service as "actions, benefits, or saturations offered to sale or provided with the sale of goods". In this definition, there exists a deficit that physical goods and services are not separated enough. Because physical goods are also produced and sold in order to provide benefits or satisfaction (Ersöz et al.,2009).

The common sense derived from the resuIts of studies related with service explanation is that it is difficult and complex to describe the concept of service. In this context, although there are many different definitions and ideas for the concept of service, the common point for all authors is that service is an intangible concept that can be consumed as it is produced (Heizer and Render, 2011).

Services differ from products as being intangible. Also, products are not delivered to customers before the service is performed. For example; in the process of purchasing a tangible product, customers also meet the intangible features of the service. Similarly, most services contain tangible components.

4.1. Features of Service

The different structure of services arises from some unique characteristics and it is necessary to consider characteristics in marketing. These characteristics reveal different points for services as they bring out programs and applications different from marketing of goods.

4.1.1. Intangibility

Intangibility of services describe the customers' right to use, experience or consumption of customers after purchasing service (Üner, 1994). The main difference between physical goods and services is that services are intangible. Flipo (1987) states that intangibility is the only characteristic common to all services. Harker (1995) humorously defined services as "something that you can not drop on your foot" which exemplifies intangibility of services. The intangibility of services distinguishes their marketing from physical goods. Customers' thoughts, experiences and attitudes are influential in purchasing.

4.1.2. Heterogeneity

Heterogeneity is concerned with the variability of services**.** It may differ according to different quality standards related with different costs or cultural background. Services differ fundamentally due to customer perceptions. Since services are produced according to different needs of customers (health services, transportations services, etc.) differences may occur in quality and content of services.

It is not possible make standardization of the goods produced by companies operating in service industry. Because service is presented by human. Due to each person has different presentation style, personality and habits, it is not possible to present and receive the same service. Service may vary from person to person who present it, from customer to customer, and from day to day.

4.1.3. Perishability

The perishability dimension which distinguishes between services and goods is that services cannot be stored, they cannot be saved, and their unused capacity cannot be reserved in the same way as physical goods. For instance, unsold air tickets or theatre tickets, empty hotel rooms, unused doctor inspection cannot be assessed for that time. Whereas storage is available for physical goods.

4.1.4. Inseparability

Inseparability of service means that the use of service and the creation of the service occur at the same time. However, goods are usually produced before they are consumed. Inseparability requires direct sale in the marketing of service. Customer of service exists in the production process of service. On contrast, customer does not participate in production processes of goods.

4.2.Service Quality

Service quality is the major strategic tool for business sustainability in today's global market place. One of the most important factors that differs a company from its rivals is to produce and present higher service quality (Ghobadian et al., 1994). Service quality is the sensation created by what customer is provided from the service and it expresses how much customer is satisfied by the service. Therefore, service quality expresses the requirements and expectations of a customer, the features have to be in service, the degree of service ownership in these features and qualifications (Esin, 2002). It depends on the reliability of the service, the pleasure taken from the service, the retrieval of the received service (Pride & Ferrell, 2000). The increase of interest in service quality issues results from service expectation of customers (Arora & Stoner, 1996). Customers always compare the service offered to them and the service they expected. If the service is greater than the expectations, customers are satisfied and they keep on taking the service. Most of the companies get superiority advantage in rivalry by being outstanding to its rivals, keeping its profitability continuous with the strategy of producing and presenting service with different and desired quality. It is much more important to deal with how the service is delivered than the aim of the service for these companies (Seth et al., 2005).

Product-based quality definitions is different from service quality definition because services differ from goods in that they are intangible, variable, unstable and in addition the production and consumption of services occurs at the same time. On the other hand, goods are tangible, therefore they are felt by sensory organs. In addition goods are usually produced first, then they are bought and consumed. The features of trust and experience remain in the forefront intensively. This situation makes it difficult to measure and assess the service quality (Parasuraman et al., 1985).

Service quality is one of the topics that has the most research in marketing. Research indicates that service quality is related to the performance of a company (Zeithaml et al., 1996 and Boulding et al., 1993), customer satisfaction, (Cronin and Taylor, 1992; Oliver, 1993; Taylor and Baker, 1994) and intention of purchasing (Zeithaml et al., 1996a; Boulding et al., 1993).

In recent years, the rapid development in service sector, the rivalry of service enterprises in wider markets, and being sensitive and conscious about quality has increased the importance of quality day by day in developed country economies. Increase in the importance of service quality leads to competition among companies. One of the crucial factors in the achievement of firms operating in the service sector and providing advantage of strategic rivalry is the development of service quality. In today's competitive and competitive environment, not only good producing companies, but also service producing companies are also affected by the competition. Service quality attracts customer attention. The level of service quality provided to customer has an influence on whether or not the customer will prefer to buy the service from the same company (Gerson, 1997). The success of a service organization is measured by increase of loyal customers and sustainability of service competence (Kandampully, 2010).

4.2.1. Service quality GAP model

Parasuraman et al. found that there were four fundamental differences in service processes characteristics of services. The GAP model of service quality was developed by Parasuraman, Berry and Zeithaml (1985), and more currently explained in Zeithaml and Bitner (2003). The basic properties of the GAP model is that it actually puts an emphasis on the quality between the customer and service provider and are straightly connected with the attitudes towards the perception and expectations. The model defines four specific gaps leading to a fifth overall gap between customers’’ expectations and perceived service.

GAP 1 represents the gap between customer expectations and management perceptions of customer expectations. It occurs when management doesn’t perceive customers expectations accurately and precisely. It is referred to as the knowledge gap. The factors that create the GAP 1 are as follows;

1. Market Research Problems,
    1) Insufficient Market Research,
    2) Using the results of insufficient market research,
    3) Lack of interaction between management and customer,
2. Deficiencies and mistakes during the transfer of information to the management
3. Multitude of Management Levels

GAP 2 indicates difference between service design specifications and perceptions of the management about the expectations of customers. Management definitely needs to understand customer expectation and by using this information, management should determine quality standards. The factors that create the GAP 2 are as follows;

1. The deficiencies of loyalty that management’s opinion of service quality is important,
    1) Non-allocation of resources to the current departments of company that will be used in improving service quality,
    2) The intention of the business to maintain sales target more than present service to the customers.

GAP 3 is related to the variation in service design and service delivery. It is not always possible to expect the same performance from all employees and to make it standard. Quality specifications should not be too complex, they should be adopted by all employees and appropriate for company culture. The factors that create the GAP 3 are as follows;

1. The uncertainty about the role of employees in the company: the expectations of the managers from themselves and employees’ lack of clear knowledge about how these expectations are satisfied.

1) Management does not provide accurate information to the employees for their job description, business policies and methods and performance appraisal
2) Lack of knowledge of the employees about the products and service provided by company
3) Lack of training for employees about the effective interaction with customers

2. Conflict between the roles of the employees of the organization
   1) Non-perception of customer demand satisfaction by employees
   2) Different expectation of customer and management from employees,
   3) Requesting the same service at the same time by many customers,
   4) The incompatibility between abilities and the employees' job

GAP 4 is the variation between service provided to customer and what customer is actually told about the service. It is also called communication gap. The promised service should be given to customer in order to make this gap small or not occur at all. The factors that create the GAP 4 are as follows;

1) Communication between different departments of the company,

GAP 5 is the difference between customer expectations and their perceptions of the service delivered. This difference is the difference that results the four gaps that affect the quality perceptions of the customer. GAP 5 can also be regarded as the function of the four gaps described above.

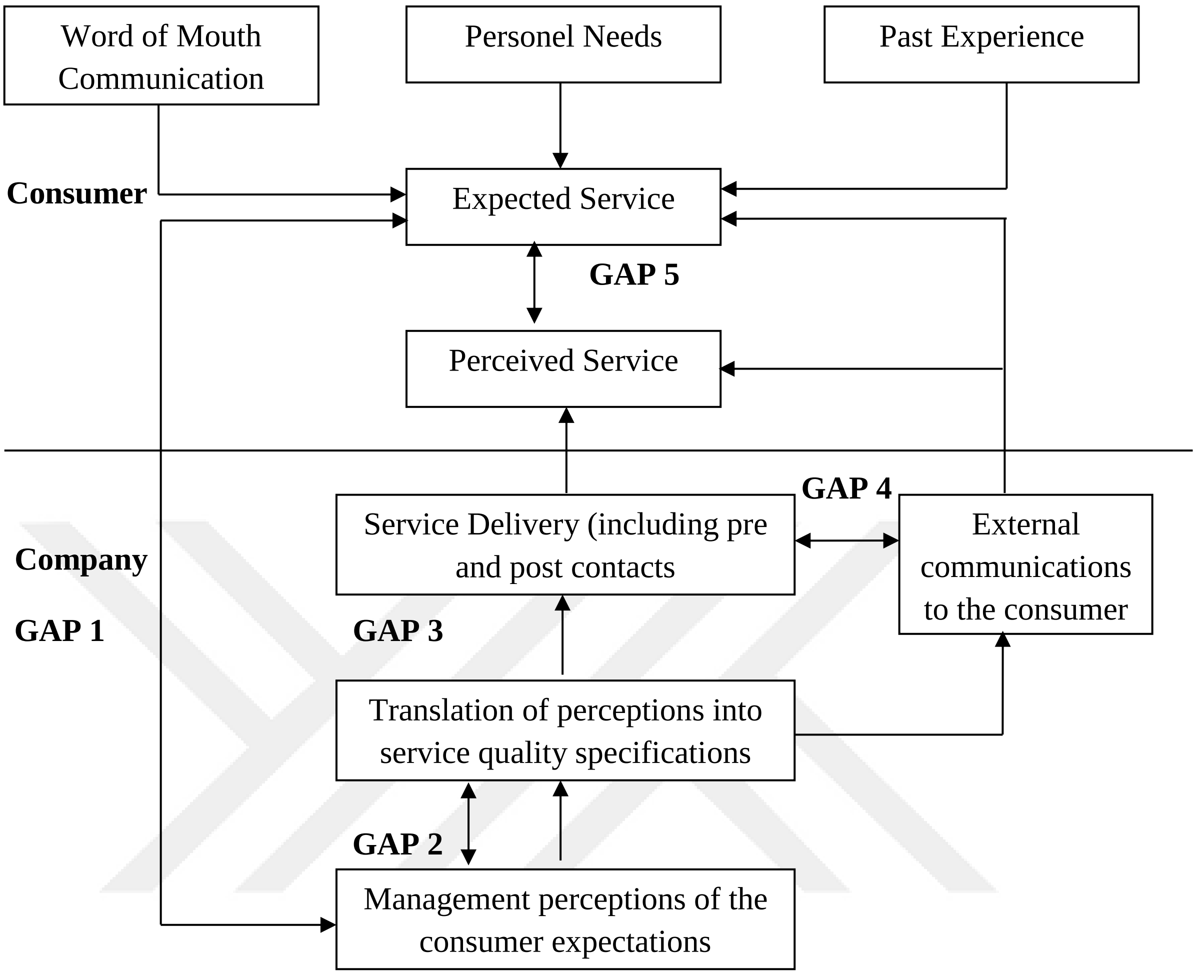


Figure 4.1. Service Quality GAP Model by Parasuraman et al. (1985)

Qualified service occurs when the expected service is at least equal or greater than the perceived service. In order to measure the service quality, the expected service and the perceived service need to be measured. In this measurement, service user performs the measurement by giving points to expected service and perceived service. These points are fundamental to make SERVQUAL analysis which was improved in order to define service quality by Parasuraman, Berry and Zeithaml (1988).

4.3.SERVQUAL

Several scales were developed to measure service quality. The scale commonly used in academic researches among these is the Servqual method developed by Parasuraman, Zeithalm and Berry between 1983-1990 (Wang et al., 2015). The scale measures the service quality with the perception of the service received.

Parasuraman, Zeithaml and Berry (PZB) developed a broader concept of SERVQUAL to measure the service quality from the perspective. The scale measures the service quality based on the perception of the service received and the comparison of the expectations how the service has to be before the service received. If the perceptions are equal to or higher than the expectations, the service received is good; in opposite case, the service received is bad. Parasuraman et al. (1985) determine the service quality by using 10 different criteria as service quality determinants of customers, regardless of what the service is. These dimensions are summarized as below;

1) Tangibility contains physical facilities, tool and appearance of personnel. Additionally, physical environmental circumstances occured as an obvious evidence of the care and attention paid for the details proposed by the service provider (Fitzsimmons & Fitzsimmons, 2001). Davis et al. (2003) summarize tangibles like the physical confirmation of the service.
2) Reliability relates to the personnel's ability to deliver the service dependably and accurately.
3) Responsiveness is about willing to help customers and delivering prompt service.
4) Competence is the possession of necessary abilities, and information to perform the service effectively.
5) Access contains the convenience of accessibility and contact
6) Courtesy is related with politeness, respect, and friendliness of employees also their behavior to customer
7) Communication is about keeping customers informed about the service in a language that they can understand.
8) Credibility contains trustworthiness, honesty and belief of service provider.
9) Security allows the customer be protected from danger, risk and doubt.
10) Understanding/Knowing is the understanding requirements and expectations of customers.

22 questions and 5 basic dimensions which are asked separately for expectations and perceptions in SERVQUAL scale. Customers use five dimensions in order to evaluate service quality. These five basic dimensions are shown in Table 4.1.

Table 4.1. Dimensions of SERVQUAL Scale (Parasuraman et al., 1988)

Dimensions	Features	Explanations
Tangibility	1-4	The physical appearance of the business, equipment and tools used, written materials, staff working
Reliability	5-9	Consistency of performance and dependability.
Responsiveness	10-13	The willingness to help customers (illness) and quick service delivery
Assurance	14-17	Knowledgeable and courtesy of employees and skills of conveying trust and confidence
Empathy	18-22	Good understanding of the customer's needs and wants

4.4. Service Quality in Healthcare

In today's highly competitive environment, health care corporations are aware of the significance of service quality as a measure to improve their competitive status. Every hospital should provide good quality of services to their patients to stay in competition. Hospitals that can successfully apply a convenient business process improvement tend to receive a major competitive benefit. Patients' perceptions about the services provided effects the image and profitability of the hospital (Donabedian, 1980). Furthermore, it considerably affects the patient behavior in terms of their devotion and word-of-mouth.

It is observed that there is no full consensus on which factors influence the multidimensional concept of patient satisfaction. Factors affecting patient satisfaction according to researches are personnel-patient interaction (physician-patient relationship, nurse-patient relationship), other health staff-patient relationship), service environment (physical and environmental nutrition services, comfort), bureaucracy, wages, information and trust (Kavuncubaşı, 2000).

Total Quality Management (TQM) applications which started in 1980s in the healthcare sector, ‘patient satisfaction’ was considered as an important dimension in presenting healthcare quality and measurement of service quality feedback has become important. Patients' perceptions and evaluations have been found effective not only their own preferences but also their surroundings’ preferences (Press, 2002).

In order to monitor the quality and reliability of patient care in the United States, standards have been started to be developed and Joint Commission on Accreditation of Health Care Organizations (JCAHO) was founded. The aim of this institution is to develop, monitor and supervise service standards in hospitals and other care establishments. The rules consist of top management leadership, process orientation (Patient-focused processes and support processes) performance improvement and patient care (patient rights and corporate ethics, patient’s assessment) as well as information and environment management

It was accepted that surgeon Ernest Codman made statistical study to determine the standards of the hospitals is the first application in measuring service quality even if it is not focused on patients satisfaction in the USA. Codman examined the accuracy of diagnosis, success of surgery, the benefits and side effects provided by the treatment and conluded that the adequacy of the service providers was not the sole determinant of caregiver quality and monitored progress and the results of clinical care provided by hospitals.

There exists many studies to determine the quality dimensions of health care. There are two types of quality which are technical and functional in health care services. It is very difficult to evaluate the technical skills of service providers during the delivery of service and after the delivery of service. Technical quality in health care is related to the ability of employees to provide professional knowledge. For instance, skill of a doctor in clinic and in surgery, nurses’ well-being of drugs, or the expertness of laboratory technician for blood tests, patients’ average length of lying in the hospital, infection rates and measurement of results are included in technical quality (Mangold

Babakus, 1991; Berwick, 1988; Lytle, Mowka, 1992; Tomes, Peng, 1995). Functional quality is concerned with how the services are assessed by the patient group. Patients can evaluate this quality easily. Service quality is a parameter that managers should measure periodically since it is the most influential factor in recommending the institution and the intention of taking the service again from the same hospital.

SERVQUAL scale has also been adapted to hospital services (Mangold, Babakus, 1991). The scale is also measured in health care institutions in Turkey (Devebakan, Aksarayli, 2003; Rahman et al., 2007; Savas, Kesmez, 2014).

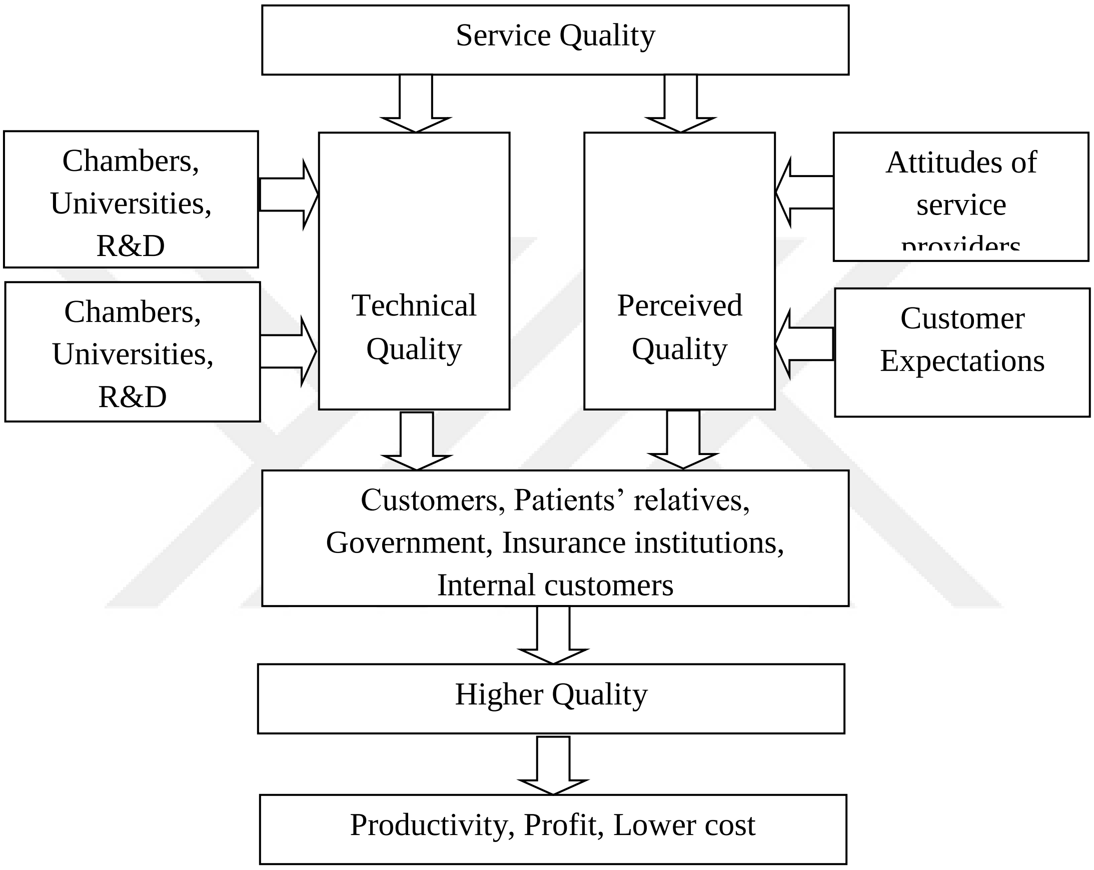


Figure 4.2. Determinants of Service Quality in Healthcare

Figure 4.2. expresses that perceived service quality is the outcome of the customer's comparison of expected service with perceived service (Parasuraman et al., 1985). Parasuraman et al. (1988) present the scale is universal and can be adapted to all sectors with a few modifications. Healthcare is one of the areas that have gained importance among the service quality applications and there are many studies in this area on domestic and foreign literature (Saleh and Ryan, 1991). Service quality concept begins from customers as quality concerns for customers and their perceptions.

5. AN IVIF-PROMETHEE METHODOLOGY AND ITS APPLICATION FOR A PUBLIC HOSPITAL SERVICE QUALITY EVALUATION PROCESS

5.1. IVIF-PROMETHEE Application to Hospital Service Quality Evaluation

Hospital service quality evaluation is a complicated decision making problem including multiple criteria. Because of the need for consideration a number of qualitative and quantitative criteria, MCDM methodology is applicable for evaluating the hospital service quality. By implementing IVIF-PROMETHEE methodology, service quality of five divisions of a public hospital is evaluated. The five divisions that questionnaire is applied are internal diseases service, pulmonary diseases service, cardiology, otorhinolaryngology, and neurology. In order to apply questionnaire to the patients in hospital, Ethics Committee approval is required. After taking permission from the Ethics Committee of School of Medicine in Marmara University, questionnaires are applied to the patients of each of five divisions to measure the expectations and perceptions of the patients' service quality. The first part of the questionnaire contains questions about the demographic characteristics (age, gender, education level) of the participants. The second part of the questionnaire contains questions that includes four main criteria in order to evaluate the five divisions. The respondents are asked to rate on a nine-point scale from 'very very good' to (9) 'very very bad' (1). The third part includes the questions about importance level of four criteria from 'very important' (5) to 'not important'(1). Service quality model SERVQUAL which is developed by Parasuraman et al. (1985) is utilised while determining the criteria and a comprehensive literature review are utilised. The patients responses to questionnaire in a limited time also taken into account and a total of ten sub-criteria are determined. The four main criteria and their sub-criteria are as follows: behavioral criteria contain demeanors of doctors and medical personnel to the patients, communication of doctors and medical personnel with patients and willing to help patients. Technical criteria are concerned with medical cure and diagnoses of illnesses. Time dependent criteria are about waiting time of patient to see the doctor, waiting time to make tests, waiting time to get the results of tests, the promptness of doctors and medical staff in case of emergency. Physical conditions criteria contain cleanliness and cosiness of waiting area, cleanliness and cosiness of patient rooms, temperature and sound in waiting area, temperature and sound in patient rooms. The interval-valued intuitionistic fuzzy numbers (IVIFNs) corresponding to the linguistic importance weights of the criteria are applied as recommended by Chen (2015).

Behavioral criteria

X_1 : Demeanors of doctors and medical personnel to the patients

X_2 : Communication of doctors and medical personnel about treatment with patients

Technical criteria

X_3 : Modern and sufficient medical equipment in the hospital

X_4 : Sufficient knowledge and experience of doctors for diagnosis and treatment

Time dependent criteria

X_5 : Waiting time of patient to see the doctor

Physical conditions criteria

X_6 : Cleanliness and cosiness of waiting area

X_7 : Cleanliness and cosiness of patient rooms

X_8 : Temperature and ventilation in waiting area

X_9 : Temperature and ventilation in patient rooms

X_{10} : Adequate and comfortable seating area in the waiting area

Table 5.1. IVIFN scale for evaluating alternatives and criteria (adapted from Chen,2015)

Survey scale for alternatives evaluation	Linguistic terms for alternative evaluation	Survey scale for criteria evaluation	Linguistic terms for criteria evaluation	Corresponding IVIFN
9	Very very good (VVG)	5	Very important (VI)	([0.85, 0.90], [0.05, 0.10])
8	Very good (VG)			([0.75, 0.80], [0.05, 0.10])
7	Good (G)	4	Important (I)	([0.65, 0.70], [0.15, 0.20])
6	Medium good (MG)			([0.55, 0.60], [0.25, 0.30])
5	Fair (F)	3	Medium important (MI)	([0.45, 0.50], [0.35, 0.40])
4	Medium bad (MB)			([0.35, 0.40], [0.45, 0.50])
3	Bad (B)	2	Unimportant (UI)	([0.20, 0.25], [0.55, 0.60])
2	Very bad (VB)			([0.05, 0.10], [0.70, 0.75])
1	Very very bad (VVB)	1	Very unimportant (VUI)	([0.05, 0.10], [0.85, 0.90])

The respondents are asked to rate divisions for each criterion on a nine-point scale as shown in Table 5.1. which is proposed by Chen (2015).

5.1.1. Sample of the study

The questionnaire that includes service quality evaluation questions is distributed to 500 patients for five divisions in a public hospital. The five divisions that questionnaire is applied are internal diseases service, pulmonary diseases service, cardiology, otorhinolaryngology, and neurology. For each division, 100 patients answer the questions. The questionnaire respondents are adults and include both women and men. Children are not considered for the research. Responses to the questionnaire are taken from randomly chosen patients through face to face interviews during two months period in randomly chosen days and hours.

Cronbach's alpha is calculated in order to measure internal consistency of the patients' evaluation. The Cronbach's alpha value for patients' evaluation of weights of criteria is 0.878. The Cronbach's alpha value for patients' evaluation of departments according to criteria is 0.955. Both values suggest high internal consistency since they are greater than 0.8.

$$\alpha = \frac{N\bar{c}}{\bar{v} + (N-1)\bar{c}}$$

where N is equal to the number of criteria, is the average of all covariances between criteria and equals the average variance.

5.2.Analysis and Results

The set of divisions is represented by $Z = \{z_1, z_2, z_3, z_4, z_5\}$ and the set of criteria is represented by $X = \{X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}\}$.

Table 5.2. Generalized criteria and parameters

Criteria	Types of generalized criteria	Parameters
X_1	Type III: V-shaped	p=0.3
X_2	Type III: V-shaped	p=0.3
X_3	Type III: V-shaped	p=0.3
X_4	Type III: V-shaped	p=0.3
X_5	Type III: V-shaped	p=0.3
X_6	Type I: Usual	-
X_7	Type I: Usual	-
X_8	Type III: V-shaped	p=0.3
X_9	Type III: V-shaped	p=0.3
X_{10}	Type III: V-shaped	p=0.3

Table 5.2. shows the types of criteria, preference function types and responding parameters of each criterion. The interval-valued intuitionistic fuzzy numbers (IVIFNs) corresponding to the linguistic importance weights of the criteria are used as proposed by Chen (2015).

The linguistic terms are converted to interval-valued intuitionistic fuzzy numbers using IVIFN scale for each patient and then assigning each patient equal importance ($\lambda_1=\lambda_2=\ldots=\lambda_K=1/K$ where K is the number of patients) the group decision making formulas proposed by Hashemi et al. (2016) for criterion weight $\tilde{w}_j$ and alternative rating $\tilde{A}_{ij}$ are applied (Eq.32).

$$\begin{aligned}
&\tilde{W}_j = ([\omega_j^-, \omega_j^+],[\varpi_j^-, \varpi_j^+]) = \\
&\left(\left[\left(1-\prod_{k=1}^{K}(1-\omega_{jk}^-)^{\lambda k}\right),\left(1-\prod_{k=1}^{K}(1-\omega_{jk}^+)^{\lambda k}\right)\right],\left[\prod_{k=1}^{K}(\varpi_j^-)^{\lambda k},\prod_{k=1}^{K}(\varpi_j^+)^{\lambda k}\right]\right) \\
&\tilde{A}_{ij} = ([\mu_{ij}^-, \mu_{ij}^+],[\nu_{ij}^-, \nu_{ij}^+]) = \\
&\left(\left[\left(1-\prod_{k=1}^{K}(1-\mu_{ij}^-)^{\lambda k}\right),\left(1-\prod_{k=1}^{K}(1-\mu_{ij}^+)^{\lambda k}\right)\right],\left[\prod_{k=1}^{K}(\nu_{ij}^-)^{\lambda k},\prod_{k=1}^{K}(\nu_{ij}^+)^{\lambda k}\right]\right)
\end{aligned} \quad (32)$$

Table 5.3. The outcomes of the lower inclusion comparison possibilities

Criteria	*X1*		*X2*		*X3*		*X4*		*X5*	
$p-(\tilde{A}_{1j} \supseteq \tilde{A}_{2j})$	1,101	0	0,383	0,616	0,472	0,527	0,473	0,526	0,457	0,542
$p-(\tilde{A}_{1j} \supseteq \tilde{A}_{3j})$	1,144	0	0,404	0,595	0,465	0,534	0,418	0,581	0,373	0,626
$p-(\tilde{A}_{1j} \supseteq \tilde{A}_{4j})$	1,420	0	0,537	0,462	0,554	0,445	0,520	0,479	0,510	0,489
$p-(\tilde{A}_{1j} \supseteq \tilde{A}_{5j})$	1,384	0	0,531	0,468	0,628	0,371	0,559	0,440	0,331	0,668
$p-(\tilde{A}_{2j} \supseteq \tilde{A}_{1j})$	0,931	0,068	0,989	0,010	0,902	0,097	0,916	0,083	0,939	0,061
$p-(\tilde{A}_{2j} \supseteq \tilde{A}_{3j})$	0,707	0,292	0,678	0,321	0,676	0,323	0,630	0,369	0,597	0,402
$p-(\tilde{A}_{2j} \supseteq \tilde{A}_{4j})$	0,826	0,173	0,694	0,305	0,759	0,240	0,734	0,265	0,733	0,266
$p-(\tilde{A}_{2j} \supseteq \tilde{A}_{5j})$	0,828	0,172	0,823	0,176	0,839	0,160	0,782	0,217	0,564	0,435
$p-(\tilde{A}_{3j} \supseteq \tilde{A}_{1j})$	1,939	0	0,962	0,037	0,896	0,103	0,942	0,057	1,009	0
$p-(\tilde{A}_{3j} \supseteq \tilde{A}_{2j})$	1,505	0	0,657	0,342	0,680	0,319	0,734	0,265	0,757	0,242
$p-(\tilde{A}_{3j} \supseteq \tilde{A}_{4j})$	1,806	0	0,672	0,327	0,755	0,244	0,767	0,232	0,803	0,196
$p-(\tilde{A}_{3j} \supseteq \tilde{A}_{5j})$	1,771	0	0,800	0,199	0,834	0,165	0,815	0,185	0,639	0,360
$p-(\tilde{A}_{4j} \supseteq \tilde{A}_{1j})$	1,654	0	0,825	0,174	0,804	0,195	0,843	0,157	0,878	0,121
$p-(\tilde{A}_{4j} \supseteq \tilde{A}_{2j})$	1,230	0	0,523	0,476	0,594	0,405	0,634	0,365	0,630	0,369
$p-(\tilde{A}_{4j} \supseteq \tilde{A}_{3j})$	1,269	0	0,541	0,458	0,586	0,413	0,573	0,426	0,545	0,454
$p-(\tilde{A}_{4j} \supseteq \tilde{A}_{5j})$	1,491	0	0,669	0,330	0,744	0,255	0,715	0,284	0,511	0,489
$p-(\tilde{A}_{5j} \supseteq \tilde{A}_{1j})$	1,730	0	0,850	0,149	0,742	0,257	0,813	0,186	1,055	0
$p-(\tilde{A}_{5j} \supseteq \tilde{A}_{2j})$	1,286	0	0,540	0,459	0,528	0,471	0,598	0,401	0,796	0,203
$p-(\tilde{A}_{5j} \supseteq \tilde{A}_{3j})$	1,327	0	0,558	0,441	0,520	0,479	0,537	0,462	0,706	0,293
$p-(\tilde{A}_{5j} \supseteq \tilde{A}_{4j})$	1,594	0,689	0	0,310	0,607	0,392	0 ,690	0,361	0,843	0,156

Table 5.3. indicates the lower inclusion comparison possibilities for the criteria and each pair of alternatives (z_ρ, z_β) where $z_\rho, z_\beta \in Z$. The first row of each criteria indicates

$\left\{1-\max\left\{\frac{(1-\nu^-_{\beta j})-\mu^-_{\rho j}}{(1-\mu^-_{\rho j}-\nu^+_{\rho j})+(1-\mu^+_{\beta j}-\nu^-_{\beta j})},0\right\},0\right\}$ which is the part of Eq.8. The second row of each criteria indicates the lower inclusion comparison $p^-(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j})$.

Table 5.3. (continued) The outcomes of the lower inclusion comparison possibilities

Criteria	X_6		X_7		X_8		X_9		X_{10}	
$p-(\tilde{A}_{1j} \supseteq \tilde{A}_{2j})$	0,441	0,5586	0,3802	0,6197	0,4444	0,555	0,3909	0,6090	0,313	0,686
$p-(\tilde{A}_{1j} \supseteq \tilde{A}_{3j})$	0,432	0,5670	0,384	0,615	0,4356	0,564	0,3901	0,6098	0,302	0,697
$p-(\tilde{A}_{1j} \supseteq \tilde{A}_{4j})$	0,541	0,4581	0,4909	0,5090	0,5896	0,410	0,5811	0,4188	0,596	0,403
$p-(\tilde{A}_{1j} \supseteq \tilde{A}_{5j})$	0,404	0,5954	0,3881	0,6118	0,4596	0,540	0,4467	0,5532	0,281	0,718
$p-(\tilde{A}_{2j} \supseteq \tilde{A}_{1j})$	0,941	0,0587	1,0089	0	0,9389	0,061	0,9864	0,0135	1,069	0
$p-(\tilde{A}_{2j} \supseteq \tilde{A}_{3j})$	0,667	0,3323	0,6797	0,3202	0,6714	0,328	0,6791	0,3208	0,665	0,334
$p-(\tilde{A}_{2j} \supseteq \tilde{A}_{4j})$	0,774	0,2258	0,7863	0,2136	0,8239	0,176	0,8627	0,1372	0,943	0,056
$p-(\tilde{A}_{2j} \supseteq \tilde{A}_{5j})$	0,6502	0,3497	0,6924	0,3075	0,6982	0,301	0,7371	0,2628	0,646	0,353
$p-(\tilde{A}_{3j} \supseteq \tilde{A}_{1j})$	0,9415	0,0584	0,9920	0,0079	0,9335	0,066	0,9754	0,0245	1,073	0
$p-(\tilde{A}_{3j} \supseteq \tilde{A}_{2j})$	0,6813	0,3186	0,6731	0,3268	0,6808	0,319	0,6700	0,3299	0,680	0,319
$p-(\tilde{A}_{3j} \supseteq \tilde{A}_{4j})$	0,7761	0,2238	0,7749	0,2250	0,8202	0,179	0,8527	0,1472	0,9475	0,052
$p-(\tilde{A}_{3j} \supseteq \tilde{A}_{5j})$	0,6535	0,3464	0,6827	0,3172	0,6962	0,303	0,7274	0,2725	0,6508	0,349
$p-(\tilde{A}_{4j} \supseteq \tilde{A}_{1j})$	0,8362	0,1637	0,8890	0,1109	0,7874	0,212	0,7930	0,2069	0,7868	0,213
$p-(\tilde{A}_{4j} \supseteq \tilde{A}_{2j})$	0,5799	0,4200	0,5720	0,4279	0,5374	0,462	0,4955	0,5044	0,4104	0,589
$p-(\tilde{A}_{4j} \supseteq \tilde{A}_{3j})$	0,5702	0,4297	0,5715	0,4284	0,5279	0,472	0,4949	0,5050	0,3996	0,600
$p-(\tilde{A}_{4j} \supseteq \tilde{A}_{5j})$	0,5489	0,4510	0,5809	0,4190	0,5525	0,447	0,5506	0,4493	0,3802	0,619
$p-(\tilde{A}_{5j} \supseteq \tilde{A}_{1j})$	0,9722	0,0277	0,9862	0,0137	0,9106	0,089	0,9200	0,0799	1,0953	0
$p-(\tilde{A}_{5j} \supseteq \tilde{A}_{2j})$	0,7031	0,2968	0,6618	0,3381	0,6564	0,343	0,6149	0,3850	0,7010	0,298
$p-(\tilde{A}_{5j} \supseteq \tilde{A}_{3j})$	0,6918	0,3081	0,6594	0,3405	0,6456	0,354	0,6145	0,3854	0,6901	0,309
$p-(\tilde{A}_{5j} \supseteq \tilde{A}_{4j})$	0,8004	0,1995	0,7655	0,2344	0,7970	0,202	0,7989	0,2010	0,9679	0,032

Table 5.4. The outcomes of the upper inclusion comparison possibilities

Criteria	X_1		X_2		X_3		X_4		X_5	
$p+(\tilde{A}_{1j} \supseteq \tilde{A}_{2j})$	0,0685	0,931	0,010	0,989	0,0977	0,902	0,0838	0,916	0,060	0,939
$p+(\tilde{A}_{1j} \supseteq \tilde{A}_{3j})$	0,0961	0,903	0,037	0,962	0,1037	0,896	0,0574	0,942	-	1
$p+(\tilde{A}_{1j} \supseteq \tilde{A}_{4j})$	0,2318	0,768	0,174	0,825	0,1959	0,804	0,157	0,842	0,1212	0,878
$p+(\tilde{A}_{1j} \supseteq \tilde{A}_{5j})$	0,2106	0,789	0,149	0,850	0,2575	0,742	0,186	0,813	-0,055	1
$p+(\tilde{A}_{2j} \supseteq \tilde{A}_{1j})$	0,5594	0,440	0,616	0,383	0,5272	0,472	0,526	0,473	0,5421	0,457
$p+(\tilde{A}_{2j} \supseteq \tilde{A}_{3j})$	0,3500	0,649	0,342	0,657	0,3191	0,680	0,265	0,734	0,2423	0,757
$p+(\tilde{A}_{2j} \supseteq \tilde{A}_{4j})$	0,4775	0,522	0,476	0,523	0,4057	0,594	0,365	0,634	0,3694	0,630
$p+(\tilde{A}_{2j} \supseteq \tilde{A}_{5j})$	0,4626	0,537	0,459	0,540	0,4719	0,528	0,401	0,598	0,2035	0,796
$p+(\tilde{A}_{3j} \supseteq \tilde{A}_{1j})$	0,5320	0,467	0,595	0,404	0,5344	0,465	0,581	0,418	0,6267	0,373
$p+(\tilde{A}_{3j} \supseteq \tilde{A}_{2j})$	0,2922	0,707	0,305	0,694	0,3238	0,676	0,369	0,630	0,4020	0,597
$p+(\tilde{A}_{3j} \supseteq \tilde{A}_{4j})$	0,4501	0,549	0,458	0,541	0,4133	0,586	0,426	0,573	0,4542	0,545
$p+\tilde{A}_{3j} \supseteq \tilde{A}_{5j})$	0,4345	0,565	0,441	0,558	0,4793	0,520	0,462	0,537	0,2933	0,706
$p+(\tilde{A}_{4j} \supseteq \tilde{A}_{1j})$	0,9169	0,083	0,462	0,537	0,4454	0,554	0,479	0,520	0,4891	0,510
$p+(\tilde{A}_{4j} \supseteq \tilde{A}_{2j})$	0,4993	0,500	0,176	0,823	0,2402	0,759	0,265	0,734	0,2667	0,733
$p+(\tilde{A}_{4j} \supseteq \tilde{A}_{3j})$	0,5470	0,452	0,199	0,800	0,2445	0,755	0,232	0,767	0,1960	0,803
$p+(\tilde{A}_{4j} \supseteq \tilde{A}_{5j})$	0,753	0,246	0,310	0,689	0,3301	0,669	0,360	0,639	0,1568	0,843
$p+(\tilde{A}_{5j} \supseteq \tilde{A}_{1j})$	0,936	0,063	0,468	0,531	0,3714	0,628	0,440	0,559	0,6684	0,331
$p+(\tilde{A}_{5j} \supseteq \tilde{A}_{2j})$	0,501	0,498	0,176	0,823	0,1603	0,839	0,217	0,782	0,4357	0,564
$p+(\tilde{A}_{5j} \supseteq \tilde{A}_{3j})$	0,551	0,448	0,199	0,800	0,1656	0,834	0,185	0,814	0,3604	0,639
$p+(\tilde{A}_{5j} \supseteq \tilde{A}_{4j})$	0,823	0,176	0,334	0,665	0,2554	0,744	0,284	0,715	0,4889	0,511

Table 5.4. indicates the upper inclusion comparison possibilities for the criteria and each pair of alternatives (z_ρ, z_β) where $z_\rho, z_\beta \in Z$. The first row of each criteria indicates

$$\left\{1-\max\left\{\frac{(1-\nu_{\beta j}^{-})-\mu_{\rho j}^{-}}{(1-\mu_{\rho j}^{-}-\nu_{\rho j}^{+})+(1-\mu_{\beta j}^{+}-\nu_{\beta j}^{-})},0\right\},0\right\}$$ which is the part of Eq.8. The second row of each

criteria indicates the lower inclusion comparison $p^{+}(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j})$.

Table 5.4. (continued) The outcomes of the upper inclusion comparison possibilities

Criteria	X_6		X_7		X_8		X_9		X_{10}	
$p+(\tilde{A}_{1j} \supseteq \tilde{A}_{2j})$	0,0587	0,9412	-0,008	1	0,061	0,938	0,013	0,986	-0,0697	1
$p+(\tilde{A}_{1j} \supseteq \tilde{A}_{3j})$	0,0584	0,94159	0,007	0,9920	0,066	0,933	0,024	0,975	-0,073	1
$p+(\tilde{A}_{1j} \supseteq \tilde{A}_{4j})$	0,16376	0,8362	0,1109	0,88900	0,212	0,787	0,206	0,793	0,21313	0,7868
$p+(\tilde{A}_{1j} \supseteq \tilde{A}_{5j})$	0,02776	0,9722	0,0137	0,98622	0,089	0,910	0,079	0,920	-0,0953	1
$p+(\tilde{A}_{2j} \supseteq \tilde{A}_{1j})$	0,55860	0,4413	0,6197	0,38026	0,555	0,444	0,609	0,390	0,68662	0,3133
$p+(\tilde{A}_{2j} \supseteq \tilde{A}_{3j})$	0,31864	0,6813	0,3174	0,68259	0,317	0,682	0,320	0,679	0,32401	0,6759
$p+(\tilde{A}_{2j} \supseteq \tilde{A}_{4j})$	0,42006	0,5799	0,4279	0,57204	0,462	0,537	0,504	0,495	0,58958	0,4104
$p+(\tilde{A}_{2j} \supseteq \tilde{A}_{5j})$	0,29684	0,7031	0,3381	0,66189	0,343	0,656	0,385	0,614	0,29898	0,7010
$p+(\tilde{A}_{3j} \supseteq \tilde{A}_{1j})$	0,56706	0,4329	0,6157	0,38421	0,564	0,435	0,609	0,390	0,69793	0,3020
$p+(\tilde{A}_{3j} \supseteq \tilde{A}_{2j})$	0,33235	0,6676	0,3202	0,67973	0,328	0,671	0,320	0,679	0,33487	0,6651
$p+(\tilde{A}_{3j} \supseteq \tilde{A}_{4j})$	0,42971	0,5702	0,4284	0,57159	0,472	0,527	0,505	0,494	0,60032	0,3996
$p+(\tilde{A}_{3j} \supseteq \tilde{A}_{5j})$	0,30811	0,6918	0,3405	0,65948	0,354	0,645	0,385	0,614	0,30982	0,6901
$p+(\tilde{A}_{4j} \supseteq \tilde{A}_{1j})$	0,45811	0,5418	0,5090	0,49090	0,410	0,589	0,418	0,581	0,40310	0,5968
$p+(\tilde{A}_{4j} \supseteq \tilde{A}_{2j})$	0,22586	0,7741	0,2136	0,78639	0,176	0,823	0,137	0,862	0,05641	0,9435
$p+(\tilde{A}_{4j} \supseteq \tilde{A}_{3j})$	0,22389	0,7761	0,2250	0,77495	0,179	0,820	0,147	0,852	0,05249	0,9475
$p+(\tilde{A}_{4j} \supseteq \tilde{A}_{5j})$	0,32459	0,6754	0,2344	0,76556	0,202	0,797	0,201	0,798	0,03205	0,9679
$p+(\tilde{A}_{5j} \supseteq \tilde{A}_{1j})$	0,59540	0,4045	0,6118	0,38816	0,540	0,459	0,553	0,446	0,71868	0,2813
$p+(\tilde{A}_{5j} \supseteq \tilde{A}_{2j})$	0,34977	0,6502	0,3075	0,69247	0,301	0,698	0,262	0,737	0,35378	0,6462
$p+(\tilde{A}_{5j} \supseteq \tilde{A}_{3j})$	0,34649	0,6535	0,3172	0,68276	0,303	0,696	0,272	0,727	0,34910	0,6508
$p-(\tilde{A}_{5j} \supseteq \tilde{A}_{4j})$	0,45100	0,5489	0,4190	0,58099	0,447	0,552	0,449	0,550	0,61975	0,3802

Table 5.5. The outcomes of the inclusion comparison possibilities

Criteria	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
$p(\tilde{A}_{1j} \supseteq \tilde{A}_{2j})$	0,465	0,802	0,714	0,7214	0,740	0,749	0,809	0,747	0,7977	0,8433
$p(\tilde{A}_{1j} \supseteq \tilde{A}_{3j})$	0,451	0,778	0,715	0,7621	0,813	0,754	0,803	0,748	0,7926	0,8490
$p(\tilde{A}_{1j} \supseteq \tilde{A}_{4j})$	0,384	0,643	0,624	0,6610	0,684	0,647	0,699	0,598	0,6059	0,5950
$p(\tilde{A}_{1j} \supseteq \tilde{A}_{5j})$	0,394	0,659	0,557	0,6268	0,834	0,783	0,799	0,725	0,7366	0,8593
$p(\tilde{A}_{2j} \supseteq \tilde{A}_{1j})$	0,254	0,197	0,285	0,2786	0,259	0,250	0,190	0,252	0,2023	0,1567
$p(\tilde{A}_{2j} \supseteq \tilde{A}_{3j})$	0,471	0,489	0,502	0,5520	0,579	0,506	0,501	0,505	0,5001	0,5054
$p(\tilde{A}_{2j} \supseteq \tilde{A}_{4j})$	0,348	0,414	0,417	0,4502	0,448	0,402	0,392	0,356	0,3164	0,2334
$p(\tilde{A}_{2j} \supseteq \tilde{A}_{5j})$	0,354	0,358	0,344	0,4080	0,616	0,526	0,484	0,479	0,4389	0,5274
$p(\tilde{A}_{3j} \supseteq \tilde{A}_{1j})$	0,234	0,221	0,284	0,2379	0,186	0,245	0,196	0,251	0,2074	0,1510
$p(\tilde{A}_{3j} \supseteq \tilde{A}_{2j})$	0,353	0,518	0,497	0,4480	0,420	0,493	0,503	0,495	0,5046	0,4923
$p(\tilde{A}_{3j} \supseteq \tilde{A}_{4j})$	0,274	0,434	0,415	0,4030	0,370	0,397	0,398	0,353	0,3211	0,2261
$p(\tilde{A}_{3j} \supseteq \tilde{A}_{5j})$	0,282	0,379	0,343	0,3613	0,533	0,519	0,488	0,474	0,4436	0,5196
$p(\tilde{A}_{4j} \supseteq \tilde{A}_{1j})$	0,041	0,356	0,375	0,3390	0,316	0,352	0,301	0,401	0,3941	0,4050
$p(\tilde{A}_{4j} \supseteq \tilde{A}_{2j})$	0,250	0,650	0,582	0,5498	0,551	0,597	0,607	0,643	0,6836	0,7666
$p(\tilde{A}_{4j} \supseteq \tilde{A}_{3j})$	0,226	0,629	0,584	0,5970	0,629	0,602	0,601	0,646	0,6789	0,7739
$p(\tilde{A}_{4j} \supseteq \tilde{A}_{5j})$	0,123	0,510	0,462	0,4616	0,666	0,563	0,592	0,622	0,6241	0,7938
$p(\tilde{A}_{5j} \supseteq \tilde{A}_{1j})$	0,032	0,340	0,443	0,3732	0,165	0,216	0,201	0,274	0,2634	0,1407
$p(\tilde{A}_{5j} \supseteq \tilde{A}_{2j})$	0,249	0,641	0,655	0,5920	0,383	0,473	0,515	0,520	0,5611	0,4726
$p(\tilde{A}_{5j} \supseteq \tilde{A}_{3j})$	0,224	0,620	0,656	0,6387	0,466	0,480	0,511	0,525	0,5564	0,4804
$p(\tilde{A}_{5j} \supseteq \tilde{A}_{4j})$	0,088	0,488	0,568	0,5384	0,333	0,374	0,407	0,377	0,3759	0,2062

The inclusion comparison possibility $p(\tilde{A}_{Pj} \supseteq \tilde{A}_{\beta j})$ of $\tilde{A}_{Pj}$ and $\tilde{A}_{\beta j}$ is identified. The computational outcomes of $p(\tilde{A}_{Pj} \supseteq \tilde{A}_{\beta j})$ are illustrated in Table 5.5.

Table 5.6. Difference Between $\boldsymbol{p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j})}$ and 0.5.

Criteria	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
$D(\tilde{A}_{1j} \supseteq \tilde{A}_{2j})$	-0,034	0,302	0,214	0,221	0,240	0,249	0,3098	0,2472	0,2977	0,3433
$D(\tilde{A}_{1j} \supseteq \tilde{A}_{3j})$	-0,048	0,278	0,215	0,262	0,3133	0,2542	0,3039	0,2489	0,2926	0,3489
$D(\tilde{A}_{1j} \supseteq \tilde{A}_{4j})$	-0,115	0,143	0,124	0,161	0,183	0,1471	0,1990	0,0988	0,1059	0,0949
$D(\tilde{A}_{1j} \supseteq \tilde{A}_{5j})$	-0,105	0,159	0,056	0,126	0,334	0,2838	0,2990	0,2254	0,2366	0,3593
$D(\tilde{A}_{2j} \supseteq \tilde{A}_{1j})$	-0,245	-	-0,214	-0,221	-0,240	-0,249	-0,309	-0,247	-0,297	-0,343
$D(\tilde{A}_{2j} \supseteq \tilde{A}_{3j})$	-0,028	-	0,002	0,052	0,079	0,0068	0,0014	0,0055	0,0001	0,0054
$D(\tilde{A}_{2j} \supseteq \tilde{A}_{4j})$	-0,151	-	-0,082	-0,049	-0,051	-0,097	-0,107	-0,143	-0,183	-0,266
$D(\tilde{A}_{2j} \supseteq \tilde{A}_{5j})$	-0,145	-	-0,155	-0,091	0,116	0,0264	-0,015	-0,020	-0,061	0,0274
$D(\tilde{A}_{3j} \supseteq \tilde{A}_{1j})$	-0,266	-	-0,215	-0,262	-0,313	-0,254	-0,303	-0,248	-0,292	-0,348
$D(\tilde{A}_{3j} \supseteq \tilde{A}_{2j})$	-0,146	-	-0,002	-0,052	-0,079	-0,006	0,0032	-0,004	0,0045	-0,007
$D(\tilde{A}_{3j} \supseteq \tilde{A}_{4j})$	-0,225	-	-0,084	-0,097	-0,129	-0,102	-0,101	-0,146	-0,178	-0,273
$D(\tilde{A}_{3j} \supseteq \tilde{A}_{4j})$	-0,217	-	-0,156	-0,138	0,033	0,0191	-0,011	-0,025	-0,056	0,0196
$D(\tilde{A}_{3j} \supseteq \tilde{A}_{4j})$	-0,458	-	-0,124	-0,161	-0,183	-0,147	-0,199	-0,098	-0,105	-0,094
$D(\tilde{A}_{3j} \supseteq \tilde{A}_{4j})$	-0,249	0,150	0,082	0,049	0,051	0,0971	0,1071	0,1432	0,1836	0,2665
$D(\tilde{A}_{3j} \supseteq \tilde{A}_{4j})$	-0,273	0,129	0,084	0,097	0,129	0,1029	0,1016	0,1461	0,1788	0,2739
$D(\tilde{A}_{3j} \supseteq \tilde{A}_{4j})$	-0,376	0,010	-0,037	-0,038	0,166	0,0632	0,0922	0,1222	0,1241	0,2938
$D(\tilde{A}_{3j} \supseteq \tilde{A}_{4j})$	-0,468	-	-0,056	-0,126	-0,334	-0,283	-0,299	-0,225	-0,236	-0,359
$D(\tilde{A}_{3j} \supseteq \tilde{A}_{4j})$	-0,250	0,141	0,155	0,091	-0,116	-0,026	0,0152	0,0208	0,06109	-0,0274
$D(\tilde{A}_{3j} \supseteq \tilde{A}_{4j})$	-0,275	0,120	0,156	0,138	-0,033	-0,019	0,0116	0,0253	0,05642	-0,019
$D(\tilde{A}_{3j} \supseteq \tilde{A}_{4j})$	-0,411	-	0,068	0,038	-0,166	-0,125	-0,092	-0,122	-0,124	-0,293

Table 5.6. indicates the results of difference between $\boldsymbol{p(\tilde{A}_{\rho j} \supseteq \tilde{A}_{\beta j})}$ and 0.5.

Table 5.7. The outcomes of $\psi(D)$ Function

Criteria	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
$\psi(D)(\tilde{A}_{1j} \supseteq \tilde{A}_{2j})$	0,1142	1	0,7159	0,7379	0,80200	1	1	0,824	0,9924	1
$\psi(D)(\tilde{A}_{1j} \supseteq \tilde{A}_{3j})$	0,1602	0,9297	0,7178		1	1	1	0,829	0,9754	1
$\psi(D)(\tilde{A}_{1j} \supseteq \tilde{A}_{4j})$	0,3863	0,4789	0,4157	0,5367	0,61322	1	1	0,329	0,3531	0,3166
$\psi(D)(\tilde{A}_{1j} \supseteq \tilde{A}_{5j})$	0,3511	0,5319	0,1898	0,4225	1	1	1	0,751	0,7887	1
$\psi(D)(\tilde{A}_{2j} \supseteq \tilde{A}_{1j})$	0,8181	1	0,7159	0,7379	0,80200	1	1	0,824	0,9924	1
$\psi(D)(\tilde{A}_{2j} \supseteq \tilde{A}_{3j})$	0,0964	0,0357	0,0078	0,1734	0,26618	1	1	0,018	0,0004	0,0181
$\psi(D)(\tilde{A}_{2j} \supseteq \tilde{A}_{4j})$	0,5059	0,2838	0,2758	0,1658	0,17120	1	1	0,477	0,6120	0,8886
$\psi(D)(\tilde{A}_{2j} \supseteq \tilde{A}_{5j})$	0,4844	0,4719	0,5193	0,3065	0,38689	1	1	0,069	0,2036	0,0913
$\psi(D)(\tilde{A}_{3j} \supseteq \tilde{A}_{1j})$	0,8866	0,9297	0,7178	0,8735	1	1	1	0,829	0,9754	1
$\psi(D)(\tilde{A}_{3j} \supseteq \tilde{A}_{2j})$	0,4870	0,0617	0,0078	0,1734	0,26618	1	1	0,015	0,0151	0,0257
$\psi(D)(\tilde{A}_{3j} \supseteq \tilde{A}_{4j})$	0,7502	0,2183	0,2813	0,3233	0,43033	1	1	0,487	0,5962	0,9130
$\psi(D)(\tilde{A}_{3j} \supseteq \tilde{A}_{5j})$	0,7242	0,4032	0,5228	0,4624	0,11174	1	1	0,084	0,1880	0,0654
$\psi(D)(\tilde{A}_{4j} \supseteq \tilde{A}_{1j})$	1	0,4789	0,4157	0,5367	0,61322	1	1	0,329	0,3531	0,3166
$\psi(D)(\tilde{A}_{4j} \supseteq \tilde{A}_{2j})$	0,8321	0,5003	0,2758	0,1658	0,17120	1	1	0,477	0,6120	0,8886
$\psi(D)(\tilde{A}_{4j} \supseteq \tilde{A}_{3j})$	0,9116	0,4318	0,2813	0,3233	0,43033	1	1	0,487	0,5962	0,9130
$\psi(D)(\tilde{A}_{4j} \supseteq \tilde{A}_{5j})$	1	0,0337	0,1246	0,1280	0,55360	1	1	0,407	0,4137	0,9794
$\psi(D)(\tilde{A}_{5j} \supseteq \tilde{A}_{1j})$	1	0,5319	0,1898	0,4225	1	1	1	0,751	0,7887	1
$\psi(D)(\tilde{A}_{5j} \supseteq \tilde{A}_{2j})$	0,8364	0,4717	0,5193	0,3065	0,38689	1	1	0,069	0,2036	0,0913
$\psi(D)(\tilde{A}_{5j} \supseteq \tilde{A}_{3j})$	0,9191	0,4022	0,5228	0,4624	0,11174	1	1	0,084	0,1880	0,0654
$\psi(D)(\tilde{A}_{5j} \supseteq \tilde{A}_{4j})$	1	0,0396	0,2286	0,1280	0,55360	1	1	0,407	0,4137	0,9794

Table 5.7. indicates the results of $\psi(D)$ function. For the criteria of X_6 and X_7 Type I inclusion based usual criterion is applied, Type III inclusion based V shaped criterion is applied for the other criteria.

Table 5.8. The outcomes of the preference functions and the global preference indices

Criteria	Type	$h(\tilde{A}_{1j},\tilde{A}_{2j})$	$h(\tilde{A}_{1j},\tilde{A}_{3j})$	$h(\tilde{A}_{1j},\tilde{A}_{4j})$	$h(\tilde{A}_{1j},\tilde{A}_{5j})$	$h(\tilde{A}_{2j},\tilde{A}_{1j})$	$h(\tilde{A}_{2j},\tilde{A}_{3j})$	$h(\tilde{A}_{2j},\tilde{A}_{4j})$	$h(\tilde{A}_{2j},\tilde{A}_{5j})$	$h(\tilde{A}_{3j},\tilde{A}_{1j})$
X_1	III	0	0	0	0	0	0	0	0	0
X_2	III	1	0,929	0,478	0,531	0	0	0	0	0
X_3	III	0,715	0,717	0,415	0,189	0	0,007	0	0	0
X_4	III	0,737	0,873	0,536	0,422	0	0,173	0	0	0
X_5	III	0,802	1	0,613	1	0	0,266	0	0,386	0
X_6	I	1	1	1	1	0	1	0	1	0
X_7	I	1	1	1	1	0	1	0	0	0
X_8	III	0,824	0,829	0,329	0,751	0	0,018	0	0	0
X_9	III	0,992	0,975	0,353	0,788	0	0,000	0	0	0
X_{10}	III	1	1	0,316	1	0	0,018	0	0,091	0

The computational results for the inclusion-based global preference index ħ(z) are shown in Table 5.8.

Table 5.8. (continued) The outcomes of the preference functions and the global preference indices

Criteria	Type	$h(\tilde{A}_{3j},\tilde{A}_{2j})$	$h(\tilde{A}_{3j},\tilde{A}_{4j})$	$h(\tilde{A}_{3j},\tilde{A}_{5j})$	$h(A_{4j},\tilde{A}_{1j})$	$h(\tilde{A}_{4j},\tilde{A}_{2j})$	$h(\tilde{A}_{4j},\tilde{A}_{3j})$	$h(\tilde{A}_{4j},\tilde{A}_{5j})$	$h(\tilde{A}_{5j},\tilde{A}_{1j})$
X_1	III	0	0	0	0	0	0	0	0
X_2	III	0,061	0,929	0	0	0,500	0,431	0	0
X_3	III	0	0,717	0	0	0,275	0,281	0	0
X_4	III	0	0,873	0	0	0,165	0,323	0	0
X_5	III	0	1	0,111	0	0,171	0,430	0	0
X_6	I	0	1	1	0	1	1	0	0
X_7	I	1	1	0	0	1	1	0	0
X_8	III	0	0,829	0	0	0,477	0,487	0	0
X_9	III	0,015	0,975	0	0	0,612	0,596	0	0
X_{10}	III	0	1	0,065	0	0,888	0,913	0	0

Table 5.8. (continued) The outcomes of the preference functions and the global preference indices

Criteria	Type	$h(\tilde{A}_{5j},\tilde{A}_{2j})$	$h(\tilde{A}_{5j},\tilde{A}_{3j})$	$h(\tilde{A}_{5j},\tilde{A}_{4j})$
X_1	III	0	0	0
X	III	0,471	0,402	0
X_3	III	0,519	0,522	0,228
X_4	III	0,306	0,462	0,128
X_5	III	0	0	0
X_6	I	0	0	0
X_7	I	1	1	0
X_8	III	0,069	0,084	0
X_9	III	0,203	0,188	0
X_{10}	III	0	0	0

By implementing IVIF- PROMETHEE I procedure, outcomes for $\Phi^{+}(z_i)$, $S(\Phi^{+}(z_i))$, $\Phi^{-}(z_i)$, $S(\Phi^{-}(z_i))$ for $z_i \in Z$ are calculated. When score functions are compared (Table 5.9.), it is seen that best leaving flow belongs to alternative Z_1 and best entering flow belongs to alternative Z_1.

Table 5.9. The outcomes of IVIF-PROMETHEE I method

Alternatives	$\Phi^{+}(z_i)$	$S(\Phi^{+}(z_i))$	**Rank**
Z_1	([1.0000, 1.0000],[$4.02\text{x}10^{-28}$, $7.45\text{x}10^{-23}$])	1.0000000	1
Z_2	([0.9948, 0.9980],[0.0001, 0.0008])	0.9959123	4
Z_3	([0.9500, 0.9712],[0.0065, 0.0170])	0.9488372	5
Z_4	([1.0000, 1.0000],[$3.21\text{x}10^{-15}$, $1.95\text{x}10^{-12}$])	0.9999999	2
Z_5	([0.9995, 0.9999],[$3.08\text{x}10^{-6}$, $1.95\text{x}10^{-12}$])	0.9996752	3
Alternatives	$\Phi^{-}(z_i)$	$S(\Phi^{-}(z_i))$	**Rank**
Z_1	([0.0000, 0.0000],[1.0000, 1.0000])	-1.0000000	1
Z_2	([1.0000, 1.0000],[0.0000, 0.0000])	1.0000000	4
Z_3	([1.0000, 1.0000],[0.0000, 0.0000])	1.0000000	5
Z_4	([0.9993, 0.9998],[0.0000, 0.0001])	0.9995131	2
Z_5	([1.0000, 1.0000],[0.0000, 0.0000])	0.9999999	3

The procedure of IVIF- PROMETHEE I method gives the following results:

$$S(\Phi^{+}(z_1)) > S(\Phi^{+}(z_4)) > S(\Phi^{+}(z_5)) > S(\Phi^{+}(z_2)) > S(\Phi^{+}(z_3))$$

$$S(\Phi^{-}(z_1)) < S(\Phi^{-}(z_4)) < S(\Phi^{-}(z_5)) < S(\Phi^{-}(z_2)) < S(\Phi^{-}(z_3))$$

There is no incomparability, therefore, IVIF- PROMETHEE I results in the partial preorder of alternatives as $z_1 \succ^{I} z_4 \succ^{I} z_5 \succ^{I} z_2 \succ^{I} z_3$. .Although the ranking of alternatives is found, because the score values are very close to each other, IVIF-PROMETHEE II procedure is also applied.

Table 5.10. The outcomes of the IVIF-PROMETHEE II method

Alternatives	$S(\Phi(z_i)) = S(\Phi^{+}(z_i)) - S(\Phi^{-}(z_i))$	Rank
Z_1	2.000000000	1
Z_2	-0.004087703	4
Z_3	-0.051162829	5
Z_4	0.000486873	2
Z_5	-0.000324796	3

The scores of each net flow $\Phi(z_i)$ are given in table 5.10. According to IVIF-PROMETHEE II method, Z_1 is determined as the best alternative and the complete pre-order of the alternatives are defined as $z_1 \succ^{I} z_4 \succ^{I} z_5 \succ^{I} z_2 \succ^{I} z_3$. It is concluded that division of pulmonary diseases service outranks other divisions and division of otorhinolaryngology is the worst among all divisions in evaluation. Hygiene and comfort of patient rooms criterion has the best core for pulmonary diseases service, while the behavior of doctors and medical personnel to the patients is the worst criterion for pulmonary diseases service. On the other hand, modern and sufficient medical equipment in the hospital criterion is the best criterion for otorhinolaryngology.

6. CONCLUSIONS

Nowadays, in an intensive competition environment, importance of service quality has increased considerably. Customer perception of service quality is very important. Perceived service quality is quite effective for determining customers' behavioral purpose and providing customer satisfaction. The perceived service quality is the evaluation of service quality provided by service provider. Perceived service quality of customers may affect their future behavior.

One of the most significant branch of the service industry is healthcare sector. Hospitals that present service in healthcare sector and service quality of these hospitals is quite effective on customer behavior. Measuring patients satisfaction degrees and understanding their perceptions are necessary for quality improvement activities.

It is very important for hospitals to present qualified services in order to be able to stay and be preferred in an competitive environment. Hospital management need to know patients' expectations related to service presentation and features to be included in a service. Therefore, providing a service that patients and their relatives will be satisfied and making them a loyal customer will be possible.

Evaluation of hospital service quality is a complicated decision making problem containing multiple criteria. Besides, by nature, a significant amount of uncertainty presents for the evaluation procedure. In this thesis, to reflect the problem's fuzzy nature, an IVIF-PROMETHEE approach is applied to measure service quality of five divisions of a hospital. PROMETHEE is a powerful method by providing the decision maker the opportunity of choosing among generalized criteria types and related parameters. IVIF sets are considered an appropriate tool because of the complexity and vagueness of healthcare systems. Criteria depend on SERVQUAL model are determined and a survey including these criteria is applied to patients. By using the outcomes of the survey, IVIF-PROMETHEE method is implemented. In order to identify the consistency of patients, Cronbach's alpha is calculated and it suggests high internal consistency. Analysis of IVIF-PROMETHEE concludes that pulmonary diseases division is the best division since it has the highest net flow score among other divisions. Using level of divisions may ensure a good starting point for the quality development efforts.

This study provide a guide to the service quality improvement studies of other hospitals. It should be noted that the number of criteria and their weight can differ from hospital to hospital due to patients' differences. In this study, adult outpatients are responded to the questionnaire.

For the future research, other MCDA techniques can be used, such as IVIF-TOPSIS and IVIF-VIKOR. Criteria set can be extended.

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APPENDIX

Appendix1: The classification of literature review studies in hospital service quality evaluation

Author	Methodologies	Evaluation Area	Criteria
Birsel et al., 2006	AHP and Fuzzy PROMETHEE	Turkish hospital web sites	Seven major e-service quality dimensions tangibles, reliability, responsiveness, confidence, empathy, quality of information, and integration of communication issues of Web sites.
Zaim et al., 2008	DEA	Evaluating Efficiency of 12 Hospitals Through Total Quality Management	Role of divisional top management and quality policy, quality data and reporting, employee relations, process management,
Herrera et al., 2008	AHP	Information and Communication Technology Network System in three hospitals in Chile.	Functionality, efficiency, reliability, availability, serviceability
Khan et al., 2010	AHP	SERVQUAL of three hospitals from the southern region of India	Tangibility, Reliability, Responsiveness, Empathy, Assurance
Shieh et al., 2010	DEMATEL	Service quality of a hospital in Taiwan	7 major criteria based on the SERVQUAL
Buyukozkan, Ciftci, 2010	Fuzzy AHP and Fuzzy TOPSIS	Web sites of 13 hospitals.	Tangibility, Responsiveness, Reliability, Information quality, Assurance, Empathy
Lee et al., 2010	AHP, TOPSIS Fuzzy Set Theory	4 online auctions service quality	Tangibility, Reliability, Responsiveness, Assurance, Empathy

Afkham et al., 2011	AHP and fuzzy TOPSIS	Service qualities of four hospitals in Iran.	Tangibility, Reliability, Responsiveness, Assurance, Empathy
Chang, 2011	A fuzzy preference relation approach	Service quality of 4 public hospitals	Hospital Environment, Service Attitude, Pharmacy Treatment, Professional Capability, Administrative Policy
Buyukozkan et al., 2011	Fuzzy AHP	Service quality of four hospitals	Tangibility, Responsiveness, Reliability, Assurance, Empathy, Professinalism
Buyukozkan, Ciftci, 2012	Fuzzy AHP and Fuzzy TOPSIS	Electronic Service Quality of Hospitals	Tangibility, Responsiveness, Reliability, Information Quality, Assurance, Empathy
Ho, 2012	Fuzzy AHP	Evaluation indexes of Health Management Center Health	Health Management, Personnel Service, Health Examination Service, Marketing, Environment
Wollmann et al., 2012	AHP	Evaluation the service quality of seven health service providers in Southern Brazil	Location, Effectiveness, Promptness, Ease of access, Price, Diversity of available doctors and centers
Altuntas et al., 2012	AHP and ANP	Service Quality of three hospitals in Turkey	Tangibility, Reliability, Responsiveness, Assurance, Empathy
Sinimole, 2012	Fuzzy AHP	Service quality of four large hospitals in India	Tangibility, Reliability, Responsiveness, Assurance, Empathy
Hojati et al., 2012	Balanced Score Card and ANP	Surgery department of a hospital hospitals in Iran	Tangibility, responsiveness, reliability, assurance, empathy
Hamidi et al., 2012	ANP and Fuzzy TOPSIS	Electronic Service Quality of Hospitals	Tangibility, responsiveness, reliability, information quality, assurance, empathy.
Basu, Bhola, 2014	TOPSIS	Service quality determinants in IT	Operational Effciency, Cost Control, Income and Growth, Clinical and Medical Quality and Productivity

Gul et al., 2014	DEMATEL	Evaluation of quality of service in a private medical center in Istanbul	Reliable service, Quick service Well-equipped personnel, Hygienic and comfortable environment, Waiting times
Chang, 2014	Fuzzy VIKOR	Service quality of 5 hospitals	Hospital equipment, Service attitude, Pharmacy and medical treatment, Professional capability, Administrative policy, Hospital sanitation and environment
Akdag, 2014	Fuzzy MCDM (AHP AND TOPSIS)	Service quality of some Turkish hospitals.	tangibility, reliability, responsiveness, assurance, empathy
Manolitzas et al., 2014	The Multicriteria Satisfaction Analysis (MUSA)	Evaluation of patient satisfaction in emergency department	Cleanliness, Waiting room, Access to the hospital, Courtesy, friendliness and professional attitude
Aktas et al., 2015	AHP	Service quality of three Turkish hospitals.	information system, staff attributes, physical conditions, and department qualifications
Birdogan, İskender, 2015	Fuzzy AHP and Fuzzy TOPSIS	Service quality of hospitals	Tangibility, Reliability, Responsiveness, Assurance, Empathy
Alimohammadzadeh et al., 2015	AHP	Radiology departments of 6 Tehran educational hospitals	Safety, quality improvement and data accumulation, Requirements & facilities, Management & organizing, Management & empowerment of human resources
Taskin et al., 2015	Fuzzy VIKOR, Fuzzy ANP and Fuzzy DEMATEL	two public and three private hospitals in Turkey	Patient Satisfaction, Education and Resarch, Institutation, Administrive Policy, Financial Aspects, Infrastructure
Felice, Petrillo, 2015	AHP	Evaluation of economic prospective, social prospective and strategic prospective	Patient-centered care, Reliability, Costs, Stakeholders/Suppliers

Mirbargkar, Zadmehr, 2015	ANP, Fuzzy TOPSIS	Assessing the quality of electronic services of three hospitals	Tangibility, Responsiveness, Reliability, Information quality, Assurance and Empathy
Drosos et al., 2015	MUSA	Evaluation the patient satisfaction treated by the Greek Red Cross	Services, Nursing Staff, Patient service
Lupo, 2016	Fuzzy AHP	Service quality of nine relevant public hospitals.	Healthcare staff, Responsiveness, Relationships, Support services
Shafii et al., 2016	Fuzzy AHP and TOPSIS	Orthopedics,Obstetrics,Cardiac,Surgery of training hospitals in Yazd University of Medical Sciences	Responsiveness, assurance, security, tangibles, health communication and Patient orientation
Khanjankhani et al., 2016	DEMATEL and TOPSIS	Evaluation of the patients' perceived quality in three hospitals	Responsiveness, assurance, security, tangibility, communication, and patient orientation
Oyatoye et al., 2016	AHP	Evaluation the proportional weight of five criteria in measuring the quality of service.	Tangibility, Reliability, Responsiveness Assurance Empathy,
Amole et al., 2015	AHP	six public teaching hospitals	Tangibility, Reliability Responsiveness Assurance Empathy, Effective communication, Waiting time
Zhi-min, Dan, 2005	Fuzzy Multiple Index Approach	Assessment the service quality of three hospitals	The condition of therapy service, security of theraphy, outfit service measure of hospital, affiliated service establishment of hospital
Khan et al., 2012	AHP	Assesment of service quality of five hospitals in India	Tangibility Reliability Responsiveness Empathy Assurance
Hsu and Pan, 2009	AHP and Monte Carlo Simulation	Service quality of a large dental service chain	Interaction quality, environment quality, result quality

Birsen et al., 2006	AHP and Fuzzy PROMETHEE	Seven major e-service quality dimensions tangibles, reliability, responsiveness, confidence, empathy, quality of information, and integration of communication issues of Web sites.	Turkish hospital web sites

Appendix2: Survey Applied to Patients

Education Status:

Primary School Secondary School High School University Master/PHD

Age:

15-24 25-64 65+

Gender:

Male Female

Job status

Retired

Employed Not Employed Retired

Polyclinic Evaluation	Very very Good	Very Good	Good	Medium good	Fair	Medium bad	Bad	Very Bad	Very Very Bad
Doctors are reassuring									
Treatments to be applied like exercises and drugs are explained understandable									
Equipments in hospital are modern and adequate									
Information and experience of doctors are adequate for diagnosis and treatment									
Waiting Time for Inspection									
Cleanliness of waiting area									
Cleanliness of inspection rooms									
Air Condition and temperature of waiting rooms									
Air Condition and temperature of inspection rooms									
Adequate of seats in waiting rooms									

Appendix2(Continued): Survey Applied to Patients

Importance Level of Criteria	Very Important	Important	Less Important	Not Important	Never Important
Doctors are reassuring					
Treatments to be applied like exercises and drugs are explained understandable					
Equipments in hospital are modern and adequate					
Information and experience of doctors are adequate for diagnosis and treatment					
Waiting Time for Inspection					
Hygiene and cleanliness of waiting area					
Hygiene and cleanliness of inspection rooms					
Air Condition and temperature of waiting rooms					
Air Condition and temperature of inspection rooms					
Adequate of seats in waiting rooms					

PERSONAL INFORMATION

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EDUCATION

2014- :Marmara University, Industrial Engineering, M.S.

2008-2013: İstanbul Kültür University, Industrial Engineering, B.Sc.

2004-2008: Büyükşehir Hüseyin Yıldız Anatolian High School

WORK INFO

2011-2012 July: Perfetti Van Melle - Production Internship

2011-2012 August: Arçelik A.Ş. - Human Resources Internship

2013 September - 2015 December: Istanbul Kültür University, Engineering Faculty, Department of Industrial Engineering - Research Assistant

2015 December - 2016 December BSH Bosch Siemens Home Appliences Group – Method Engineer

2016 December – Continue BSH Bosch Siemens Home Appliences Group – Financial Controller