A SERVICE LEVEL IMPROVEMENT METHODOLOGY FOR PUBLIC TRANSPORTATION

(TOPLU TAŞIMA HİZMET SEVİYESİNİN GELİŞTİRİLMESİ İÇİN BİR YÖNTEM ÖNERİSİ)

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LIST OF SYMBOLS

AHP : Analytic Hierarchy Process
ANP : Analytic Network Process
CODAS : Combinative Distance-Based Assessment
COPRAS : Complex Proportional Assessment
DEMATEL : The Decision Making Trial and Evaluation Laboratory
EDAS : Evaluation based on Distance from Average Solution
ELECTRE : The Elimination And Choice Translating Reality
EN13816 : European Standard for transportation service quality
GRA : Grey Relation Analysis
IETT : General Directorate of Istanbul Electricity Tramway and Tunnel
IOAS : Istanbul Bus Operations Inc.
IT2FSs : Interval Type-2 Fuzzy Sets
MABAC : Multi-Attributive Border Approximation Area Comparison
MCDA : Multi Criteria Decision Analysis
MCDM : Multi Criteria Decision Making
MCIC : Multi Criteria Inventory Classification
MOORA : Multi-Objective Optimization On The Basis Of Ratio Analysis
OECD : The Organisation for Economic Co-operation and Development
OHO : Private Public Transportation Buses
SAW : Simple Additive Weighting
SQ : Service Quality
SWARA : Step-Wise Weight Assessment Ratio Analysis
SWOT : Strengths, Weaknesses, Opportunities and Threats Analysis
TOPSIS : The Technique for Order Preference by Similarity to an Ideal Solution
VIKOR : Vise Kriterijumska Optimizacija I Kompromisno Resenje
WASPAS : Weighted Aggregated Sum Product Assessment

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ABSTRACT

Quality of service is one of the most important agents which encourages the use of public transportation systems. Therefore, service quality criteria for public transportation buses in Istanbul are defined systematically and their performance is measured regularly by applying customer satisfaction surveys. To obtain high customer satisfaction levels is of great importance for public transportation authorities. This study aims to propose a convenient methodology for the evaluation of customer satisfaction levels to show and improve service level for each bus operator in Istanbul. An interval type-2 fuzzy EDAS method is proposed for the evaluation and improvement of public transportation bus operators' service level based on customer satisfaction surveys. In total, 3.350 customer satisfaction surveys are conducted by IETT to investigate the satisfaction levels in year 2017. The evaluation criteria are based on EN13816 criteria for each bus operator, the importance level of each criteria are determined from the passengers' perspective. Furthermore, the proposed model reveals improvement opportunities for each operator. The environmental impact criteria is the worst scored criteria that needs to be improved among all three bus operators. Also, we conclude with specific suggestions for each bus operator. The proposed approach contributes decision makers to determine future investment fields for service level improvement meanwhile it shows a general level for the operational shortcomings of the service provided. For further research, this method can be applied for specific bus transit routes in order to measure the service level of each bus transit route. Moreover, the proposed model can be modified in order to analyze the relation between customer satisfaction and customer loyalty for future work.

ÖZET

Hizmet kalitesi, toplu taşıma sistemlerinin kullanımını teşvik eden en önemli unsurlardan biridir. Bu nedenle, İstanbul'daki toplu taşıma otobüsleri için hizmet kalitesi kriterleri sistematik olarak tanımlanmakta ve müşteri memnuniyeti anketleri uygulanarak performansları düzenli olarak ölçülmektedir. Toplu taşıma otoriteleri için yüksek müşteri memnuniyeti seviyelerinin elde edilmesi büyük önem taşımaktadır. Bu çalışma, İstanbul'daki her otobüs operatörünün hizmet düzeyini belirlemek ve iyileştirmek için müşteri memnuniyeti seviyelerinin değerlendirilmesinde uygun bir metodoloji önermeyi amaçlamaktadır. Toplu taşıma otobüs operatörlerinin hizmet seviyelerinin müşteri memnuniyeti anketlerine dayanarak değerlendirilmesi ve iyileştirilmesi için aralıklı tip 2 bulanık EDAS yöntemi önerilmiştir. Memnuniyet düzeylerini araştırmak amacıyla 2017 yılında İETT tarafından toplam 3.350 adet müşteri memnuniyeti anketi yapılmıştır. Değerlendirme kriterleri, her operatör için EN13816 kriterlerine dayanmaktadır, kriterlerin önem seviyesi ise yolcuların bakış açısına göre belirlenmiştir. Ayrıca, önerilen model her operatör için iyileştirme fırsatları ortaya koymaktadır. Her üç operatör için çevresel etki kriteri memnuniyeti en düşük kriter olmuştur. Bunların dışında, her operatör için ayrıca iyileştirme önerileri sunulmuştur. Önerilen yaklaşım, karar vericilerin hizmet seviyesini iyileştirmek için gelecekteki yatırım alanlarınının belirlenmesine katkı sağlarken, sunulan hizmetin operasyonel eksikliklerinin analiz edilmesi için de genel hizmet seviyesini göstermektedir. Gelecek araşatırmalar için yapılan, bu çalışma belirli hatlara uygulanarak hat bazlı hizmet seviyesi ölçülebilir. Ayrıca, önerilen model müşteri memnuniyeti ve müşteri sadakati arasındaki ilişkiyi analiz edecek şekilde geliştirilebilir.

1. INTRODUCTION

The role of urban public transport has been increasing due to increasing population and economic development of the cities. Enhancing urban public transport has become an important concern as a consequence of the need for mobility. Developing high quality and cost efficient transportation systems with limited resources has become a significant challenge for transportation planners.

Passenger transport includes all transport systems that passengers use, other than their own vehicles. There are many passenger transport systems both at national and international level. One of these systems is the urban public transport which covers the journeys within the boundaries of a city and occupies an important place within the whole transport system.

The urban public transport can be described in the most comprehensive way; “Continuous services without regard to the means of transport, vehicle and infrastructure ownership, the length of the journey, the mode of payment and the legal status of service providers, which is open to everyone, with fixed timetables, frequencies or operating periods announced to the public, with fixed routes and bus stops or starting and ending points or defined operating area with a published fee.” (European Committee for Standardization, 2002).

It can be seen that the most widely used public transportation system is bus transportation in our country. Although some of the travel demand in the cities is met partially with increasing rail system investments recently, bus transportation will maintain its effectiveness for a longer period of time. Therefore, short and medium term solutions for bus transportation are generally trying to meet the same travel demand at a lower cost without lowering the service level.

Public transportation systems has a straight impact on both economic and social perspectives of the city residents (Tang and Waters, 2005). In order to direct people to public transportation systems, it is necessary to meet the transportation demands of the increasing population by creating comfortable and safe public transportation systems with high capacity and service quality. With this regard, providing solutions for transport issues is of high significance for the municipality of Istanbul to reinforce urban mobility.

Providing public transport systems high service level and adequate capacity will lower the private vehicle use and will have a direct effect on traffic congestion in crowded cities like Istanbul. This will result in decreased CO2 emissions caused by vehicles with regard to environmental impact (Litman, 2008). Furthermore, sustainable public transportation systems has many other positive impacts by means of moves down incident ratios, lowers fuel utilization and allows high urban mobility opportunities for all socioeconomic groups (APTA, 2007).

To enhance the service level of public transportation systems becomes significant to measure the quality of service. Conducting customer satisfaction surveys is one of the ways to measure the service quality by passengers' view so that the level of service and fields need to be improved can be derived from the outcomes of the survey.

Multi Criteria Decision Making (MCDM) is a methodology which has been commonly used by many investigators (Mardani et al., 2015a). This methodology enables decision makers to evaluate and choose between alternatives by ranking them from the best performing to the worst with regard to their predilections beneath contradictory criteria.

Amaral and Costa (2014) stated that a MCDM method should consist of the main features listed below:

- Evaluation alternatives,
- Evaluation criteria towards which the alternatives are assessed,
- Performance ratings that represents the worth of an alternative with regard to each criteria,
- Weights of criteria which quantifies the relative importance of each criterion confronted with each other.

Evaluation based on Distance from Average Solution (EDAS) method is a relatively new method firstly proposed by Ghorabaee and his friends as an alternative to the previously studied MCDM methods. The EDAS method considers the average solution for the evaluation of alternatives. The validity of this method was proved by comparing it with existing MCDM techniques (Ghorabaee et al., 2015a).

Since the evaluation procedure in MCDM problems usually includes vagueness, imprecise information is unavoidable due to the nature of decision-making problems. Therefore, many studies combined multi criteria decision-making techniques with fuzzy sets as stated in the comprehensive review article of Mardani et al. (2015b).

Mendel et al. (2006), proposed interval type-2 fuzzy sets (IT2FSs), a specific kind of general type-2 fuzzy sets which eliminates the complex calculation efforts. IT2FSs has been used widely, due to its simplicity and convenience for projecting uncertainties compared with type-2 fuzzy sets in multi-criteria decision-making problems (Kahraman et al., 2014, Çelik et al., 2015).

This study aims to propose a service level improvement methodology for public transportation bus operators in Istanbul. The satisfaction levels of public transport passengers are evaluated in Istanbul by using customer satisfaction surveys. An interval type-2 fuzzy EDAS methodology is proposed to assess the service level in public transport. Thereafter, the criteria required to be enhanced are decided and several enhancement recommendations are made for each public transportation bus operators to increase the service level.

The main contributions of the proposed approach are as follows: First, the importance level of each criteria and the performance values of each alternative are determined from the passengers' perspective. Second, it involves multiple criteria for assessment by using EDAS method and by using interval type-2 fuzzy numbers the imprecise and vague information is eliminated and it combines customer satisfaction evaluation in public transportation with EDAS method by a real case application. Finally, several improvement suggestions are made for each alternative to enhance the service level provided.

The remainder of this study is organized as follows: Section 2 offers a brief literature on public transportation systems, MCDM techniques applied on transportation problems and applications of EDAS method. Section 3 gives a brief information about the methodology which will be used further for this research. Section 4 offers a numerical application of the proposed method for evaluating customer satisfaction of bus operators in Istanbul and makes suggestions for each operator to further development. Section 5 concludes briefly with proposals for further research.

2. LITERATURE REVIEW

In this part of the study, a comprehensive literature review is hold out, considering public transportation, MCDM applications in public transportation and the EDAS methodology applications.

2.1 Public Transportation

The increasing urban traffic demand due to rapid increase in population and fast development of the economy resulted in a need for enhancing urban public transport by means of higher service quality, efficiency with fast and cost effective system implementations. A considerable challenge for transport planners now is to develop a high quality transport system under limited funding.

The transport sector will continue to have a major impact on society and the environment in the future – as a means of transportation, as an oil-consuming industry and as a source of greenhouse gases (Siedler, 2014). Concerns over severe traffic congestion, environmental pollution and energy security issues have prompted decision-makers to look for Mass Transit systems to mitigate traffic problems (Deng & Nelson, 2012).

Sustainability is a requirement for modern public transportation networks, as these are expected to play a critical role in environment-friendly transportation systems (Pterna, 2015). Sustainable development is an important and strategic priority for global nations which requires simultaneously satisfying multiple conflicting objectives involving social, economic, energy, and environmental constraints (Jayaraman et al., 2015).

The Earth Summit in Rio de Janeiro (1992) also focalized on encouraging sustainable land-use arrangement and administration, and supporting sustainable energy and transportation systems in human habitations. "The ability to access jobs, education and public service is a fundamental part of human development. An efficient and cost effective public transport essentially connects people to daily life."

A major amount of cities along the world does not have enough developed public transportation services as they ought to be; and accordingly, the mobility of people is left to private vehicles and poor quality transit operations. As a consequence, these cities front vigorous traffic congestion, accidents, air and noise pollution and loss of a sense of society (Wright et al., 2007).

To achieve sustainable development it is crucial to take urban transport into account owing to the fact that it has the lowest share in sustainable sectors of urban development. The growing usage of private vehicles and the declining usage of public transport and non-motorized transport modes constitutes unsustainable expansion in urban transport. The outcome of this tendency results in; reliance on petroleum, which is a non-renewable and limited outer source requiring import for many countries, arising greenhouse gas emissions causing global warming and environmental pollution, major accidental costs, time depletion in traffic and imbalance by means of accessibility. To provide effective and sustainable solutions to transportation systems all planning, executing, operating and reporting features related with transportation systems need to be based on social, environmental, economic and cultural impact fields (Henning et al., 2011).

The unfavorable environmental outcomes of automobile dependent expansion is not only global warming, but also depletion of the ozone layer, effuse of toxic materials and consuming of the natural resources. Furthermore, these toxic substances harms countryside and soil (Kassens, 2009). Moreover, automobile dependent growth results in urban spread and large road constructions which quickly spends natural landscape and converts it into built environment and asphalt (Newman and Kenworthy, 2000).

Dependency on automobiles also results in serious economic problems. All over the world the transportation sector is more or less entirely in need for petroleum. EU Transport White Paper (2001), reported that 98% of fuels and energy consumed in this sector is relied on petroleum, which is a speedily decreasing non-renewable resource. OECD (1996), defined sustainable transport as a system which does not threaten public welfare or ecosystems, and underlines that this system should be capable of satisfying mobility demands by utilizing renewable resources below a proportion of their renewal rates. Meanwhile, keeping the utilization of non-renewable resources, like petroleum, below a proportion of development of the renewal replacements. Therefore, the superior reliance on petroleum is one of the features that needs substantial change.

Automobile dependency rises also a number of obstacles which confronts sustainable development from social features too. Number of cars both in the traffic and parking on city streets prevents street life as well as social interaction. Because of disorganized development which automobile permits, sense of society derogates. This is additionally intensified with suburban way of livings which isolate people in their remote residential areas and in their automobiles (Yüce, 2013). Furthermore, automobile-based transport infrastructure composes a system which benefits car users while disrupting accessibility for those who don’t have or drive a car (Newman and Kenworthy, 2000).

With regard to sustainable transportation notion, motorized vehicles consuming renewable and clean energy resources should be launched and public transportation, and non-motorized transportation like pedestrian and bicycle transportation should be prioritized in policy establishment. By the meantime private car usage should be restricted and dissuaded in urban areas. Taking into account all the negativities related to with considerable automobile usage it is of great importance that automobile based transportation systems should be converted to a more balanced, integrated and particularly accessible transportation systems (Urbanization Council, 2009, Ministry of Public Works and Settlement). Good public transport networks and high service quality are usually considered to be the main basis of such accessible urban systems.

The necessity to decrease automobile dependency figures out that an important focus on public transportation needs to be maintained to enable sustainable development. Additional alternatives to the automobile are non-motorized modes like bicycle and pedestrian transport, nevertheless especially in big metropolitan cities, these non-motorized systems cannot be as effective alternatives as public transport, because of higher travel distances.

Performance measures support managers' decision-making processes. The quality of a decision depends largely on the quality of the measure. For this reason, measurement is a very important process of management. Therefore, performance measures such as efficiency and productivity are important in terms of improving the performance of the system and ensuring its sustainability and service quality.

In addition, measuring service quality also provides a control mechanism for managers. In particular, the control mechanism in services where public resources are used is important in terms of not wasting resources and optimally assessing them. Public transport service operations has a considerable impact on the budget of public institutions. In addition, only a little part of these expenses is saved back by passenger tickets. It is very important to measure technical efficiency to show how the resources of public enterprises are allocated. It can be seen from the literature, the efficiency measures of public transportation has been of great interest.

Fielding et al. (1985) has explained the growing importance of performance evaluation in urban public transport systems to the demands of public institutions that provide financial support to these systems, and in part to the willingness of managers to improve the performance of institutions. Similarly, Talley and Anderson (1981) emphasized the importance of performance evaluation of transport systems because of the increased financial support of the state transport systems. The authors investigated whether the same number of passengers could be transported with less financial support in their studies, which proofs that technical efficiency has gained importance.

Until 1970's, when the urban public transport sector was predominantly operated by the private sector, the most significant and unique outcome of public transport was seen as profitability. Due to the decline of passengers using public transport systems since 1950's, the private sector began to withdraw from urban transport systems and urban transport service started to be operated by the public sector and different performance dimensions gained importance (Karlaftis and McCarthy, 1997). Accordingly, researchers have sought to develop measures to ensure service quality for urban public transport systems.

In order to ensure a sustainable transport plan and policy, it is significant that public transport systems develop advanced systems with high capacity, improve accessibility and increase service quality of the existing systems. Providing high service quality transport systems will attract people to use public transport which will contribute to environmental development by means of decreasing automobile-dependency.

Table 2.1a and Table 2.1b shows a brief review of studies done in different areas related with public transportation.

Table 2.1a: Literature review of public transportation studies

Author	Year	Analytic Technique	Problem Area
Dell'Olio et al.	2011	Multinomial discrete choice model	Desired service quality by transport users
Chen and Xu	2012	Goal programming	Network design problem
Shirzadi et al.	2013	MCDM	Mode selection
Caulfield et al.	2013	Data envelopment analysis	Transport mode evaluation
Bouhana et al.	2013	Choquet integral	Personalized itinerary in multimodal systems
Bilişik et al.	2013	SERVQUAL	Service quality
Hassan et al.	2013	TOPSIS	Performance evaluation

Table 2.1b: Literature review of public transportation studies

Author	Year	Analytic Technique	Problem Area
Lupo	2013b	Fuzzy-AHP	Customer satisfaction analysis
Liu and Teng	2014	Simulation based empirical approach	Capacity increase
Currie and Delbosc	2014	Key performance indicators	Transit performance
Tao et al.	2014	Data mining	Passenger travel behavior
Georgiadis et al.	2014	Clustering algorithm	Route performance analysis
Ceder et al.	2015	Optimization	Transit stop placement
Zilske and Nagel	2016	Simulation model	Travel demand management
Bhaskar et al.	2017	Data envelopment analysis	Route performance analysis
Moeckel and Nagel	2016	Integrated simulation model	Land use and transport models
Liou and Ceder	2017	Bi-objective bi-level model	Timetable synchronization
Sun and Cui	2018	Panel regression model	Urban public transportation infrastructure development
Li et al.	2018	Structural equation modelling	Competitiveness of public transportation
Tamaki et al.	2019	Stochastic frontier analysis	Efficiency analysis

2.2 MCDM Applications in Public Transportation

Transit service quality has long been a crucial component dominating passengers' behavior, and is one of the main leading parts of sustainable transport policies since it has a positive impact on passengers to prefer transport modes which are more efficient in energy and space (European Commission, 2007). Service quality in public transportation becomes an important task for authorities to ensure sustainable public transport. Therefore, to measure the performance of the service is a requirement for transit service providers in order to evaluate the efficiency and effectiveness of the service provided.

These measures can be used to show and assess economic performance, regulate the organization, to confront the organization’s accomplishments and hassles, to initiate service design standards and to consider community benefits (Transportation Research Board, 2003).

In public transportation systems multiple criteria and sub-criteria are considered during decision making process and decision makers both in public and private sectors are involved in this procedure (Pérez et al., 2014). Therefore, multi criteria decision-making techniques has been used widely by many researchers in the evaluation of public transportation systems. Yeh et al. (2000) utilized fuzzy MCDM analysis method to assess performance of bus transport companies. Mardani et al. (2015a) reviewed 89 papers, published from 1993 to 2015 which include MCDM techniques applied in urban passenger transport systems. They concluded that MCDM techniques are convenient to the exact decision difficulties, and it can be a powerful tool for solving problems in transportation systems.

Awasthi et al. (2011) used a integrated approach based on SERVQUAL and fuzzy TOPSIS for assessment of service quality in metro service in Montreal. They conducted the study in three steps. First, they applied a questionnaire to metro passengers based on SERVQUAL to measure the transportation service quality. Second, the linguistic responses collected from surveys were transformed into triangular fuzzy numbers and fuzzy TOPSIS methodology is applied to rank the four alternative metro lines and the first ranked alternative is chosen as the metro line with the best service quality. Lastly, a sensitivity analysis is carried out to decide the impact of criteria weights and it was concluded that the decision making is comparatively sensitive to the criteria weights.

Çelik et al. (2013) applied a hybrid novel interval type-2 fuzzy TOPSIS and GRA to assess customer satisfaction public transportation system in Istanbul. In this study, the public transportation system in Istanbul is investigated by appliying a customer satisfaction survey and then the survey data is prepared for further research by using statistical analysis and finally an integrated fuzzy MCDM approach is used for the evaluation of four different transit operators under certain criteria. In conclusion, all the alternatives are ranked and the best performing operator is obtained with suggestions for each operator to improve service level based on each evaluation criteria.

Lupo (2013) presented a new extended SERVQUAL model by combining fuzzy set theory and AHP for the performance analysis of urban public transport service in the city of Palermo (Italy). AHP method is proposed to decide the importance weights of the critical service attributes while fuzzy set theory is applied to manage the uncertain, imprecise and subjective judgements from the side of the customers. A questionnaire is established consisting of two sections. In first section, customers were asked to mention the relative importance of all service attributes and dimensions by pairwise comparisons. In second section, the customers were asked to evaluate their perceptions according to defined service attributes. A "Gaps (difference between expectations and perceptions) oriented" strategy to improve service quality is formulated and as a result difference between customers' expectations and management's perceptions has a meaningful effect on customer satisfaction level. Furthermore, a service quality improvement strategy is proposed by means of service dimensions to support the decision maker.

Celik et al. (2014), evaluated the performance of rail transit lines in Istanbul by applying an integrated statistical analysis, SERVQUAL, interval type-2 fuzzy sets and VIKOR model. The current customer satisfaction level based on attributes are determined by using surveys. The data is processed by using statistical analysis and transformed to linguistic variables by using interval type-2 fuzzy sets to eliminate the imprecise and uncertain data. Then the combined interval type-2 fuzzy sets and VIKOR model is applied to obtain the rankings of rail transit network. Five rail transit lines are evaluated under five dimensions and 26 attributes. Finally, F1 rail transit line is ranked best and several improvement directions are proposed for rail transit network in Istanbul.

Liou et al. (2014) used fuzzy DEMATEL and ANP for assessment and improvement of service quality of public transport bus companies in city of Taipei. The proposed model utilizes DEMATEL technique in order to find relationships between the criteria and combines it with ANP to calculate the influential weights of criteria. Moreover, they extended traditional performance evaluation by utilizing an information fusion technique, fuzzy integrals to combine the weighted gaps among the bus companies and to eliminate the inconsistency due to assuming that the criteria are interdependent and expectation level gaps are realized. Conclusions are made to support the managers to set priorities for improvement of service quality.

Aydın et al. (2015) presented a new hierarchical framework for evaluation of customer satisfaction in rail transit systems by combining Fuzzy-AHP, Choquet integral and trapezoidal fuzzy sets. The performance of six rail transit lines are obtained from customer satisfaction surveys. First, the relative importance of main criteria are evaluated by using fuzzy AHP. Second, the evaluation of alternatives are achieved by passengers' opinions about each sub-criteria. Fuzzy- Choquet integral method is used to order the criteria so that the data reflecting the passengers' ideas are measured in a more realistic way. Finally, the customer satisfaction levels and the criteria based best and worst scores for all rail transit lines are specified. The outcomes indicated that M4 has the best performance among all alternatives by means of customer satisfaction level. The criteria which need to be improved for each alternative are deduced and various enhancement recommendations are made for each rail transit line.

Chen (2016) used a combined model based on DEMATEL and ANP to select airline service quality improvement criteria for the airline transport industry. They constructed this combined methodology to overcome the technical restriction caused by considering the evaluation criteria to be independent in previously performed research. DEMATEL method is adopted to build correlations among evaluation criteria to obtain an impact relations map. The correlations between the four measurement criteria (safety, service, satisfaction and management) were obtained by a survey applied to airline expert group. The network evaluation structure obtained from DEMATEL is used for the ANP analysis to calculate the relative weights of the service improvement criteria. Based on the results, top five critical service quality improvement criteria are addressed and suggestions are made for each criteria to increase service quality for long-term competitive advantage.

Li et al. (2017) proposed a hybrid approach by combining Fuzzy AHP and 2-tuple fuzzy linguistic method to evaluate in-flight service quality. The study is conducted in three steps. Firstly, an assessment index system for in-flight service quality is developed by modifying SERVQUAL method. Secondly, a questionnaire is performed to evaluate criteria and sub-criteria, to determine weighs, and to identify key factors affecting in-flight service quality. Lastly, a hybrid approach is proposed based on fuzzy AHP and 2-tuple fuzzy linguistic method for in-flight service quality evaluation. The method is applied to three airlines' in-flight service quality in China. The key factors which should be taken into account by managers revealed to be flight schedule and information, employees and facilities. These criteria should be prioritized for strategic decisions in order to improve in-flight service quality.

Güner (2018), applied AHP and TOPSIS methods to measure the service quality of bus transit routes operated in province Sakarya. First, service quality attributes are determined and a questionnaire is conducted. Then AHP method is utilized to allocate weights to each criteria from the passengers' opinion. Finally, TOPSIS method is applied to evaluate and rank each bus transit route by their service quality level. The outcome of the study indicated that the most important service quality attribute is frequency, followed by capacity, route directness, air-conditioned vehicles and network coverage. It concluded that the service quality of the poor performing bus routes can be improved by proposing solutions to the most important service criteria.

The reviews of multi criteria decision making studies that evaluates service quality in public transportation are shown in Table 2.2a, Table 2.2b, Table 2.2c Table 2.2d and Table 2.2e.

Table 2.2a: Literature review of MCDM techniques in public transportation

Year	Author(s)	MCDM Technique	Application Field	Purpose of Study	Research Problem	Results and Findings
2011	Awasthi et al.	Fuzzy TOPSIS	Metro transportation	Service quality evaluation of metro transportation service in Montreal	The difficulty to perform assessment of service quality due to lack of quantitative measures and restricted information	The proposed approach proved its' ability to evaluate service quality of transportation systems under limited or deficient information
2011	Chou et al.	Fuzzy AHP	Airline industry	Evaluate the quality of service in the international air travel transportation industry.	A small number of studies assessed the quality of service in the airline industry based on the weighted SERVQUAL measurement.	Results of this paper indicate that the reliability, assurance and responsiveness are important dimensions of the service quality and safety is the most important criterion.
2013	Çelik et al.	Interval Type-2 Fuzzy TOPSIS and GRA	Public transportation	Evaluate and improve customer satisfaction in Istanbul public transportation system	The problems of public transportation system in Istanbul is investigated by using customer satisfaction surveys to improve service quality	The operators are ranked and Metrobus is found to be the best Performing alternative by means of customer satisfaction level

Table 2.2b: Literature review of MCDM techniques in public transportation

Year	Author(s)	MCDM Technique	Application Field	Purpose of Study	Research Problem	Results and Findings
2013	Chou and Ding	MCDM and IPA	Shipping industry	Assess the service quality in three international ports.	Little attention has been given to the service gap between the expectation service from the shipping carriers and the real service delivered by ports.	Results of this paper found that the proposed model is suitable for the evaluation and analysis of the service quality in international ports.
2013	Lupo	Fuzzy AHP	Public transportation	Extended SERVQUAL with a new approach to analyze the performance of urban public transport service in city Palermo	There is a need to deal with vagueness and uncertainty within The performance analysis of public transport service	The outcome of this paper revealed that management's perception of service quality has a positive impact on all dimensions of
2014	Celik et al.	Interval Type-2 Fuzzy VIKOR	Rail transit	Evaluation of Customer satisfaction levels in rail transit network in Istanbul	Due to the importance of ensuring high customer satisfaction levels is a crucial task for municipalities, the existing satisfaction levels are analyzed to propose improvement strategies in rail transit	The results indicated that the attributes which need to be improved to increase customer satisfaction are: crowdedness and passenger density, air-conditioning systems, noise level and vibration, phone services

Table 2.2c: Literature review of MCDM techniques in public transportation

Year	Author(s)	MCDM Technique	Application Field	Purpose of Study	Research Problem	Results and Findings
2014	Liou et al.	Fuzzy DEMATEL and ANP	Public transportation	To examine the main service quality criteria to be improved for the bus companies in city of Taipei by using a novel information fusion model which allows the dependent relationships among criteria to be calculated for a more realistic improvement strategy development	To avoid the inconsistency with the assumption of interdependency among evaluation criteria for service quality improvement	The result revealed that there is an important interdependent effect among criteria. The main criteria needs to be improved are safety, punctuality and interior facilities respectively
2014	Wang	DEMATEL	Airline industry	Evaluation of the service quality in the airline industry.	In practical industrial operations with limited resources, there is an urgent need to delve into the assessment guidelines that have an impact on customers when they choose an airline, which can be used as a basis for improving customer satisfaction.	Results show that aviation safety and consumer feelings of comfort during the flight have become the most important evaluation criteria that affect the quality of airline services.

Table 2.2d: Literature review of MCDM techniques in public transportation

Year	Author(s)	MCDM Technique	Application Field	Purpose of Study	Research Problem	Results and Findings
2015	Lupo	Fuzzy ELECTRE III	Airport evaluation	Assessment of the service quality of international airports.	Authors of this paper believed the assessment and accuracy are important for the quality of passenger service.	Outcomes of this study indicate that some aspects of the service quality are the main contributors to the quality of airport service.
2015	Aydın et al.	Fuzzy AHP and Choquet Integral	Rail transit	Proposed a new hierarchical methodology for customer satisfaction evaluation in Istanbul	To support transport authorities by means of decision making with the evaluation of customer satisfaction levels in rail transit	The result showed that that station comfort, time, accessibility and safety are important criteria for customer satisfaction
2016	Chen	DEMATEL and ANP	Airline industry	To choose the service quality improvement criteria for Taiwanese airline industry to obtain competitive advantage over long term	The previous studies considered the measurement dimensions to be independent leading to inadequate criteria for measuring service quality correlations among evaluation criteria are taken into account	The outcomes indicated the top five critical improvement criteria which need to be prioritized and concluded with improvement suggestions for each critical criteria for enhancing service quality to competitive advantage

Table 2.2e: Literature review of MCDM techniques in public transportation

Year	Author(s)	MCDM Technique	Application Field	Purpose of Study	Research Problem	Results and Findings
2017	Li et al.	Fuzzy AHP and 2-tuple fuzzy linguistic method	Airline industry	To propose a method for measurement and evaluation of in-flight service quality for allocating limited resources to prioritized service quality criteria	The need for evaluating in-flight service quality by eliminating information loss during human judgements while estimating their preference	The result showed that the key factors which need to be focused to improve in-flight service quality are flight schedule and information employees and facilities
2018	Güner	AHP and TOPSIS	Bus transit	To measure service quality of bus transit routes operated in city Sakarya	There is a need for service quality evaluation of bus transit routes operated in city Sakarya	The outcome of the study indicated that the most important service quality attribute is frequency followed by capacity, route directness, air-conditioned vehicles and network coverage for the examined bus transit routes

2.3 EDAS Method Applications

The EDAS method, a newly developed method as an alternative to the previously mentioned MCDM methods, will be used in this research. EDAS method was firstly proposed by Ghorabaee and his friends and compared with other MCDM techniques to prove its validity (Ghorabaee et al., 2015a). The EDAS method considers the average solution for the evaluation of alternatives.

Ghorabaee et al. (2015a) firstly introduced Evaluation based on Distance from Average Solution (EDAS) method for multi-criteria inventory classification (MCIC) problems. The results obtained by using EDAS method were compared with the results of previously used methods, it was observed that EDAS gave similar outputs as other methods in ABC classification of inventory items. In addition, the authors put forward that the proposed method can also be used for multi-criteria decision-making (MCDM) problems. They compared the EDAS method with other MCDM methods (VIKOR, TOPSIS, SAW and COPRAS) and tested the validity of the EDAS method. The comparison results were analyzed using Spearman’s correlation coefficient. According to the results, the EDAS method proved its stability in different criteria weights and consistency among other methods by achieving similar results to existing MCDM methods.

Ghorabaee et al. (2016) extended EDAS method with fuzzy logic and linguistic terms and their corresponding trapezoidal fuzzy numbers were utilized to extend the EDAS method in fuzzy environment. A real case application for supplier selection problem of a detergent manufacturer was carried out to indicate the effectiveness of the extended method. In addition, sensitivity analysis was made by changing the weight of the sub-criteria. The result showed the stability and the efficiency of the fuzzy EDAS method in solving MCDM problems.

Peng and Liu (2017) combined the EDAS method with the neutrosophic cluster method. The EDAS method was combined with the single-valued neutrosophic numbers and the model was validated with a numerical sample solution for an internet company who wants to select a software development project to invest. In addition, both objective and subjective weights were combined in this study. As a result, a new axiomatic definition of single-valued neutrosophic similarity measure and a similarity formula was constructed. Also, a novel single-valued neutrosophic soft approach in MCDM based on EDAS was explored for the first time.

Kahraman et al. (2017) developed an intuitive fuzzy EDAS method by combining the EDAS method with an interval-valued intuitionistic fuzzy numbers. This method has been used in the assessment of solid waste disposal sites. The authors used three different forms of EDAS method; crisp EDAS, ordinary fuzzy EDAS and interval-valued intuitionistic fuzzy EDAS methods to solve the problem of solid waste disposal site selection. They also carried out a sensitivity analysis by changing the criteria weights to reveal how robust decisions are obtained through the proposed intuitionistic fuzzy EDAS. They concluded that the produced rankings may vary from ordinary fuzzy EDAS (OF EDAS) to intuitionistic fuzzy EDAS because the uncertainty included by trapezoidal fuzzy sets and interval-valued intuitionistic fuzzy sets are basically different. It is suggested to use different ranking equations of EDAS and interval-valued intuitionistic fuzzy EDAS.

Ghorabaee et al. (2017) combined the interval type -2 fuzzy sets with EDAS method. The proposed method was used in the evaluation of subcontractors in the construction sector. A comparison with some existing methods and a sensitivity analysis were performed to validate the results of the proposed method. These analyses proved that the results of the extended EDAS method were relatively consistent with the other methods and had a good stability in different sets of criteria weights.

Stanujkic et al. (2017) combined gray numbers with EDAS method; thus, an extension of EDAS method based on the use of interval grey numbers emerged. The model was used in the selection of contractors for a construction project. The usability of the proposed approach was confirmed by checking the results on a previous MCDM example (Zavadskas et al., 2009).

Juodagalvienė et al. (2017) used the extended EDAS method based on the use of interval grey numbers for the selection of single-family house's plan shape. They applied SWARA method to assign relative importance of the criteria and they used the EDAS method to rank the alternatives. Finally, the usability and effectiveness of the proposed approach were checked on a known MCDM example. The results were confirmed by a comparison with an existing MCDM example to prove the usability of the proposed approach.

Ecer (2018), integrated Fuzzy AHP and EDAS to present an integrated fuzzy MCDM model and verified this model by a case study for the selection of 3PLs providers. Fuzzy AHP was used for calculating priority weights of the criteria and EDAS was applied for prioritizing 3PLs providers. Also, a sensitivity analysis is performed to discuss and explain the proposed model results. The results validated that the proposed model is an effective and efficient decision making tool for comprehensive evaluation of 3PLs provider based on the opinion of experts under fuzzy environments.

Karabasevic et al. (2018) proposed a new approach based on the EDAS method for the purpose of personnel selection. The SWARA method is utilized in order to determine the weights, whereas the EDAS method is applied in order to rank the alternatives. The usability and effectiveness of the proposed EDAS approach is considered in the conducted empirical application of the proposed model for the selection of Information Technologies Business Systems Support Experts. Based on the conducted empirical application of the proposed model, it is verified to be an effective, adjustable and an easy to use method in personnel selection.

Mathew and Sahu (2018) applied four newly developed MCDM methods, i.e. CODAS, EDAS, WASPAS and MOORA methods, in material handling equipment selection problem. Both a conveyor selection problem and an automated guided vehicle selection problem with conflicting criteria were solved with this methods. Furthermore, Spearman rank correlation coefficient was calculated between the ranks obtained by these methods. In addition, the ranks obtained by various methods were compared with the ranks of other MCDM methods and it was found that the relatively new methods CODAS, EDAS and

WASPAS had a good stability within each other. In conclusion, the new MCDM methods like CODAS, EDAS and WASPAS were effective in solving material handling equipment selection problem.

Stević et al. (2018) developed an application of fuzzy EDAS method to select the most suitable manufacturer of PVC carpentry for the apartment refurbishing. After obtaining the results, a sensitivity analysis was conducted in order to interpret the stability of the model. In conclusion, based on the conducted sensitivity analysis, the results were stable and that the model gave the best solution for manufacturer of PVC carpentry for the apartment refurbishing.

The reviews of EDAS studies and their application area are shown in Table 2.3a and Table 2.3b.

Table 2.3a: Literature review of EDAS technique and application area

Author(s) and Year	**Objective(s)**	**Technique(s)**	**Application Area**
Ghorabaee et al. (2015a)	Introduction of EDAS method for inventory classification problems and to prove its validity among other MCDM techniques	EDAS	Inventory Classification
Ghorabaee et al. (2016)	Extension of EDAS method in fuzzy environment, for supplier selection problem of a detergent manufacturer	Fuzzy EDAS	Supplier Selection
Stevic et al. (2016)	To evaluate the scenarios for city logistics by using hybrid MCDM approach based on the AHP and EDAS methods	AHP, EDAS	City Logistics
Peng and Liu (2017)	To choose a software development project for an internet company by combining EDAS method with single-valued neutrosophic numbers	A novel single-valued neutrosophic approach based on EDAS	Software Development

Table 2.3b: Literature review of EDAS technique and application area

Author(s) and Year	Objective(s)	Technique(s)	Application Area
Ghorabaee et al. (2017)	To evaluate five airlines with multiple service quality criteria by using a hybrid simulation-based assignment approach	TOPSIS, COPRAS, WASPAS, EDAS	Airline Service Quality Evaluation
Kahraman et al. (2017)	Assessment of solid waste disposal sites by combining the EDAS method with an interval-valued intuitionistic fuzzy numbers.	Intuitionistic Fuzzy EDAS	Waste Disposal Site Selection
Ghorabaee et al. (2017)	To evaluate subcontractors in the construction sector by combining interval type -2 fuzzy sets with EDAS method	Interval type -2 fuzzy EDAS	Subcontractor Evaluation
Stanujkic et al. (2017)	To select contractors for a construction project by combining grey numbers with EDAS method	EDAS based on use of interval grey numbers	Construction
Juodagalvienė et al. (2017)	Multi criteria evaluation of single-family house's plan shape based on EDAS and SWARA methods	EDAS, SWARA	Construction
Ecer (2018)	To select 3PLs providers by using integrated Fuzzy AHP and EDAS methods.	Fuzzy AHP, EDAS	3PLs Provider Selection
Karabasevic et al. (2018)	To select IT Business Systems Support Experts by using EDAS and SWARA methods	EDAS, SWARA	Personnel Selection
Karaşan et al. (2018)	To prioritize social responsibility projects by applying interval-valued neutrosophic EDAS method.	Interval-Valued Neutrosophic EDAS	Social Responsibility Project Selection
Mathew and Sahu (2018)	To apply four newly developed MCDM methods, i.e. CODAS, EDAS, WASPAS AND MOORA methods, in material handling equipment selection problem.	CODAS, EDAS, WASPAS, MOORA	Material Handling Equipment Selection
Stević et al. (2018)	To select the most suitable manufacturer of PVC carpentry for the apartment refurbishing by applying fuzzy EDAS method	Fuzzy EDAS	Manufacturer Selection

3. METHODOLOGY

In this section, first the basic definitions of interval type-2 fuzzy sets and their application with MCDM methods are briefly reviewed. Then, the proposed model interval type-2 fuzzy EDAS methodology is defined step by step.

3.1 Interval Type-2 Fuzzy Sets

Since the evaluation procedure in MCDM problems usually includes vagueness, imprecise information is unavoidable due to the nature of decision-making problems. To define the ratings of several criteria and alternatives linguistic variables are widely used in real life situations (Chen, 2000). To convert linguistic variables to fuzzy sets is a common issue since it represents the uncertainty more sensible than exact numbers (Zadeh, 1975). Therefore, many studies combined multi criteria decision-making techniques with fuzzy sets as stated in the comprehensive review article of Mardani et al. (2015b).

Type-1 fuzzy sets was proposed by Zadeh (1965) to deal with the uncertainty of multi-criteria decision-making problems. Although, type-1 fuzzy sets are capable of modelling the multi-criteria decision-making process, in some conditions a more flexible degree of uncertainty is required.

Zadeh (1975), utilized ordinary fuzzy sets and introduced type-2 fuzzy sets which allows more responsive levels of uncertainty. On the other hand, the implementation of a type-2 fuzzy set requires complex calculation operations (Mendel et al., 2006) so it hasn't become a common application method for real life situations. Mendel et al. (2006), proposed interval type-2 fuzzy sets, a specific kind of general type-2 fuzzy sets which eliminates the complex calculation efforts. IT2FSs has been used widely, due to its simplicity and convenience for projecting uncertainties compared with type-2 fuzzy sets in multi-criteria decision-making problems (Kahraman et al., 2014, Çelik et al., 2015).

Some of the recent studies based on MCDM approaches combined with the use IT2FSs are summarized in Table 3.3a, Table 3.3b and Table 3.3c respectively

Defining linguistic terms implies a variable defined by words in a natural or artificial language (Zadeh, 1975). The significance level of criteria and order of alternatives in MCDM problems are computed based on decision makers' evaluation using preset linguistic variables. Çelik et al. (2015), in their review study indicate the interval type-2 fuzzy numbers related with the linguistic terms for determining importance weights of criteria according to the pairwise comparisons as shown in Table 3.1a and Table 3.1b.

The linguistic variables are also utilized for the assessment of the alternatives to handle the complexity and difficulty of data collection process. According to review study of Çelik et al. (2015), the most applied linguistic variables by authors for ranking the alternatives are presented in Table 3.2. The proposed linguistics variables can also be used for determining importance weights of criteria.

Table 3.1a: Linguistic terms for importance weights of criteria.

Author(s)	Linguistic terms	Interval type-2 fuzzy sets
Abdullah and Najib (2014)	Equally Important	((0;0.1;0.1;0.1;1;1),(0;0.1;0.1;0.05;0.9;0.9))
	Intermediate Value	((0.1;0.2;0.2;0.3;1;1),(0.05;0.2;0.2;0.25;0.9;0.9))
	Moderately More Important	((0.2;0.3;0.3;0.4;1;1),(0.25;0.3;0.3;0.35;0.9;0.9))
	Intermediate Value	((0.3;0.4;0.4;0.5;1;1),(0.35;0.4;0.4;0.45;0.9;0.9))
	Strongly More Important	((0.4;0.5;0.5;0.6;1;1),(0.45;0.5;0.5;0.55;0.9;0.9))
	Intermediate Value	((0.5;0.6;0.6;0.7;1;1),(0.55;0.6;0.6;0.65;0.9;0.9))
	Very Strong More Important	((0.6;0.7;0.7;0.8;1;1),(0.65;0.7;0.7;0.75;0.9;0.9))
	Intermediate Value	((0.7;0.8;0.8;0.9;1;1),(0.75;0.8;0.8;0.85;0.9;0.9))
	Extremely More Important	((0.8;0.9;0.9;1;1;1),(0.85;0.9;0.9;0.95;0.9; 0.9))

Table 3.1b: Linguistic terms for importance weights of criteria.

Author(s)	Linguistic terms	Interval type-2 fuzzy sets
Kahraman et al. (2014)	Absolutely Strong	((7;8;9;9; 1;1), (7.2; 8.2; 8.8;9; 0.8; 0.8))
	Very Strong	((5;6; 8;9; 1; 1), (5.2; 6.2; 7.8; 8.8; 0.8;0.8))
	Fairly Strong	((3;4; 6; 7; 1;1), (3.2; 4.2; 5.8; 6.8; 0.8; 0.8)
	Slightly Strong	((1;2; 4; 5; 1;1), (1.2; 2.2; 3.8; 4.8;0.8;0.8))
	Exactly Equal	((1;1; 1; 1; 1;1), (1;1; 1; 1;0.8; 0.8))
Celik et al. (2014)	Absolutely Strong	((8;9;9;10;1;1), (8.5;9;9;9.5; 0.9; 0.9))
	Very Strong	((6;7; 7; 8; 1;1), (6.5;7; 7; 7.5; 0.9; 0.9))
	Fairly Strong	((4;5; 5; 6; 1;1), (4.5;5; 5; 5.5; 0.9; 0.9))
	Slightly Strong	((2;3; 3; 4; 1;1), (2.5;3; 3; 4.5; 0.9; 0.9))
	Exactly Equal	((1;1; 1; 1; 1;1), (1;1; 1; 1;0.9; 0.9))
Abdullah and Zulkifli (2015)	Very High Influence	((0.8;0.9;0.9;1;1;1),(0.85;0.9;0.9;0.95;0.9;0.9))
	High Influence	((0.6;0.7;0.7;0.8;1;1),(0.65;0.7;0.7;0.75;0.9;0.9))
	Low Influence	((0.4; 0.5; 0.5; 0.6; 1;1),(0.45; 0.5; 0.5;0.55; 0.9; 0.9))
	Very Low Influence	((0.2; 0.3; 0.3; 0.4; 1;1),(0.25; 0.3; 0.3;0.35; 0.9; 0.9))
	No Influence	((0;0.1;0.1;0.1;1;1),(0;0.1;0.1;0.05;0.9;0.9))

Table 3.2: Linguistic terms for rating of alternatives.

Author(s)	Linguistic terms	Interval type-2 fuzzy sets
Chen and Lee (2010)	Very Low	((0; 0;0; 0.1;1; 1),(0; 0;0; 0.05;0.9; 0.9))
	Low	((0; 0.1; 0.1; 0.3;1; 1),(0.05; 0.1; 0.1; 0.2; 0.9; 0.9))
	Medium Low	((0.1; 0.3; 0.3; 0.5;1; 1),(0.2; 0.3; 0.3; 0.4; 0.9; 0.9))
	Medium	((0.3; 0.5; 0.5; 0.7;1; 1),(0.4; 0.5; 0.5; 0.6; 0.9; 0.9))
	Medium High	((0.5; 0.7; 0.7; 0.9;1; 1),(0.6; 0.7; 0.7; 0.8; 0.9; 0.9))
	High	((0.7; 0.9; 0.9; 1; 1;1),(0.8; 0.9; 0.9; 0.95;0.9; 0.9))
	Very High	((0.9;1; 1;1; 1; 1),(0.95;1; 1;1; 0.9; 0.9))
Chen	Absolutely Low	((0; 0; 0; 0; 1 ;), (0; 0; 0; 0; 1))
(2013),	Very Low	((0.0075;0.0075;0.015;0.0525;0.8),(0;0;0.02; 0.07;1))
Wang and	Low	((0.0875;0.12;0.16;0.1825;0.8),(0.04;0.1;0.18;0.23;1))
Chen	Medium Low	((0.2325;0.255;0.325;0.3575;0.8),(0.17;0.22;0.36;0.42;1))
(2014),	Medium	((0.4025;0.4525;0.5375;0.5675;0.8),(0.32;0.41;0.58;0.65;1))
Chen et al.	Medium High	((0.65; 0.6725; 0.7575; 0.79; 0.8), (0.58; 0.63; 0.8;0.85;1))
(2013)	High	((0.7825;0.815;0.885;0.9075;0.8),(0.72;0.78;0.92;0.97;1)
	Very High	((0.9475; 0.985; 0.9925; 0.9925; 0.8), (0.93; 0.98; 1;1;1))
	Absolutely H.	((1; 1; 1; 1; 1;),(1;1; 1; 1; 1))

Table 3.3a: Literature review of IT2FSs combined with MCDM techniques

Author(s) and Year	**Purpose of the Study**	**Combined MCDM Approach**											
		TOPSIS	**GRA**	**VIKOR**	**SERVQUAL**	**AHP**	**PROMETHEE**	**DEMATEL**	**ANP**	**MCDA**	**MABAC**	**ELECTRE**	**EDAS**
Chen and Lee (2010)	To select personnel for a software company	X											
Celik et al. (2013)	To evaluate public transportation SQ	X	X										
Celik et al. (2014)	To evaluate CS in public transportation			X	X								
Kahraman et al. (2014)	To select the best supplier					X							
Qin et al. (2015)	To decide the best project investment			X									
Kılıç and Kaya (2016)	To prioritize cities for grants allocation	X				X							
Çelik and Gümüş (2016)	To assess the response ability and readiness of humanitarian relief org.					X	X						

Table 3.3b: Literature review of IT2FSs combined with MCDM techniques

Author(s) and Year	Purpose of the Study	Combined MCDM Approach											
		TOPSIS	GRA	VIKOR	SERVQUAL	AHP	PROMETHEE	DEMATEL	ANP	MCDA	MABAC	ELECTRE	EDAS
Soner et al. (2017)	To select hatch cover design for a bulk ship			X		X							
Deveci et al. (2017)	To select a new route for an airline company	X											
Baykasoğu et al. (2017)	To select the best SWOT - based strategy	X						X					
Şentürk et al. (2017)	To evaluate third-party logistics providers								X				
Chen (2017)	To select a landfill site									X			
Yu et. al (2017)	To select a hotel from a tourism website										X		
Çelik (2017)	To decide location of temporary shelters							X					

Table 3.3c: Literature review of IT2FSs combined with MCDM techniques

Author(s) and Year	Purpose of the Study	Combined MCDM Approach											
		TOPSIS	**GRA**	**VIKOR**	**SERVQUAL**	**AHP**	**PROMETHEE**	**DEMATEL**	**ANP**	**MCDA**	**MABAC**	**ELECTRE**	**EDAS**
Çolak and Kaya (2017)	To rank the renewable energy alternatives	X				X							
Kundu et al. (2017)	To select transportation mode									X			
Zhong and Yao (2017)	To select the best supplier											X	
Görener et al. (2017)	To evaluate the suppliers performance	X				X							
Ghorabaee et al. (2017)	To evaluate the suppliers												X
Abdullah and Zulkıflı (2018)	To measure knowledge management performance							X					

As stated above, type-2 fuzzy sets are one of the major extensions of the type-1 fuzzy sets. Type-2 fuzzy sets are demonstrated by primary and secondary membership values. The basic definitions of interval type-2 fuzzy sets are briefly stated below.

Definition 1: A type-2 fuzzy set $\tilde{\tilde{A}}$ in the universe of discourse *X* can be represented by a type-2 membership function $\mu_{\tilde{\tilde{A}}}$ expressed as follows (Mendel et al., 2006):

$$\tilde{\tilde{A}} = \{((x,u), \mu_{\tilde{\tilde{A}}}(x,u)) \mid \forall x \in X, \forall u \in J_x \subseteq [0,1], 0 \leq \mu_{\tilde{\tilde{A}}}(x,u) \leq 1\} \tag{3.1}$$

Where J_x defines an interval in [0, 1]. The type-2 fuzzy set $\tilde{\tilde{A}}$ can also expressed as follows (Mendel et al., 2006):

$$\tilde{\tilde{A}} = \int_{x \in X} \int_{u \in J_x} \mu_{\tilde{\tilde{A}}}(x,u)/(x,u) \tag{3.2}$$

Where $J_x \subseteq [0, 1]$ and $\int\int$ denotes union over all admissible x and u.

Definition 2: Let $\tilde{\tilde{A}}$ be a type-2 fuzzy set in the universe of discourse *X* defined by the type-2 membership function $\mu_{\tilde{\tilde{A}}}$. If all $\mu_{\tilde{\tilde{A}}}(x,u) = 1$, then $\tilde{\tilde{A}}$ is called an interval type-2 fuzzy set (Mendel et al., 2006). An interval type-2 fuzzy set $\tilde{\tilde{A}}$ can be considered as a specific condition of a type-2 fuzzy set, expressed as follows (Mendel et al., 2006):

$$\tilde{\tilde{A}} = \int_{x \in X} \int_{u \in Jx} 1/(x,u) \tag{3.3}$$

Where $J_x \subseteq [0, 1]$.

Definition 3: If the upper membership function and the lower membership function are both trapezoidal fuzzy sets then it is called trapezoidal interval type-2 fuzzy sets. Let $\tilde{\tilde{A}}$ be a trapezoidal interval type-2 fuzzy set. $\tilde{\tilde{A}}$ can be expressed as follows (Chen and Lee, 2010):

$$\tilde{\tilde{A}} = (\tilde{A}^T \mid T \in \{U, L\}) = a_i^T;\ H_{1A}^T;\ H_{2A}^T \mid T \in \{U, L\}, i = 1,2,3,4) \qquad (3.4)$$

Where $\tilde{A}^U$ and $\tilde{A}^L$ defines the upper and lower membership functions of $\tilde{\tilde{A}}$, respectively. $H_j^U \in [0, 1]$ and $H_j^L \in [0, 1]$ (j = 1, 2) defines the membership values of the corresponding elements a_{j+1}^U *and* a_{j+1}^L, respectively. Figure 3.1 demonstrates an example of a trapezoidal interval type-2 fuzzy sets.

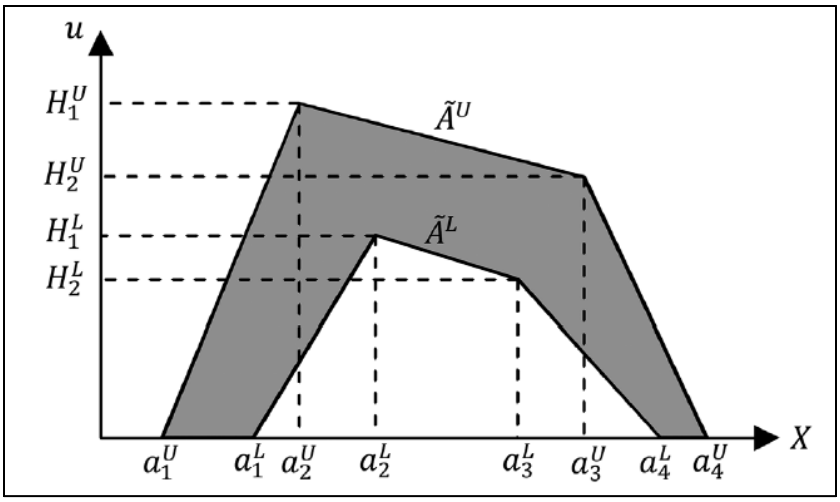

Figure 3.1: The upper and the lower trapezoidal membership functions of interval type-2 fuzzy sets (Chen & Lee, 2010)

Definition 4: Let $\tilde{\tilde{A}}$ and $\tilde{\tilde{B}}$ be two trapezoidal interval type-2 fuzzy sets and d is a crisp number, then the arithmetic calculations of $\tilde{\tilde{A}}$ and $\tilde{\tilde{B}}$ are defined as follows (Ghorabaee et al., 2015b; Ghorabaee et al., 2016b).

Where,

$$\tilde{\tilde{A}} = \left(\tilde{\mathrm{A}}^{T} \,\middle|\, T \in \{U, L\}\right) = a_{\mathrm{i}}^{T};\; H_{1A}^{T};\; H_{2A}^{T} \mid T \in \{U, L\}, i = 1,2,3,4) \tag{3.5}$$

$$\tilde{\tilde{B}} = \left(\tilde{\mathrm{B}}^{T} \,\middle|\, T \in \{U, L\}\right) = b_{\mathrm{i}}^{T};\; H_{1B}^{T};\; H_{2B}^{T} \mid T \in \{U, L\}, i = 1,2,3,4 \tag{3.6}$$

- Addition:

$$\tilde{\tilde{A}} \oplus \tilde{\tilde{B}} = (a_i^T + b_i^T; \min(H_{1A}^T, H_{1B}^T), \min(H_{2A}^T, H_{2B}^T)) \mid T \in \{U, L\}, i = 1,2,3,4) \tag{3.7}$$

$$\tilde{\tilde{A}} + d = (a_i^T + d;\; H_{1A}^T, H_{2A}^T) \mid T \in \{U, L\}, i = 1,2,3,4) \tag{3.8}$$

- Subtraction:

$$\tilde{\tilde{A}} \ominus \tilde{\tilde{B}} = (a_i^T - b_{5-i}^T; \min(H_{1A}^T, H_{1B}^T), \min(H_{2A}^T, H_{2B}^T)) \mid T \in \{U, L\}, i = 1,2,3,4) \tag{3.9}$$

- Multiplication:

$$\tilde{\tilde{A}} \otimes \tilde{\tilde{B}} = (X_i^T; \min(H_{1A}^T, H_{1B}^T), \min(H_{2A}^T, H_{2B}^T) \mid T \in \{U, L\}, i = 1,2,3,4) \tag{3.10}$$

$$X_i^T = \begin{cases} \min(a_i^T b_i^T, a_i^T b_{5-i}^T, a_{5-i}^T b_i^T, a_{5-i}^T b_{5-i}^T) \; if \; i = 1,2 \\ \max(a_i^T b_i^T, a_i^T b_{5-i}^T, a_{5-i}^T b_i^T, a_{5-i}^T b_{5-i}^T) \; if \; i = 3,4 \end{cases} \tag{3.11}$$

$$d.\ \tilde{\tilde{A}} = \begin{cases} \mathrm{d}. a_i^T; H_{1A}^T, H_{2A}^T | \; T \in \{U, L\}, i = 1,2,3,4) \; if \; d \geq 0 \\ \mathrm{d}. a_{5-i}^T; H_{1A}^T, H_{2A}^T | \; T \in \{U, L\}, i = 1,2,3,4) if \; d \leq 0 \end{cases} \tag{3.12}$$

Definition 5: The crisp score of a trapezoidal interval type-2 fuzzy set is expressed as follows (Ghorabaee et al., 2015b):

$$\mathfrak{S}\left(\tilde{\tilde{A}}\ \right) = \frac{1}{2}\left(\sum_{T \in \{U,L\}} \frac{a_i^T + (1 + H_{1A}^T) a_2^T + (1 + H_{2A}^T) a_3^T + a_4^T}{4 + H_{1A}^T + H_{2A}^T} \right) \tag{3.13}$$

Definition 6: In order to find the maximum between a trapezoidal interval type-2 fuzzy set fuzzy number and zero the following function is defined (Ghorabaee et al., 2015b).

$$\mathcal{Z}(\tilde{\tilde{A}}\ ) = \begin{cases} \tilde{\tilde{A}} \;\; if \;\; \mathfrak{S}\left(\tilde{\tilde{A}}\ \right) > 0 \\ \tilde{\tilde{0}} \;\; if \;\; \mathfrak{S}\left(\tilde{\tilde{A}}\ \right) \leq 0 \end{cases} \tag{3.14}$$

where $\tilde{\tilde{0}}$ = ((0,0,0,0;1,1), (0,0,0,0;1,1)).

3.2 Interval Type-2 Fuzzy EDAS Methodology

Ghorabaee et al. (2015) firstly introduced the EDAS method and Ghorabaee et al. (2017) extended the EDAS method by using interval type-2 fuzzy sets. The definitions which are presented in section 3.1 are used for extending the EDAS method by using interval type-2 fuzzy sets.

Suppose that we have a set of n alternatives ($\mathcal{A} = \{\mathcal{A}_{1,}\mathcal{A}_2, \dots \mathcal{A}_n\}$) a set of m criteria ($\mathcal{C} = \{\mathcal{C}_{1,}\mathcal{C}_2, \dots \mathcal{C}_m\}$) and k decision makers ($\mathcal{D} = \{\mathcal{D}_{1,}\mathcal{D}_2, \dots \mathcal{D}_k\}$). The steps of EDAS interval type-2 fuzzy sets method are presented as follows (Ghorabaee et al., 2017):

Step 1: The average decision matrix (X), is defined as follows:

$$X = [\tilde{\tilde{x}}_{ij}]_{nxm} \tag{3.15}$$

Where,

$$\tilde{\tilde{x}}_{ij} = \frac{1}{k} \bigoplus_{p=1}^{k} \tilde{\tilde{x}}_{ij}^{p} \tag{3.16}$$

and $\tilde{\tilde{x}}_{ij}^{p}$ denotes the performance value of alternative $\mathcal{A}_i$ $(1 \leq i \leq n)$ with respect to criterion $\mathcal{C}_j$ $(1 \leq j \leq m)$ assigned by the p^{th} decision maker $(1 \leq p \leq k)$.

Step 2: The matrix of criteria weights, is defined as follows:

$$W = [\tilde{\tilde{w}}_j]_{1xm} \tag{3.17}$$

Where,

$$\tilde{\tilde{w}}_j = \frac{1}{k} \bigoplus_{p=1}^{k} \tilde{\tilde{w}}_j^p \tag{3.18}$$

and $\tilde{\tilde{w}}_j^p$ denotes the weight of criterion $\mathcal{C}_j\ (1 \leq j \leq m)$ assigned by the p^{th} decision maker $(1 \leq p \leq k)$.

Step 3: Determine the matrix of average solutions, shown as follows:

$$AV = \left[\tilde{\tilde{\mathcal{M}}}_j\right]_{1xm} \tag{3.19}$$

Where,

$$\tilde{\tilde{\mathcal{M}}}_j = \frac{1}{n} \bigoplus_{i=1}^{n} \tilde{\tilde{x}}_{ij} \tag{3.20}$$

$\tilde{\tilde{\mathcal{M}}}_j$ interprets the average solutions with respect to each criterion. Therefore, the dimension of the matrix is equal to the dimension of criteria weights matrix.

Step 4: If B is the set of beneficial criteria and N is the set of non-beneficial criteria. Then the matrices of positive distance from average (PDA) and negative distance from average (NDA) are calculated with regard to the type of criteria as follows:

$$PDA = \left[\tilde{\tilde{\mathcal{p}}}_{ij}\right]_{nxm} \tag{3.21}$$

$$NDA = \left[\tilde{\tilde{n}}_{ij}\right]_{nxm} \quad (3.22)$$

$$\tilde{\tilde{p}}_{ij} = \begin{cases} \dfrac{\mathcal{Z}(\tilde{\tilde{x}}_{ij} \ominus \widetilde{\widetilde{\mathcal{M}}}_j)}{\mathfrak{S}\left(\tilde{\tilde{\mathcal{M}}}_j\right)} \; if \; j \in B \\ \dfrac{\mathcal{Z}(\tilde{\tilde{\mathcal{M}}}_j \ominus \tilde{\tilde{x}}_{ij})}{\mathfrak{S}\left(\tilde{\tilde{\mathcal{M}}}_j\right)} if \; j \in N \end{cases} \quad (3.23)$$

$$\tilde{\tilde{n}}_{ij} = \begin{cases} \dfrac{\mathcal{Z}(\tilde{\tilde{\mathcal{M}}}_j \ominus \tilde{\tilde{x}}_{ij})}{\mathfrak{S}\left(\tilde{\tilde{\mathcal{M}}}_j\right)} \; if \; j \in B \\ \dfrac{\mathcal{Z}(\tilde{\tilde{x}}_{ij} \ominus \widetilde{\widetilde{\mathcal{M}}}_j)}{\mathfrak{S}\left(\tilde{\tilde{\mathcal{M}}}_j\right)} if \; j \in N \end{cases} \quad (3.24)$$

where $\tilde{\tilde{p}}_{ij}$ and $\tilde{\tilde{n}}_{ij}$ denote the positive and negative distance of performance value of i^{th} alternative from the average solution in terms of j^{th} criterion, respectively.

Step 5: The weighted sum of positive and negative distances for all alternatives are calculated as follows:

$$\widetilde{\widetilde{sp}}_i = \bigoplus_{j=1}^{m} (\tilde{\tilde{w}}_j \otimes \tilde{\tilde{p}}_{ij}) \quad (3.25)$$

$$\widetilde{\widetilde{sn}}_i = \bigoplus_{j=1}^{m} (\tilde{\tilde{w}}_j \otimes \tilde{\tilde{n}}_{ij}) \quad (3.26)$$

Step 6: The normalized values of $\widetilde{\widetilde{sp}}_i$ and $\widetilde{\widetilde{sn}}_i$ for all alternatives are calculated as follows:

$$\widetilde{\widetilde{np}}_i = \frac{\widetilde{\widetilde{sp}}_i}{max_i(\mathfrak{S}\left(\widetilde{\widetilde{sp}}_i\right))} \tag{3.27}$$

$$\widetilde{\widetilde{nn}}_i = 1 - \frac{\widetilde{\widetilde{sn}}_i}{max_i(\mathfrak{S}\left(\widetilde{\widetilde{sn}}_i\right))} \tag{3.28}$$

Step 7: The appraisal score $\tilde{\tilde{h}}_i$ for all alternatives is calculated as follows:

$$\tilde{\tilde{h}}_i = \frac{1}{2}\,(\widetilde{\widetilde{np}}_i \oplus \widetilde{\widetilde{nn}}_i) \tag{3.29}$$

Step 8: The method proposed by Ghorabaee et al. (2014) is used in this step for computing the ranking value (*RV*) of trapezoidal interval type-2 fuzzy sets. The alternatives according to the decreasing ranking values of appraisal (*RV*) scores are ranked and the alternative with the highest appraisal score is accepted as the best option among other alternatives.

4. NUMERICAL APPLICATION

In this section of the study, the public transportation system in Istanbul is presented first, second a brief information about the survey is given. Lastly, the proposed method computations are listed according to the criteria obtained by customer satisfaction survey questions.

4.1 Public Transportation System in Istanbul

Istanbul, is the most crowded city in Turkey with a population of 15.067.724 and the population of Istanbul is growing day by day (TUIK, 2018). As a consequence, the need for mobility is increasing and the urban public transport systems are gaining crucial importance. To receive modern, safe and comfortable transportation options becomes an important concern for the inhabitants.

Urban public transport in Istanbul is carried out by road, rail and sea transport. The daily passenger (million) share of public transport modes is shown in Figure 4.1. As it can be seen, the road transportation has the highest share with 72%.

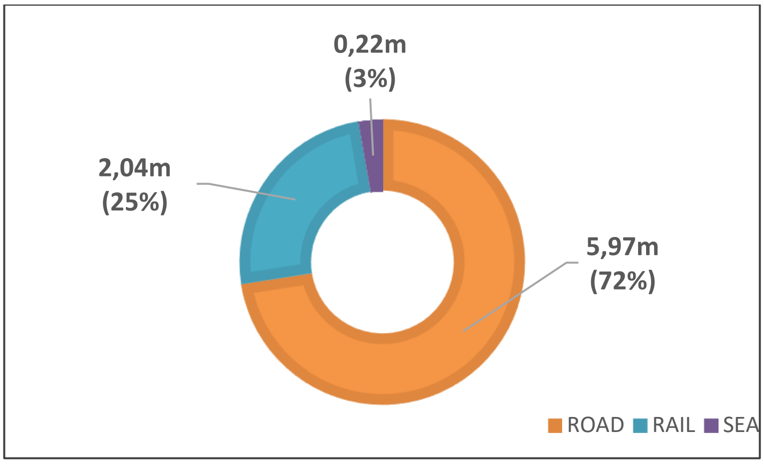

Figure 4.1: Public Transport Mode Share in Istanbul (Istanbul Transport Annual Report, 2017)

There are many different transport alternatives for passengers in Istanbul. Number of routes, number of vehicles and total length of network according to transportation types, under the classification of transportation modes, are shown in Table 4.1.

Table 4.1: Properties of Transportation Types (Istanbul Transport Annual Report, 2017)

Public Transport Mode	Type	Number of Routes	Number of Vehicles	Total Network Length (km)
Road	IETT		2.530	
	IOAS	744	1.079	6.832
	OHO		2.048	
	Metrobus	6	600	52
	Minibus	175	6.460	7.057
	Jitney	42	572	484
Rail	Metro	6	647	106,2
	Tram	2	170	34,6
	Marmaray	1	19	13,6
	Funicular	2	7	1,2
	Nostalgic Tram	2	9	4,2
	Cable Car	2	16	0,7
Sea	Ferries	24	28	
	Private Ferries	4	102	
	İDO	15	52	

In Istanbul, public transport is mostly carried out with road transport vehicles like buses, minibuses, jitneys, etc. In this part, the bus operators in Istanbul will be introduced. In Figure 4.2, the distributions of daily passengers (millions) among these operators are shown.

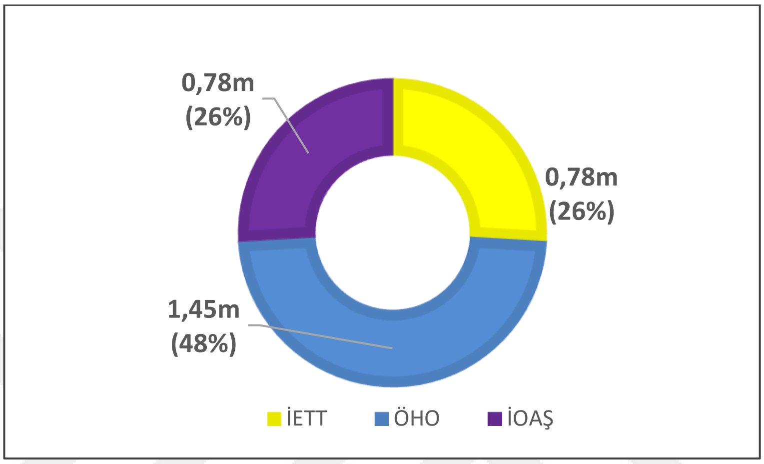

Figure 4.2: Distribution of daily passengers among bus operators (Istanbul Transport Annual Report, 2017)

The bus operators operating in Istanbul, which are the regarded as alternatives in this study are briefly introduced in below.

IETT:

General Directorate of Istanbul Electricity Tramway and Tunnel (IETT) was established in 1871 and has been giving public transportation service as a public institution affiliated to Istanbul Metropolitan Municipality. IETT provides service to passengers with buses, metrobus, nostalgic tram and tunnel.

IETT carries a daily average of 3.9 million passengers on 750 routes with 6.257 buses, 3.130 of which is operated and owned by IETT and the rest by private operators which are supervised and regulated by IETT.

IOAS:

Istanbul Bus Operations Inc. (IOAS) is company affiliated to Istanbul Metropolitan Municipality. It objects to provide passengers an appropriate and qualified public transport service, by conserving sustainable development. Otobus Inc. has 1.079 busses in its fleet.

OHO:

With the decision of Coordination of Transportation Department (UKOME) the private public bus operations are also administrated, executed and supervised by IETT since 1985. There are 2.048 vehicles in Private Public Transportation Buses (OHO).

4.2 Customer Satisfaction Survey

To measure and evaluate the services provided by IETT, which manages Istanbul road public transport in a wide area, has a great importance by means of urban public transport. Customer satisfaction surveys are widely used to measure the level of service quality in the public transport systems. IETT aims to measure the satisfaction levels and expectations of bus, metrobus and tunnel passengers in Istanbul to determine improvement opportunities in provided service quality (IETT MMA, 2017).

The questionnaire used in this study (IETT MMA, 2017) is applied both in summer and winter seasons according to the average number of passengers per day and the sample size was identified for 95% ± 0.03 confidence level, and 3.350 user interviews were conducted. Table 4.2 shows the total number of applied surveys.

Table 4.2: Number of applied surveys

	Summer	**Winter**	**Total**
Number of Surveys	1.587	1.763	**3.350**

The target number of questionnaires were determined according to the place where the survey took place, the day of the survey (weekday - weekend), the time of the survey, the type of travel card used, the status of the respondent's disability and the gender of the respondents.

In this context, the study was carried out for all survey groups according to ratios listed below:

Stops → According to Number of Passengers
Survey Day → 80% on Weekdays, 20% on Weekend,
Survey Time → 20% Morning Peak, 50% Non-Peak Hours, 30% Evening Peak Hours
Travel Card → According to Card Use Percentages
Disability Status → According to the proportion of disabled customers,
Gender → 40% Female / 60% Male

Demographic information and the questions about passengers' journey specifications like journey frequency, reason, alternatives and approximate travel time were asked in the customer satisfaction survey. Figure 4.3a, Figure 4.3b and Figure 4.4a and Figure 4.4b show these information respectively.

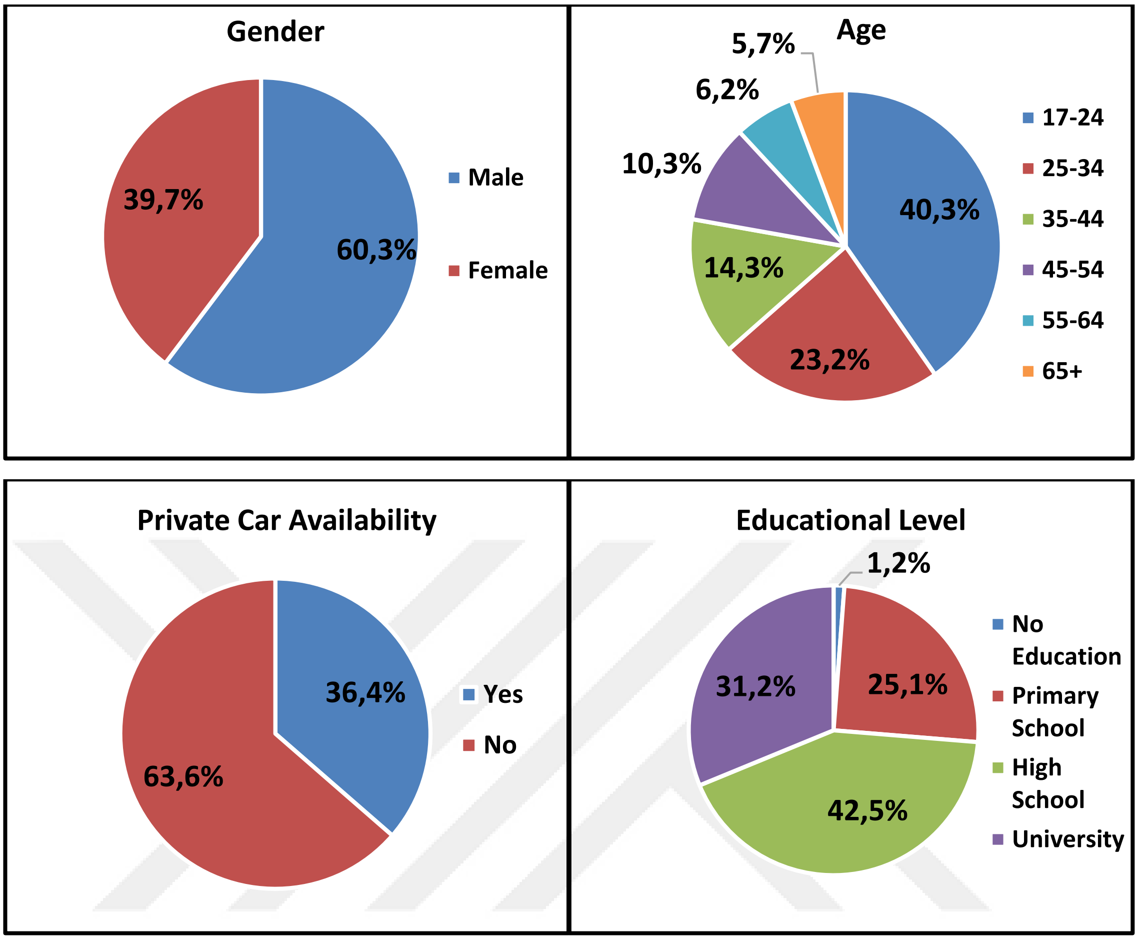

Figure 4.3a: Demographic information of the respondents

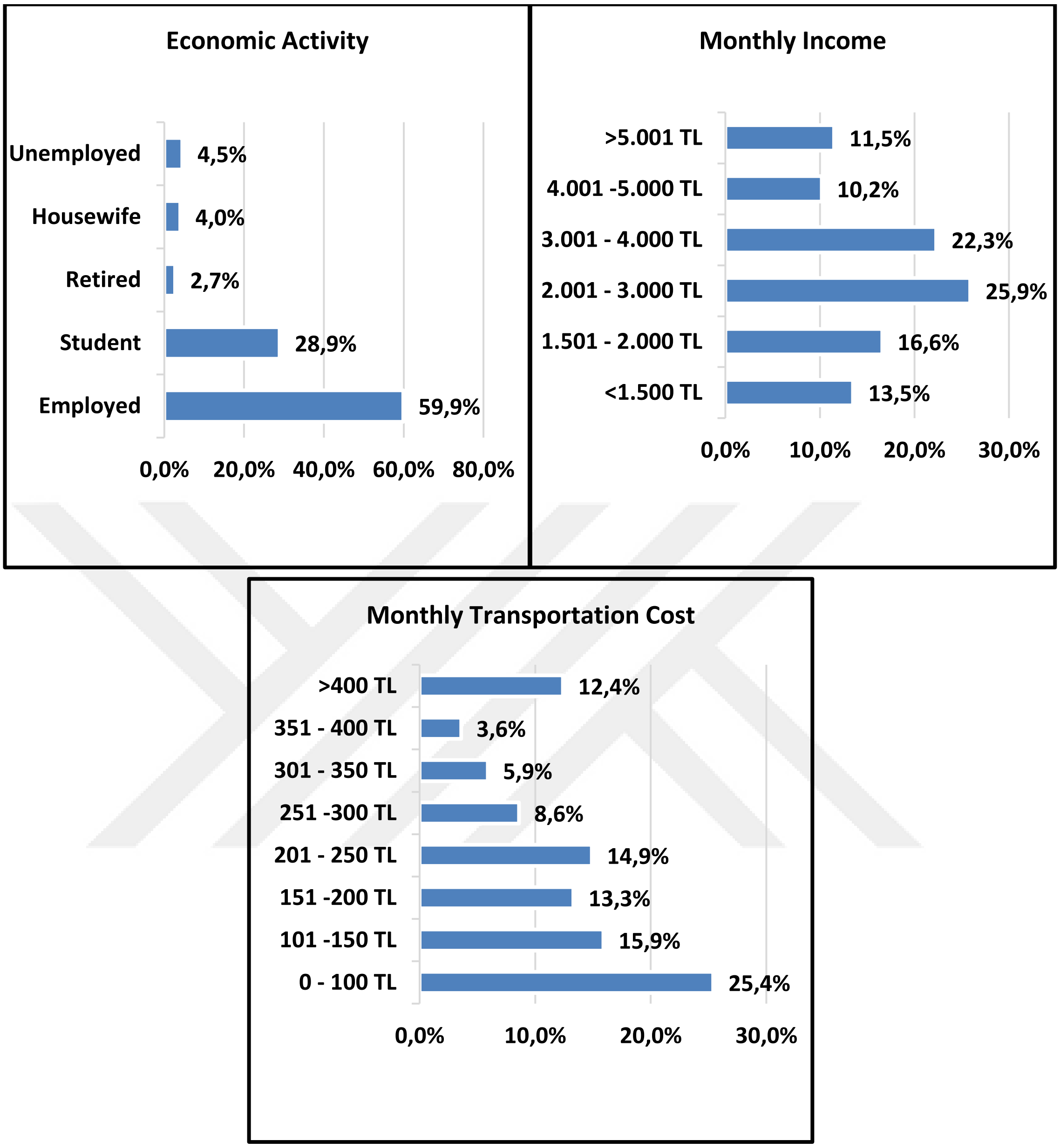

Figure 4.3b: Demographic information of the respondents

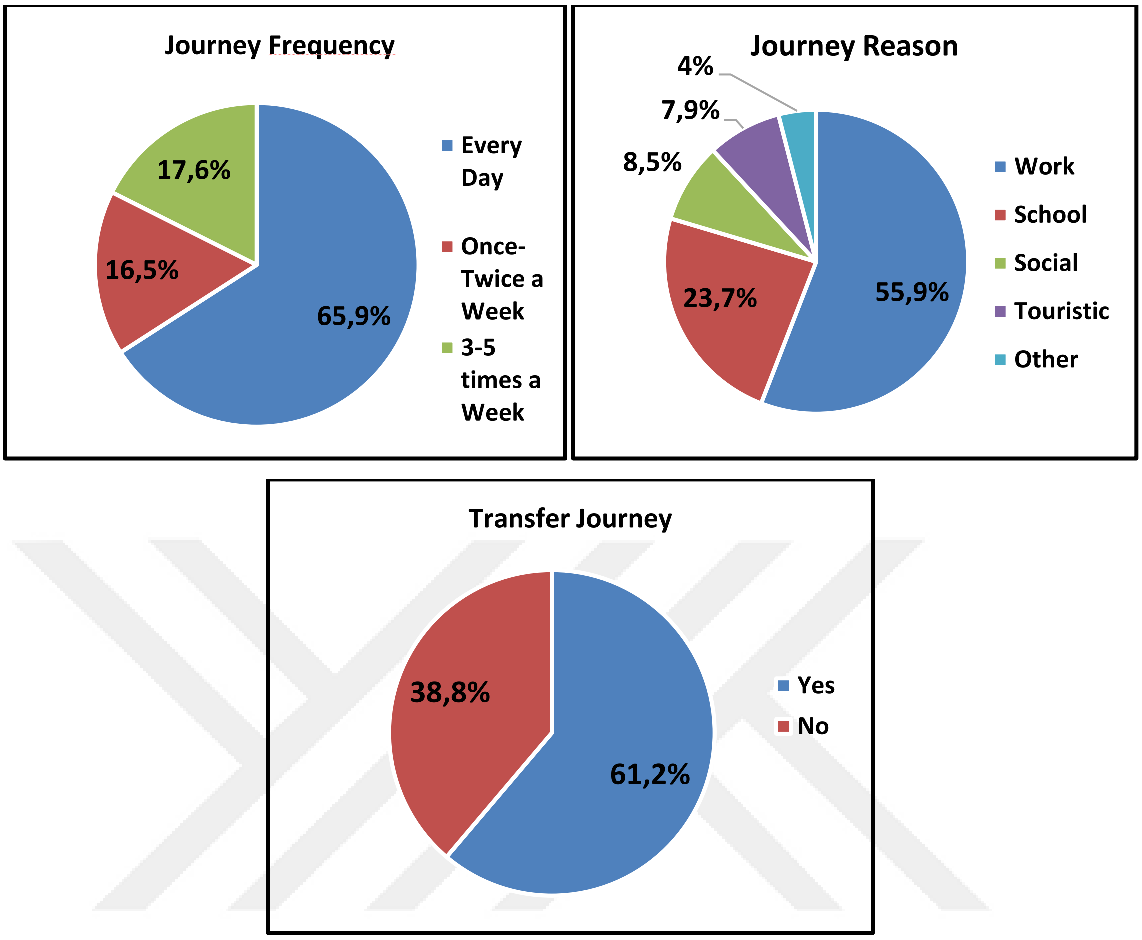

Figure 4.4a: Journey specifications of respondents

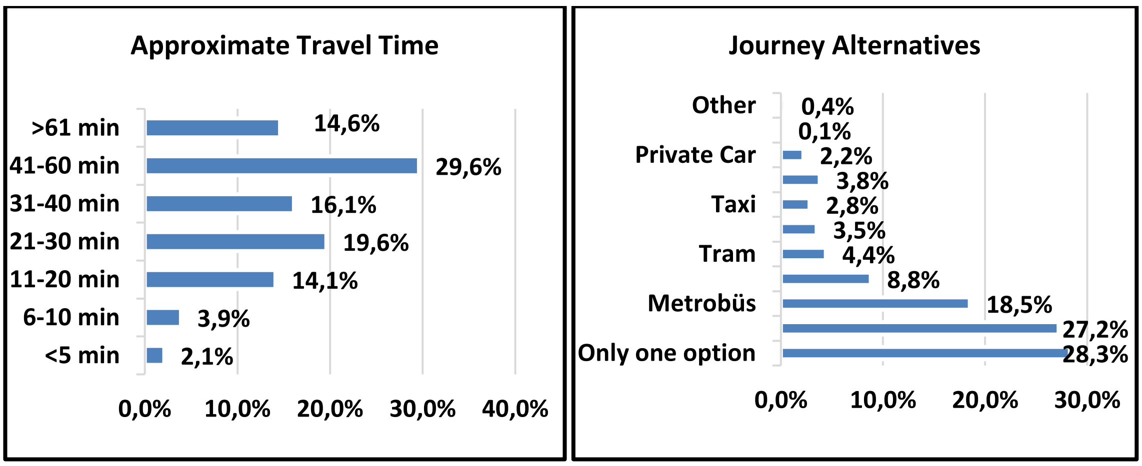

Figure 4.4b: Journey specifications of respondents

The questions in the questionnaire are grouped under 7 headings in accordance with EN13816 criteria. EN13816 is a European Standard which specifies the requirement to define, target and measure quality of service in public passenger transport. It is a widely used quality standard among European countries to improve service quality in public transportation services. IETT also uses the criteria defined in this standard to measure and improve its service quality. All these criteria is considered as beneficial criteria by means of service quality. Table 4.3 indicates the evaluation criteria and their sub-criteria and table 4.4 indicates the related literature for the evaluation criteria and their sub-criteria.

The evaluation criteria are described below:

Availability (C_1): This criterion constitutes the scope of the service in terms of geography, duration, frequency and mode of transportation.

Accessibility (C_2): This criterion expresses the easiness to access the public transport system through other modes of public transport network. It is substantially crucial for disabled, elderly and passengers travelling with children.

Comfort (C_3): This criterion implies the passengers' use of public transportation services without difficulty and appropriately during the journey. Vehicle air conditioning and crowdedness inside the bus affects this criterion.

Time (C_4): This criterion is related with issues of time during the planning and operation of service.

Customer Care (C_5): This criterion deals with how responsive the service is to the individual customer needs. It is affected by staff behavior and appearance, drivers' vehicle use.

Security (C_6): This criterion includes activities to ensure a safe journey both in the vehicle and bus stops.

Environmental Impact (C_7): This criterion measures the impact of the service on the environment. Factors affecting this criterion are noise level, exhaust emissions.

The questionnaire consists of 55 questions for bus operators. Some of the questions are about the demographic properties and customer loyalty so they are not handled in the assessment. The considered questions of questionnaire are the ones related with customer satisfaction.

Table 4.3: The evaluation criteria and sub-criteria

Main Criteria	Type	Sub-Criteria
Availability (C_1)	Beneficial	Easiness for Transfer Trip Frequency Route
Accessibility (C_2)	Beneficial	Distance to Access Istanbul Card Providing Easiness
Comfort (C_3)	Beneficial	Stops Physical Status Stops Cleanliness Vehicle Appearance Vehicle Density Vehicle Air Conditioning
Time (C_4)	Beneficial	Punctuality Transfer Time Travel Time
Customer Care (C_5)	Beneficial	Driver Behavior Driver Appearance Driver Vehicle Use Officer Behavior Fee
Security (C_6)	Beneficial	Passenger Security Vehicle Security
Environmental Impact (C_7)	Beneficial	Exhaust Emission Noise Level

Table 4.4: The related literature for the evaluation criteria and their sub-criteria

Main Criteria & Sub-Criteria	References
AVAILIBILITY	
Easiness for Transfer	Çelik et al. (2013), Liou et al. (2014)
Trip Frequency	Lupo (2013), Güner (2018)
Route	Lupo (2013), Güner (2018)
ACCESSIBILITY	
Distance to Access	Çelik et al. (2013), Çelik et al. (2014), Aydın et al. (2015), Güner (2018)
Istanbulcard Providing Easiness	Çelik et al. (2013), Lupo (2013), Aydın et al. (2015)
COMFORT	
Stops Physical Status	Liou et al. (2014)
Stops Cleanliness	Awasthi et al. (2011), Çelik et al. (2014), Aydın et al. (2015)
Vehicle Appearance	Çelik et al. (2013), Liou et al. (2014)
Vehicle Density	Çelik et al. (2013), Lupo (2013), Çelik et al. (2014), Aydın et al. (2015), Güner (2018)
Vehicle Air Conditioning	Çelik et al. (2013), Lupo (2013), Çelik et al. (2014), Aydın et al. (2015), Güner (2018)
TIME	
Punctuality	Çelik et al. (2013), Lupo (2013), Çelik et al. (2014), Liou et al. (2014), Aydın et al. (2015), Chen (2016), Li et al. (2017)
Transfer Time	Çelik et al. (2013)
Travel Time	Çelik et al. (2014), Aydın et al. (2015)
CUSTOMER CARE	
Driver Behavior	Awasthi et al. (2011), Çelik et al. (2013), Lupo (2013), Liou et al. (2014), Li et al. (2017)
Driver Appearance	Awasthi et al. (2011), Lupo (2013), Liou et al. (2014), Li et al. (2017)
Driver Vehicle Use	Çelik et al. (2013), Liou et al. (2014)
Officer Behavior	Çelik et al. (2014), Aydın et al. (2015)
Fee	Çelik et al. (2013), Çelik et al. (2014), Aydın et al. (2015)
SECURITY	
Passenger Security	Awasthi et al. (2011), Çelik et al. (2013), Çelik et al. (2014)
Vehicle Security	Awasthi et al. (2011), Çelik et al. (2013), Çelik et al. (2014)
ENVIRONMENTAL IMPACT	
Exhaust Emission	Çelik et al. (2013)
Noise Level	Çelik et al. (2013), Çelik et al. (2014), Aydın et al. (2015), Li et al. (2017)

4.3 Proposed Model Application

First of all, the average importance level of each criteria obtained from the questionnaire are converted to interval type-2 fuzzy sets and then it is used for performance evaluation of each criteria. The linguistic variables and their corresponding interval type-2 fuzzy sets are shown in Table 4.5.

Table 4.5: Linguistic variables and their corresponding IT2FSs

Linguistic Variable	Interval Type-2 Fuzzy Sets
Very Low (VL)	(0.00 0.00 0.00 0.10 ; 1.00 1.00) (0.00 0.00 0.00 0.05 ; 0.90 0.90)
Low (L)	(0.00 0.10 0.15 0.30 ; 1.00 1.00) (0.05 0.10 0.15 0.20 ; 0.90 0.90)
Medium Low (ML)	(0.10 0.30 0.35 0.50 ; 1.00 1.00) (0.20 0.30 0.35 0.40 ; 0.90 0.90)
Medium (M)	(0.30 0.50 0.55 0.70 ; 1.00 1.00) (0.40 0.50 0.55 0.60 ; 0.90 0.90)
Medium High (MH)	(0.50 0.70 0.75 0.90 ; 1.00 1.00) (0.60 0.70 0.75 0.80 ; 0.90 0.90)
High (H)	(0.70 0.85 0.90 1.00 ; 1.00 1.00) (0.80 0.85 0.90 0.95 ; 0.90 0.90)
Very High (VH)	(0.90 1.00 1.00 1.00 ; 1.00 1.00) (0.95 1.00 1.00 1.00 ; 0.90 0.90)

The respondents' individual judgments defined with linguistic variables obtained from the questionnaire are utilized to evaluate fuzzy relative importance weights of each criteria. The respondents' are the decision-makers who are public transportation passengers travelled now or previously with buses operated by 3 different transportation companies. The linguistic evaluation of the respondents' is shown in Table 4.6.

The complete criteria weight matrix determined by decision-makers based on Table 4.6 is computed by using Eq. (3.17) and Eq. (3.18) as represented in Table 4.7.

The result for C_1 is obtained from average of the decision makers evaluations and their corresponding interval type-2 fuzzy sets. Sample calculation for first row upper bound U1 in Table 4.7 is as; U1=1/1*0.70=0.70 (see Eq. (3.18)).

Table 4.6: Criteria weights of decision makers

Criteria	**Weights**
Availability ($\mathcal{C}_1$)	H
Accessibility ($\mathcal{C}_2$)	MH
Comfort ($\mathcal{C}_3$)	MH
Time ($\mathcal{C}_4$)	VH
Customer Care ($\mathcal{C}_5$)	M
Security ($\mathcal{C}_6$)	H
Environmental Impact ($\mathcal{C}_7$)	ML

Table 4.7: Matrix of Criteria Weights

Criteria	**Weights**
$\mathcal{C}_1$	(0.70 0.85 0.90 1.00 ; 1.00 1.00) (0.80 0.85 0.90 0.95 ; 0.90 0.90)
$\mathcal{C}_2$	(0.50 0.70 0.75 0.90 ; 1.00 1.00) (0.60 0.70 0.75 0.80 ; 0.90 0.90)
$\mathcal{C}_3$	(0.50 0.70 0.75 0.90 ; 1.00 1.00) (0.60 0.70 0.75 0.80 ; 0.90 0.90)
$\mathcal{C}_4$	(0.90 1.00 1.00 1.00 ; 1.00 1.00) (0.95 1.00 1.00 1.00 ; 0.90 0.90)
$\mathcal{C}_5$	(0.30 0.50 0.55 0.70 ; 1.00 1.00) (0.40 0.50 0.55 0.60 ; 0.90 0.90)
$\mathcal{C}_6$	(0.70 0.85 0.90 1.00 ; 1.00 1.00) (0.80 0.85 0.90 0.95 ; 0.90 0.90)
$\mathcal{C}_7$	(0.10 0.30 0.35 0.50 ; 1.00 1.00) (0.20 0.30 0.35 0.40 ; 0.90 0.90)

From Tables 4.6 and 4.7 we can see that the most important criteria are time, availability and comfort and the least important criteria is environmental impact from passengers' perspective respectively.

The performance values of each criteria for the three public transportation bus operators are stated by each decision maker. The performance ratings of bus operators carried out from the customer satisfaction survey are calculated with the Eq. (3.15) and Eq. (3.16) for the average decision matrix as shown in Table 4.8 and Table 4.9 respectively.

The linguistic evaluation of three alternatives according to C_1 is medium high (see Table 4.8). The corresponding interval type 2 fuzzy numbers is (0.50 0.70 0.75 0.90; 1.00 1.00) (0.60 0.70 0.75 0.80; 0.90 0.90) for the 3 operators. The result is obtained from average of the decision maker's evaluations and their corresponding interval type-2 fuzzy sets. Sample calculation for C_1 upper bound for operator IETT in Table 4.9 is as; U1=1/1*0.50=0.50 (see Eq. (3.16)).

Table 4.8: Performance values of public transport bus operators

Criteria	**IETT**	**IOAS**	**OHO**
Availability ($\boldsymbol{C_1}$)	MH	MH	MH
Accessibility ($\boldsymbol{C_2}$)	VH	VH	VH
Comfort ($\boldsymbol{C_3}$)	MH	H	H
Time ($\boldsymbol{C_4}$)	MH	MH	MH
Customer Care ($\boldsymbol{C_5}$)	H	H	MH
Security ($\boldsymbol{C_6}$)	VH	VH	H
Environmental Impact ($\boldsymbol{C_7}$)	M	M	ML

The average solutions matrix is computed by using the average decision matrix indicated in Table 4.9 and the Eq. (3.19) and Eq. (3.20) respectively. The average solutions matrix and the crisp scores are presented in Table 4.10.

The result in Table 4.10 is obtained from the average of the average decision matrix. Sample calculation for C_1 upper bound in Table 4.10 is as; U1=1/3*(0.50+050+0.50) =0.50 (number of alternatives=3, see Eq. (3.20)). And the crisp score for $C_1$is obtained from the calculations; (0.50 (1+1)*0.70 (1+1)*0.75 0.90 (4+1+1) (0.50+(1+1)*0.70+(1+1)*0.75+0.90)/(4+1+1)) ((0.60 (1+0.90)*0.70 (1+90)*0.75 0.80 (4+0.90+0.90) (0.60+(1+0.90)*0.70+(1+90)*0.75+0.80)/(4+0.90+0.90) = (0.50 1.40 1.50 0.90 6 **0.72**) (0.60 1.33 1.43 0.80 5.8 **0.72**). The crisp score for C_1 is (0.72+0.72)/2=0.72.

The passengers have evaluated three bus operators with regard to availability, accessibility, comfort, time, customer care, security and environmental criteria. The highest satisfaction level is accessibility criteria for each operator and the lowest is environmental impact, followed by availability and time criteria from passengers' perspective.

By using the average decision matrix Table 4.9 and average solutions matrix Table 4.10 the positive and negative distances are calculated. Since, we don't have a non-beneficial criteria in this case only the positive distance of performance value from the average solution is calculated by using Eq. (3.21) and (3.23). The calculation of positive distances is represented in Table 4.11.

The sample calculation for C_1 and alternative IETT upper bound in Table 4.11 is calculated by the difference of average decision matrix and average solution matrix divided by the crisp score of the average solution matrix and multiplied with 1 or -1 whether it's beneficial or not. U1= [(0.50-0.50)/0.72]*1= 0.

The weighted sum of positive and negative distances and their normalized values are computed for all alternatives based on Eq. (3.25), Eq. (3.26), Eq. (3.27) and Eq. (3.28) respectively. The calculation results are shown in Table 4.12 and Table 4.13.

The sample calculation for the weighted sum of positive distance for alternative IETT upper bound in Table 4.12 is calculated by the sum of multiplication of the positive distance values and criteria weights for each criteria as; U1= (0*0.70)+ (0*0.50)+ (0*0.50)+ (0*0.90)+ (0.08*0.30)+ (0.07*0.70)+ (0.15*0.10)= 0.09.

The sample calculation for the normalized values of the weighted sum of positive distance of alternative IETT upper bound in Table 4.13 is calculated by the division of the weighted sum value to the maximum crisp value of all alternatives as; U1= 0.09/0.16=0.56.

Table 4.9: Average decision matrix

Criteria	IETT	IOAS	OHO
C_1	(0.50 0.70 0.75 0.90 ; 1.00 1.00), (0.60 0.70 0.75 0.80 ; 0.90 0.90)	(0.50 0.70 0.75 0.90 ; 1.00 1.00), (0.60 0.70 0.75 0.80 ; 0.90 0.90)	(0.50 0.70 0.75 0.90 ; 1.00 1.00), (0.60 0.70 0.75 0.80 ; 0.90 0.90)
C_2	(0.90 1.00 1.00 1.00 ; 1.00 1.00), (0.95 1.00 1.00 1.00 ; 0.90 0.90)	(0.90 1.00 1.00 1.00 ; 1.00 1.00), (0.95 1.00 1.00 1.00 ; 0.90 0.90	(0.90 1.00 1.00 1.00 ; 1.00 1.00), (0.95 1.00 1.00 1.00 ; 0.90 0.90
C_3	(0.50 0.70 0.75 0.90 ; 1.00 1.00), (0.60 0.70 0.75 0.80 ; 0.90 0.90)	(0.70 0.85 0.90 1.00 ; 1.00 1.00), (0.80 0.85 0.90 0.95 ; 0.90 0.90)	(0.70 0.85 0.90 1.00 ; 1.00 1.00), (0.80 0.85 0.90 0.95 ; 0.90 0.90)
C_4	(0.50 0.70 0.75 0.90 ; 1.00 1.00), (0.60 0.70 0.75 0.80 ; 0.90 0.90)	(0.50 0.70 0.75 0.90 ; 1.00 1.00), (0.60 0.70 0.75 0.80 ; 0.90 0.90)	(0.50 0.70 0.75 0.90 ; 1.00 1.00), (0.60 0.70 0.75 0.80 ; 0.90 0.90)
C_5	(0.70 0.85 0.90 1.00 ; 1.00 1.00), (0.80 0.85 0.90 0.95 ; 0.90 0.90)	(0.70 0.85 0.90 1.00 ; 1.00 1.00), (0.80 0.85 0.90 0.95 ; 0.90 0.90)	(0.50 0.70 0.75 0.90 ; 1.00 1.00), (0.60 0.70 0.75 0.80 ; 0.90 0.90)
C_6	(0.90 1.00 1.00 1.00 ; 1.00 1.00), (0.95 1.00 1.00 1.00 ; 0.90 0.90)	(0.90 1.00 1.00 1.00 ; 1.00 1.00), (0.95 1.00 1.00 1.00 ; 0.90 0.90)	(0.70 0.85 0.90 1.00 ; 1.00 1.00), (0.80 0.85 0.90 0.95 ; 0.90 0.90)
C_7	(0.30 0.50 0.55 0.70 ; 1.00 1.00) (0.40 0.50 0.55 0.60 ; 0.90 0.90)	(0.30 0.50 0.55 0.70 ; 1.00 1.00), (0.40 0.50 0.55 0.60 ; 0.90 0.90)	(0.10 0.30 0.35 0.50 ; 1.00 1.00), (0.20 0.30 0.35 0.40 ; 0.90 0.90)

Table 4.10: Matrix of Average Solutions

	Fuzzy Value	Crisp Scores
C_1	(0.50 0.70 0.75 0.90 ; 1.00 1.00) (0.60 0.70 0.75 0.80 ; 0.90 0.90)	**0.72**
C_2	(0.90 1.00 1.00 1.00; 1.00 1.00) (0.95 1.00 1.00 1.00 ; 0.90 0.90)	**0.99**
C_3	(0.63 0.80 0.85 0.97 ; 1.00 1.00) (0.73 0.80 0.85 0.90 ; 0.90 0.90)	**0.82**
C_4	(0.50 0.70 0.75 0.90 ; 1.00 1.00) (0.60 0.70 0.75 0.80 ; 0.90 0.90)	**0.72**
C_5	(0.63 0.80 0.85 0.97 ; 1.00 1.00) (0.73 0.80 0.85 0.90 ; 0.90 0.90)	**0.82**
C_6	(0.83 0.95 0.97 1.00 ; 1.00 1.00) (0.90 0.95 0.97 0.98 ; 0.90 0.90)	**0.95**
C_7	(0.23 0.43 0.48 0.63 ; 1.00 1.00) (0.33 0.43 0.48 0.53 ; 0.90 0.90)	**0.45**

By using Table 4.12 and Table 4.13 the evaluation scores each alternative can be calculated by using Eq. (3.29). The final ranking values of the alternatives are represented in Table 4.14.

The sample calculation for the appraisal score of the alternative IETT upper bound in Table 4.14 is calculated by the sum of normalized values of positive and negative weighted sum of distances divided by 2 as; U1= (0.56+1)/2= 0.78. And the ranking values are calculated by conversion to crisp scores as ; (0.78 (1+1)*0.88 (1+1)*0.87 0.83 (4+1+1) (0.78+(1+1)*0.88+(1+1)*0.87+0.83)/(4+1+1)) ((0.83 (1+0.90)*0.88 (1+90)*0.87 0.86 (4+0.90+0.90) (0.83+(1+0.90)*0.88+(1+90)*0.87+0.86)/(4+0.90+0.90) = (0.78 1.76 1.74 0.83 6 **0.85**) (0.83 1.67 1.66 0.86 5.8 **0.87**). The ranking value for IETT is (0.85+0.87)/2=0.8595.

The results indicate that public transportation operators are ranked as IOAS>IETT>OHO.

Among 3 operators IOAS seems to be the best performing operator by means of customer satisfaction level. Whereas, some criteria still requires to be enhanced so that to ascent the overall satisfaction. Comfort criteria needs to be improved by means of vehicle density sub-criteria. Therefore investments to decrease passenger density, which can be achieved by increasing the frequency will result in higher customer satisfaction levels for operator IOAS.

Operator IETT, is ranked second among the alternatives. The criteria which needs to be improved is availability. Availability is mainly affected by trip frequency. Thus, increasing the departure frequencies will improve the service level for operator IETT.

The operator OHO, is ranked the third among all challengers. The main criteria which decrease customer satisfaction for this operator is customer care which is related with driver vehicle use, behavior and appearance. Making investments on training programs for drivers will improve the service level for operator OHO.

Besides improvement suggestions specific to each operator, the main criteria which will increase the service level for all the bus operators is time due to its' level of importance from the perspective of passengers. The main issues affecting time criteria are transfer time, travel time and punctuality. Since, the travel times are affected by traffic congestion which is already a predicament in Istanbul, conformity to time tables is one of the crucial concerns of passengers.

On the other hand, the environmental impact criteria has the lowest satisfaction level for all the operators. In contrast, it has the lowest level of importance from passengers' perspective. This criteria is related to exhaust emissions and noise levels. To improve this criteria new technology electricity, CNG or hybrid vehicles that are more environmental friendly can be presented.

Table 4.11: Positive distances from average solution

Criteria	IETT	IOAS	OHO
c_1	(0.00 0.00 0.00 0.00; 1.00 1.00), (0.00 0.00 0.00 0.00; 1.00 1.00)	(0.00 0.00 0.00 0.00; 1.00 1.00), (0.00 0.00 0.00 0.00; 1.00 1.00)	(0.00 0.00 0.00 0.00; 1.00 1.00), (0.00 0.00 0.00 0.00; 1.00 1.00)
c_2	(0.00 0.00 0.00 0.00; 1.00 1.00), (0.00 0.00 0.00 0.00; 1.00 1.00)	(0.00 0.00 0.00 0.00; 1.00 1.00), (0.00 0.00 0.00 0.00; 1.00 1.00)	(0.00 0.00 0.00 0.00; 1.00 1.00), (0.00 0.00 0.00 0.00; 1.00 1.00)
c_3	(0.00 0.00 0.00 0.00; 1.00 1.00), (0.00 0.00 0.00 0.00; 1.00 1.00)	(0.08 0.06 0.06 0.04; 1.00 1.00), (0.08 0.06 0.06 0.06; 0.90 0.90)	(0.08 0.06 0.06 0.04; 1.00 1.00), (0.08 0.06 0.06 0.06; 0.90 0.90)
c_4	(0.00 0.00 0.00 0.00; 1.00 1.00), (0.00 0.00 0.00 0.00; 1.00 1.00)	(0.00 0.00 0.00 0.00; 1.00 1.00), (0.00 0.00 0.00 0.00; 1.00 1.00)	(0.00 0.00 0.00 0.00; 1.00 1.00), (0.00 0.00 0.00 0.00; 1.00 1.00)
c_5	(0.08 0.06 0.06 0.04; 1.00 1.00), (0.08 0.06 0.06 0.06; 0.90 0.90)	(0.08 0.06 0.06 0.04; 1.00 1.00), (0.08 0.06 0.06 0.06; 0.90 0.90)	(0.00 0.00 0.00 0.00; 1.00 1.00), (0.00 0.00 0.00 0.00; 1.00 1.00)
c_6	(0.07 0.05 0.04 0.00; 1.00 1.00), (0.05 0.05 0.04 0.02 0.90 0.90)	(0.07 0.05 0.04 0.00; 1.00 1.00), (0.05 0.05 0.04 0.02 0.90 0.90)	(0.00 0.00 0.00 0.00; 1.00 1.00), (0.00 0.00 0.00 0.00; 1.00 1.00)
c_7	(0.15 0.15 0.15 0.15 ; 1.00 1.00) (0.15 0.15 0.15 0.15; 0.90 0.90)	(0.15 0.15 0.15 0.15 ; 1.00 1.00) (0.15 0.15 0.15 0.15; 0.90 0.90)	(0.00 0.00 0.00 0.00; 1.00 1.00), (0.00 0.00 0.00 0.00; 1.00 1.00)

Table 4.12: Weighted sum of positive distances of the alternatives

	Weighted Sum
IETT	(0.09 0.12 0.12 0.10; 1.00 1.00) (0.10 0.12 0.12 0.11; 0.90 0.90)
IOAS	(0.13 0.16 0.16 0.14; 1.00 1.00) (0.15 0.16 0.16 0.16; 0.90 0.90)
OHO	(0.04 0.04 0.05 0.04; 1.00 1.00) (0.05 0.04 0.05 0.05; 0.90 0.90)

Table 4.13: Normalized values of the alternatives

	Normalized Value
IETT	(0.56 0.76 0.75 0.65; 1.00 1.00) (0.66 0.76 0.75 0.72; 0.90 0.90)
IOAS	(0.82 1.04 1.04 0.89 ; 1.00 1.00) (0.98 1.04 1.04 1.03; 0.90 0.90)
OHO	(0.26 0.27 0.29 0.23; 1.00 1.00) (0.31 0.27 0.29 0.31; 0.90 0.90)

Table 4.14: Appraisal scores and ranking values of the alternatives

Operators	Fuzzy Value	Ranking Values
IETT	(0.78 0.88 0.87 0.83 ; 1.00 1.00) (0.83 0.88 0.87 0.86 ; 0.90 0.90)	**0.8595**
IOAS	(0.91 1.02 1.02 0.94 ; 1.00 1.00) (0.99 1.02 1.02 1.01 ; 0.90 0.90)	**1.0000**
OHO	(0.63 0.63 0.64 0.60 ; 1.00 1.00) (0.65 0.63 0.64 0.64 ; 0.90 0.90)	**0.6312**

5. CONCLUSION

The role of public transportation is gaining importance by means of sustainable development in big and crowded cities like Istanbul. Therefore providing high quality service becomes an important task for transportation planners. IETT is one of the institutions affiliated to Istanbul Metropolitan Municipality which supervises and regulates private operators and provides service to passengers with buses, metrobus, nostalgic tram and tunnel.

In this paper, a service level improvement methodology is proposed for public transportation bus operators in Istanbul based on customer satisfaction surveys. Interval type-2 fuzzy EDAS method is applied to evaluate and improve the service level in Istanbul public transportation. With the proposed methodology the alternatives are ranked and the criteria which needs to be enhanced for each alternative is determined for future improvement.

The performance ratings of each bus operator and the relative importance of each criteria are acquired by distributing a questionnaire to public transportation passengers. Linguistic variables used in this paper are based on individual opinions of the survey participants to decide the performance scores of each public transport bus operator.

The importance level of each criteria are determined from the passengers' perspective. Multiple criteria is involved for assessment by using EDAS method and by using interval type-2 fuzzy numbers the imprecise and vague information is eliminated. EDAS methodology is combined with customer satisfaction evaluation in public transportation by a real case application.

In conclusion, the criteria that need to be improved for all public bus operators are decided and enhancement recommendations for each of them are proposed to increase the service level in Istanbul’s bus public transportation based on customer satisfaction surveys applied by IETT in 2017.

For further research, this method can be applied for specific bus transit routes in order to measure the service level of each bus transit route. Moreover, the proposed model can be modified in order to analyze the relation between customer satisfaction and customer loyalty for future work.

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7. APPENDIX

SURVEY QUESTIONNAIRE

Q1.	How often do you use public transport buses?		
Every day	1	1-2 days a month	4
3-5 days a week	2	1 day or less a month	5
1-2 days a week	3	1 day or less a year	6

SATISFACTION QUESTIONS		Very Poor	Poor	Medium	Good	Very Good
Availability						
Q3.	Transfer easiness to other modes	1	2	3	4	5
Q4.	Trip frequency of the buses	1	2	3	4	5
Q5.	Routes of the buses	1	2	3	4	5
Accessibility						
Q6.	The distance from your home/work to bus stop	1	2	3	4	5
Q7.	İstanbul card loading and finding easiness	1	2	3	4	5
Time						
Q8.	Vehicle departure time punctuality	1	2	3	4	5
Q9.	Transfer time (from one bus to another)	1	2	3	4	5
Q10.	Total travel time	1	2	3	4	5
Comfort						
Q11.	Physical status of the stop area	1	2	3	4	5
Q12.	Cleanliness of the stop area	1	2	3	4	5
Q13.	Appearance inside and outside the vehicles	1	2	3	4	5
Q14.	Passenger density inside the vehicle	1	2	3	4	5
Q15.	Air-conditioning system inside vehicle	1	2	3	4	5

SATISFACTION QUESTIONS		Very Poor	Poor	Medium	Good	Very Good
Customer Care						
Q16.	Drivers attitude towards passengers	1	2	3	4	5
Q17.	Drivers appearance	1	2	3	4	5
Q18.	Drivers vehicle use	1	2	3	4	5
Q19.	Officers behavior	1	2	3	4	5
Q20.	Paid fee	1	2	3	4	5
Security						
Q21.	Passenger security during the trip	1	2	3	4	5
Q22.	Security precautions	1	2	3	4	5
Environmental Impact						
Q23.	Environmental concern to exhaust emissions	1	2	3	4	5
Q24.	Environmental concern to noise	1	2	3	4	5

Disability		Yes	No
Q30.	Do you have any disability?	1	2
Q31.	Any disabled person in your family?	1	2

If Questions 30-31 are answered Yes		Very Poor	Poor	Medium	Good	Very Good
Q32.	Accessibility to bus stops are suitable for disabled	1	2	3	4	5
Q33.	Technical properties of the vehicles are suitable for boarding etc.	1	2	3	4	5
Q34.	To travel comfortable inside the vehicle	1	2	3	4	5

Q35.	**Importance Levels**	1. level	2. level	3. level
	Availability			
	Accessibility			
	Comfort			
	Time			
	Customer Care			
	Security			
	Environmental Impact			

Q36.	If you consider all the service how do you evaluate the bus service		
	IETT	IOAS	OHO
Very Poor	1	1	1
Poor	2	2	2
Medium	3	3	3
Good	4	4	4
Very Good	5	5	5

Q37.	At which level would you recommend the service to your acquaintanceship								
	1	2	3	4	5	6	7	8	9	10

Loyalty				IETT	IOAS	OHO
Q38.	If the 3 operators are available for your trip, which one would you prefer?			1	2	3
Q39.	To what extend do you agree with this expression "I think positive about IETT, I defend IETT against negative expressions"	Totally don't agree	Don't agree	Between	Agree	Totally agree
		1	2	3	4	5

JOURNEY INFORMATION QUESTIONS		
Q40.	Which bus route do you generally use?	
	Route Code:	
	Route Name:	
Q41.	Which type travel card do you use?	
	Istanbul Card	1
	Istanbul Card- Student	2
	Monthly Card	3
	Istanbul Card-Social	4
	Unpaid Card	5
	Limited Use Card	6
Q42.	What is your journey reason?	
	Work	1
	School	2
	Social	3
	Touristic	4
	Health	5
	Other	6
Q43.	How long does it take from your home to bus stop destination?	
		min.

JOURNEY INFORMATION QUESTIONS					
Q44.	How long do you wait at the bus stop?				
			min.		
Q45.	The duration of your trip from start to end?				
			min.		
Q46.	After leaving the vehicle how long does it take to your destination?				
			min.		
Q47.	How many transfers do you make during your trip?				
	1	2	3	4	5 or more
Q48.	What are the alternatives for your journey?				
	Only one option		1		
	Metro		2		
	Metrobüs		3		
	Minibus/Jitney		4		
	Tram		5		
	Sea		6		
	Taxi		7		
	Walk		8		
	Private Car		9		
	Bcycle		10		
	Other		11		

DEMOGRAPHIC INFORMATION QUESTIONS		
Q49.	Gender information	
	Male	1
	Female	2
Q50.	Age	
Q51.	Economic activities	
	Employed	1
	Student	2
	Retired	3
	Housewife	4
	Unemployed	5
Q52.	Private car availability	
	Yes	1
	No	2
Q53.	Education level	
	No Education	1
	Primary School	2
	High School	3
	University	4
	Master	5

DEMOGRAPHIC INFORMATION QUESTIONS		
Q54.	Monthly transportation cost of your family	
	0 - 100 TL	1
	101 -150 TL	2
	151 -200 TL	3
	201 - 250 TL	4
	251 -300 TL	5
	301 - 350 TL	6
	351 - 400 TL	7
	>400 TL	8
Q55.	Monthly income of your family	
	<1.500 TL	1
	1.501 - 2.000 TL	2
	2.001 - 3.000 TL	3
	3.001 - 4.000 TL	4
	4.001 -5.000 TL	5
	>5.001 TL	6
Q56.	What are your demands and expectations?	

BIOGRAPHICAL SKETCH

Suzan Tunç was born in Samsun on April 24, 1986. She graduated from Mersin Dumlupınar High School in 2005. She obtained a B.S. degree in Industrial Engineering from Gaziantep University in 2011. Since January 2013, she has been working in IETT (General Directorate of Istanbul Electricity Tramway and Tunnel) as an engineer in several departments. She is a M.Sc. candidate in Industrial Engineering at Galatasaray University, having the chance to narrow her area of expertise and to widen her knowledge in industrial engineering. She wrote a paper entitled as "A Proposed Service Level Improvement Methodology for Public Transportation Using Interval Type-2 Fuzzy EDAS Based on Customer Satisfaction Data", (Demircan, M.L., Tunç, S., 2019), to be presented at *Intelligent and Fuzzy Systems Conference (INFUS) 2019* in Istanbul, Turkey.