



Evaluation of smart city logistics solutions with fuzzy MCDM methods

Akıllı kentsel lojistik çözümlerinin bulanık ÇKKV yöntemleri ile değerlendirilmesi

Gülçin BÜYÜKÖZKAN^{1*}, Esin MUKUL²

^{1,2}Endüstri Mühendisliği Bölümü, Mühendislik ve Teknoloji Fakültesi, Galatasaray Üniversitesi, İstanbul, Türkiye.
gulcin.buyukozkan@gmail.com, emukul@gsu.edu.tr

Received/Geliş Tarihi: 15.06.2019, Accepted/Kabul Tarihi: 13.11.2019

* Corresponding author/Yazışılan Yazar

doi: 10.5505/pajes.2019.32956

Special Issue Article / Özel Sayı Makalesi

Abstract

City logistics, which started to examine as a subdivision of logistics, aims the planning and management of transportation, efficiency, protection of the environment, reduction of traffic, security, and energy-saving. Rapidly growing population and migration from rural to urban areas have an important place in many of the problems of cities. A smart city is an approach that has a significant potential to solve urban logistics problems with information technologies. "Smart city logistics solutions" such as full adaptive traffic management system, security, and emergency systems, electronic detection system, etc. present based on information technologies to meet the increasing demand for logistics services more efficiently, safely and environmentally. In this study, the evaluation of smart city logistics solutions that contain many components is considered as a multi-criteria decision-making (MCDM) problem. Given the complex nature of this problem and insufficient knowledge, the decision-making approach is supported by fuzzy logic. In this context, the smart city logistics solutions in Istanbul determined by literature review and expert opinions are modeled, analyzed, and the results are interpreted by using the House of Quality matrix of Quality Function Deployment (QFD) approach with fuzzy MCDM methods.

Keywords: Fuzzy MCDM, House of Quality, Smart city logistics, Smart city logistics solutions

Öz

Lojistiğin bir alt dalı olarak incelenmeye başlanan "Kentsel Lojistik", genel lojistikte olduğu gibi dağıtım ve ulaşımın planlanmasını, yönetilmesini, etkin bir lojistik sisteminin sağlanmasını, çevrenin korunmasını, trafiğin azaltılmasını, lojistikte güvenliği ve enerji tasarrufunu amaçlamaktadır. Hızla artan nüfus ve kırsal alanlardan kentsel alanlara olan göç, şehirdeki lojistik problemlerinin yaşanmasındaki başlıca sebepler arasındadır. Akıllı şehir yaklaşımı, bilgi teknolojileri ile bu problemleri çözmek için önemli bir potansiyele sahiptir. Lojistik hizmetlerinde artan talebin daha etkin, güvenli ve çevreci bir şekilde karşılanması için bilgi teknolojilerini baz alan tam adaptif trafik yönetim sistemi, güvenlik ve acil durum yönetim sistemi, elektronik denetleme sistemi gibi "Akıllı kentsel lojistik çözümleri" sunulmaktadır. Bu çalışmada, birçok bileşeni bünyesinde barındıran akıllı kentsel lojistik çözümleri, Çok Kriterli Karar Verme (ÇKKV) problemi olarak ele alınmaktadır. Bu problemin karmaşık yapısı ve bilginin yetersiz olduğu göz önünde bulundurularak karar verme yaklaşımı bulanık mantık ile desteklenmektedir. Bu kapsamda, İstanbul'da akıllı kentsel lojistik çözümleri literatür taraması ve uzman görüşleri ile modellenmekte, analiz edilmekte ve sonuçlar Kalite Fonksiyon Göçerimi yaklaşımının Kalite Evi matrisi ve bir bulanık ÇKKV tekniği kullanılarak elde edilmektedir.

Anahtar kelimeler: Akıllı kentsel lojistik, Akıllı kentsel lojistik çözümleri, Bulanık ÇKKV, Kalite Evi

1 Introduction

The majority of the population in the world and also majority of Turkey lives in cities. Therefore, cities are the most complex and significant impact on our daily life. Especially, logistics is the most essential area that effects city residents' life. Parallel to population growth, the use of private vehicles augments. And that reveals the need for the increment of the traffic, air pollution, transportation costs in cities and likewise the product prices. City logistics, which started to examine as a subdivision of logistics at the beginning of the 1990s, aims to plan and to manage the distribution and transportation [1].

The primary objectives of city logistics are efficiency, protection of the environment, reduction of traffic, security, and energy-saving. These aims are related to the three cornerstones of city logistics that are sustainability, mobility, and livability. Parallel to the rapid development of Internet and Information Technologies, logistics becomes one of the affected and developing sectors. "Smart city logistics solutions" are presented by Information Technologies to meet the increasing demand for logistics services more efficiently, safely, and environmentally [2].

Smart city logistics is a fundamental approach for the more efficient organization of physical and information logistics in international transportation chains. It means an optimized form for the transport of people and goods, which increases mobility, security, and the benefits of users and at the same time, reduces pollution, consumption, and bottlenecks [3]. Sustainability and livability, which are the cornerstones, are the concepts that provide the continuity of smart city logistics [4].

Logistics networks are exposed to uncertain environments. Therefore, the need for robustness, flexibility, and agility has become a focal point for future logistics system designs. Smart city logistics solutions have developed to reduce the harmful effects of increased transport in urban areas [5].

In this study, the evaluation of smart city logistics solutions that contain many components, is approached as a multi-criteria decision making (MCDM) problem. Considering the complex profile of this problem, this complexity is needed to be taken into account by experts for deciding on a suitable solution. However, it is challenging to decide on the most appropriate solution when information is in an uncertain nature.

This study aims to evaluate smart city logistics solutions with analytical methods. In this context, the smart city logistics solutions, which include customer and technological requirements in Istanbul determined by literature review and expert opinions, are modeled. This model is evaluated by using the House of Quality matrix of Quality Function Deployment (QFD) approach with fuzzy MCDM methods. Fuzzy Simple Additive Weighting (SAW) method is used to calculate the weights of customer requirements.

The SAW is a straightforward and widely used MCDM method. It is mainly used in one-dimensional decision-making problems. The weighted sum of the performance values of each alternative is obtained according to all criteria [6]. The House of Quality matrix is a tool that determines the customers' expectations and requirements. These customer requirements, which are determined by literature review and expert opinions, should have the importance degree for the evaluation of technological requirements. In this study, the importance of customer requirements is calculated with fuzzy SAW method. In addition, this method is supported by linguistic expressions. Therefore provides more realistic results with uncertain data and it provides a flexible environment for decision process [7].

The structure of the paper is as follows: The related studies about smart city logistics summarized in the next section. The third section presents the proposed model and methodology. The fourth section presents the application, and finally, conclusions have provided.

2 Smart city logistics

Smart city logistics is a fundamental approach to reach more efficient organization for physical and information logistics in international transportation chains. This approach provides economic, environmental, and social sustainable solutions by ensuring that information can be achieved quickly and efficiently [8].

The goals of smart city logistics are to provide multidimensional data exchange between passenger-vehicle-infrastructure-center, to increase traffic safety and mobility, to make use of roads in accordance with their capacity, to reduce energy loss by providing energy efficiency [9]. Smart city logistics applications can provide coordination between different modes of transportation to create ideal traffic conditions and increase the efficiency and speed of services related to freight movements. By optimizing travel times and reducing the risk of crashes and injuries, the performance of modern transport systems is improved [10].

Today, smart city logistics is a system based on advanced technologies in the regulation and management of transportation. These systems use real-time and up-to-date databases, and they serve to improve efficiency, safety, and service quality in transportation. There are many benefits of smart transportation with systems such as traffic tracking systems, advanced passenger information systems, pricing systems, advanced transportation management systems, and advanced public transportation systems [11].

There are several studies about smart city logistics in the literature. Some of these studies have shown in Table 1. According to Table 1, there are generally theoretical studies related to this subject, and the number of studies with the application area is small. In this study, this subject is proposed with an application area, Istanbul.

3 Proposed model and methodology

In this paper, the aim is to propose a methodology for determining and prioritizing the most crucial technological requirement for smart city logistics. In this context, the study proposes an integrated methodology.

A three-phase methodology in this study is as follows:

Phase 1: Determination of customer and technological requirements in the House of Quality matrix for smart city logistics.

Phase 2: Determination of customer requirements' weights by fuzzy SAW method.

Phase 3: Evaluation of the relationship between customer requirements and technological requirements, prioritization of technological requirements.

The flow chart of this methodology is given in Fig. 1.

3.1 The house of quality matrix of the QFD

QFD is an important design technique that enables the transformation of customers' needs to product or service characteristics in all functional components, and it is a planning, development, and communication tool [38]. QFD is a strategic tool used to develop improved products and services responsive to customer needs. This approach aims to translate customer requirements into appropriate technical or technological requirements.

The House of Quality is the most frequently used matrix in the QFD process. The House of Quality matrix is conducted by a team of multidisciplinary experts to translate customer requirements from market research and to benchmark data into technical requirements which will be met by designing a new product or service [39]. This matrix is used to evaluate the technological requirements in the smart city logistics system by meeting customer needs. With this approach, customer requirements have determined, and it is aimed to increase customer satisfaction by meeting the needs of customers. At the same time, design optimization and efficiency will improve. It is a systematic algorithm that is used as the essential design tool of QFD. It organizes data and establishes relationships [40].

The House of Quality matrix consists of two main parts. The first part is the part of the customer requirements, and the second one is the part of the technological requirements.

3.2 Customer Requirements

In the smart city logistics context, the determined customer requirements are as follows:

- ✓ *Accessibility and travel time (CRI):* Limited access in some cases increases travel quality. It is the restriction of individual vehicles on certain roads or areas. The limitation may be implemented on specific modes or periods. For example, borders to reduce the intensity in the city center during peak hours, the use of only environmentally friendly vehicles in some particular cases such as low emission zones, etc. Thus, there is a decrease in traffic intensity, an increase in the speed of public transportation, an improvement in the quality of the air, and an increase in pedestrian safety [41].

Table 1: Literature review of smart city logistics.

Year	Authors	Aim of the Study	Application Area
2019	Buyukozkan & Göçer [12]	to improve the smart city logistics and evaluate the required strategies with analytic methods	-
2019	Korczak & Kijewska,[13]	to present the use of the smart city logistics potential in the development of smart cities	-
2018	Taniguchi & Thompson [14]	to develop the current city logistics model	-
2018	Stoller & Wan [15]	to development of smart city logistics	China
2018	Kaźmierczak et al. [16]	to present the current state of smart city logistics project	Poland
2018	Bachanek [17]	to present practical methods for implementing the concept of management urban space	-
2018	Gruler [18]	to present simheuristics to support efficient and sustainable freight transportation in smart city logistics	-
2017	Eitzen et al. [19]	to propose an urban goods movement for smart city logistics	-
2017	Shuai & Hong-Chun [20]	to present a smart city logistics concept	China
2017	Bektaş et al. [21]	to present from urban freight to smart city logistics networks	-
2017	Melo et al. [22]	to develop a performance evaluation of re-routing	Lisbon, Portugal
2016	Kauf [23]	to present the basic development in the sustainable logistics	-
2016	Nocerino et al. [23]	to present the final results of the Italian pilots of Pro-E-Bike	-
2016	Nathanail et al. [24]	to evaluation framework for smart logistics solutions	-
2016	Baudel et al. [25]	to present smart deliveries	-
2016	Guerlain et al. [26]	to describe a Geographical Information System (GIS)	Luxembourg
2015	Navarro et al. [27]	to present new models for energy efficiency in urban freight transport for smart cities	Barcelona and Valencia
2014	Nowicka [28]	to present smart city logistics on the cloud computing model	-
2014	Malecki et al. [29]	to present influence of Intelligent Transportation Systems (ITS)	Szczecin
2014	Taniguchi [30]	to present city logistics for sustainable and livable cities	-
2014	Thompson & Hassall [31]	to present high productivity freight vehicles in urban areas	-
2014	Zidi et al. [32]	to propose a solution for congestion with an intelligent support system	-
2014	Cagliano et al. [33]	to present e-grocery by developing an ITS	-
2014	Lu [34]	to present an innovative solution	-
2011	Tesch et al. [35]	to present an innovative approach for road transportation	-
2010	Oliveira et al. [36]	to present the intelligent delivery points	Brazil
2007	Ambrosini & Routhier [37]	to compare the objectives, methods, and results of urban freight transport	USA, Canada, Australia, Japan, UK, Germany, Switzerland, The Netherlands, France

- ✓ *Road pricing (CR2)*: Road pricing is about the size of the cities and transportation capacities. Price areas are determined, and tariffs have created accordingly. In the peak periods, the tariffs may change according to the hours of the day. Top of the pricing, systems is electronic payment systems; bottleneck-based pricing, free express lines, vehicle mileage-based payment systems [42].
- ✓ *Lane management (CR3)*: Lane management is the flexible use of lanes in certain situations. Specific lanes reserved for public transport, temporary closure of roads in cases of accident, maintenance work and construction measures and the addition of extra lanes during peak hours are the lane management works [4].
- ✓ *Public transportation priority (CR4)*: The public transport priority is the setting of traffic control sets to minimize the stopping times of public transport. The timing of the traffic lights should be arranged accordingly. The public transport

system needs to be made more attractive than individual vehicle use. For this reason, it is necessary to shorten long waiting times, to provide uninterrupted and safe transportation, and at the same time, the fees should be reasonable for the users [9].

- ✓ *Park guidance (CR5)*: The drivers need to be directed during parking in the parking place. Park guidance presents dynamic information to drivers for parking in controlled areas. It is designed to help drivers navigate to parking garages and look for empty parking spaces. Thus, traffic volumes reduced. The accessibility of the city center increased. The use of parking capacity is optimized [41].
- ✓ *Travel and traffic information (CR6)*: Providing real-time information to drivers about road situations, accident situations, traffic congestion, etc. At the same time, according to the transportation between the two points, it

is possible to plan the travel based on the individual or public transport options [44].

- ✓ *Network robustness and road safety (CR7)*: Robust and reliable roads, bridges, and other infrastructure elements are essential for transport quality. Controls of these networks should frequently be fulfilled, and if a problem is encountered, it should be intervened immediately. In Turkey, CCTV cameras control public vehicles and stops. Also, elderly or disabled citizens can safely use the transportation system with the Accessible Pedestrian Button System developed by İSBAK [9].
- ✓ *Traceability (CR8)*: Traceability is the real-time communication between modes. Central traffic monitoring systems are high-speed tracking systems, red light infringement detection, bus line control, ticket gate control systems, double yellow line infringement control, traffic intensity tracking, security applications and automatic license plate recognition [42].

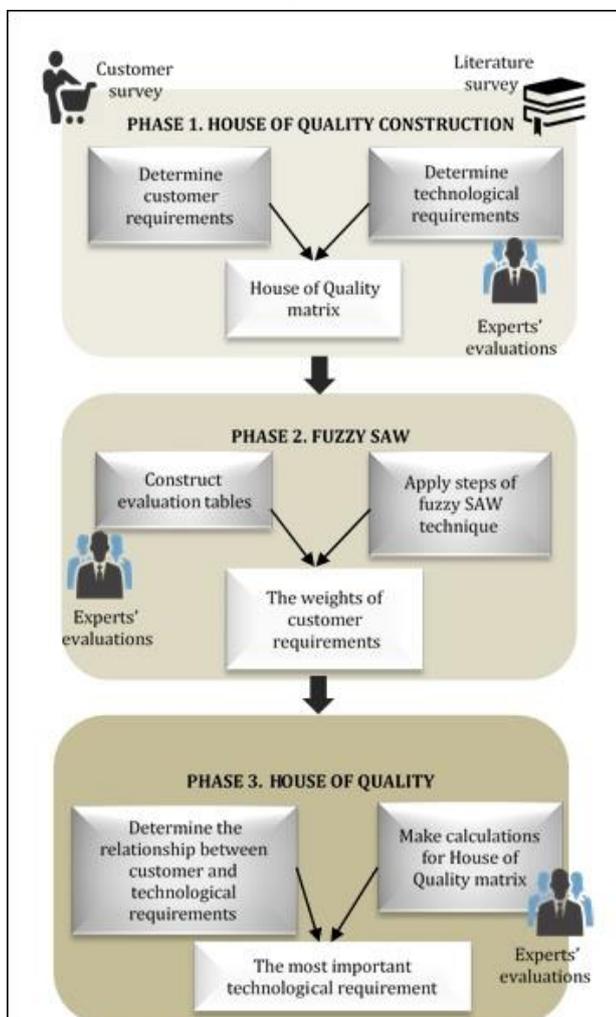


Figure 1: The flowchart of the methodology.

3.3 Technological Requirements

In the smart city logistics context, the assigned technological requirements are as follows:

- ✓ *Demand and access management (TR1)*: Demand and access management usually implemented with the use of

additional implementation strategies and variable message markings. It focuses on reducing the intensity of congestion and air pollution in large cities [41]. It determines the density according to the demand of the users and performs the pricing accordingly. It facilitates access to transportation means and services for those with restricted mobility.

- ✓ *Full adaptive traffic management system (TR2)*: Full Adaptive Traffic Management System is a working system in which the parameters have optimized for minimizing average vehicle delay times and average stop numbers. It accelerates traffic flow by intervening in real-time on blocked roads and reduces delay times. It creates ideal signal times for the system. Thus, it reduces travel time and emissions on the road network [45].
- ✓ *Security and emergency systems (TR3)*: A system that detects and prevents emergency intervention events such as traffic accidents [43]. Security systems consisting of cruise control systems and anti-lock braking systems have been developed. New generation systems such as emergency brake assist, emergency brake-force distribution, electronic stability control, and advanced speed control systems have been designed [9].
- ✓ *Variable message system (TR4)*: Variable Message Systems graphics-based fonts, shapes, and images can be displayed using LEDs for traffic purposes. Messages are used to inform drivers about traffic intensity, traffic accidents, weather, and road conditions and to control traffic flow. Thus, road traffic capacity could more efficiently be used to reducing local traffic densities [46].
- ✓ *Intelligent public transport systems (TR5)*: Public transport is one of the essential parts of city logistics. Improvement of public transportation systems with the help of developing technologies also improves transportation conditions. The system that enables the most convenient use of the public transportation needs that arise with the increasing population [43]. Passenger information systems and electronic payment systems are the most common methods used in public transport. The purpose of the passenger information system is to prevent the inefficient use of time and energy and encourage public transportation. Advanced passenger information systems include smart stops and contactless smart cards [4]. Similar applications of intelligent systems used in public transportation are also available in private vehicles.
- ✓ *Road and meteorological observation sensors (TR6)*: These include sensors that support the drivers for safe travel and road and weather sensors. Road sensors are sensors that collect data to detect traffic flow information in the city. Weather sensors are powerful and versatile sensors that measure atmospheric conditions, monitor ground temperatures, and measure moisture and heat [44].
- ✓ *Lane control systems (TR7)*: Lane control system includes an intelligent vehicle system and automatic road system. This system aims to reduce traffic accidents and ensure the safety of drivers. The system follows the lane markings on the road and gives the warning to return to the lane when the vehicle goes out of the lane [9].
- ✓ *Parking management systems (TR8)*: An intelligent system that provides the utilization of parking spaces more

efficient. Park orientation systems direct drivers to convenient parking spaces with sensors that detect occupancy or space conditions. The system combines traffic-monitoring, communication, processing, and electronic variable message technologies. Thus, vehicle and traffic intensity are also controlled [43].

- ✓ *An electronic detection system (TR9)*: It is a system, which the vehicles that violate the rules have detected with the sensors, the plates have recorded, and the drivers are subject to penalty. Using cloud technology, it has 12 different violation detection systems [41]. It has been developed in order to detect the parking lane, safety lane, pause violations that affect the traffic flow in the city logistics negatively and to prevent traffic problems caused by these violations, to prevent possible accidents by performing security control of the region with moving cameras, and to provide safety of lives and properties for pedestrians and vehicles [41, 44].
- ✓ *Communication systems (TR10)*: It provides communication between the area and central equipment of Intelligent Transportation Systems. This connection can be reached with wired and wireless networks. The communication systems solutions offered by İSBAK are fiber optic solutions, 4G / LTE, 3G, Wi-Fi and WIMAX [44].

3.4 Fuzzy SAW method

The SAW method, also known as the weighted sum method, is the most widely used MCDM method [6]. The basic principle of SAW is to obtain a weighted sum of the performance ratings of each alternative. An evaluation score is calculated for each alternative. The advantage of this method is that there is a proportional linear transformation of raw data; this means that the relative order of the sizes in the standardized points remains the same [47].

Chou et al. [48] proposed the fuzzy SAW method to solve problems under fuzzy environment. The steps of the fuzzy SAW method are as follows:

Step 1. Decision makers (DM) evaluate criteria using linguistic terms in Table 2.

Step 2. Let $D_t = \{d_1, d_2, \dots, d_k\}$ be a committee of k DMs, $A_i = \{a_1, a_2, \dots, a_l\}$ be a discrete set with l member alternatives, $C_j = \{c_1, c_2, \dots, c_j\}$ be a set consisting of the decision criteria, be the degree of importance of each DM, where $0 \leq I_t \leq 1$, $t = 1, 2, \dots, k$, and $\sum_{t=1}^k I_t = 1$, \tilde{w}_t be the fuzzy weight of the DMs. The degree of importance I_t is computed as:

$$I_t = \frac{d(\tilde{w}_t)}{\sum_{t=1}^k d(\tilde{w}_t)}, t = 1, 2, \dots, k \quad (1)$$

where $d(\tilde{w}_t)$ gives the defuzzified value of the fuzzy weight by using the signed distance.

Step 3. Aggregated fuzzy weights of individual attributes (\tilde{W}_j) are computed. The aggregated fuzzy attribute weight, $\tilde{W}_j = (a_j, b_j, c_j)$ of criterion C_j assessed by the committee of k DMs is computed as:

$$\tilde{W}_j = (I_1 \otimes \tilde{W}_{j1}) \oplus (I_2 \otimes \tilde{W}_{j2}) \oplus \dots \oplus (I_k \otimes \tilde{W}_{jk1}) \quad (2)$$

where $a_j = \sum_{t=1}^k I_t a_{jt}$, $b_j = \sum_{t=1}^k I_t b_{jt}$, $c_j = \sum_{t=1}^k I_t c_{jt}$.

Table 2: Linguistic scale for fuzzy SAW [49].

Linguistic term	S _i	Abb.	Fuzzy Numbers
None	s ₋₃	N	(0,0,0.17)
Very Low	s ₋₂	VL	(0,0.17,0.33)
Low	s ₋₁	L	(0.17,0.33,0.5)
Medium	s ₀	M	(0.33,0.5,0.67)
High	s ₁	H	(0.5,0.67,0.83)
Very High	s ₂	VH	(0.67,0.83,1)
Perfect	s ₃	P	(0.83,1,1)

Step 4. The fuzzy weights of criteria are defuzzified. The defuzzification of \tilde{W}_j is denoted as $d(\tilde{W}_j)$ and computed as:

$$d(\tilde{W}_j) = \frac{1}{3} (a_j + b_j + c_j), j = 1, 2, \dots, n \quad (3)$$

Step 5. Normalized weight of criterion C_j is denoted as W_j and computed as:

$$W_j = \frac{d(\tilde{W}_j)}{\sum_{j=1}^n d(\tilde{W}_j)}, j = 1, 2, \dots, n \quad (4)$$

where $\sum_{j=1}^n W_j = 1$ and the weight vector $W = (W_1, W_2, \dots, W_n)$ is constructed.

4 Application

In this part of the study, an application is presented to demonstrate the applicability of the proposed research methodology. Expert opinion is needed in the application of the proposed methodology to identify smart city logistics solutions.

In this context, opinions were taken from three experts, and the steps of the proposed methodology were applied with the opinions of these DMs. The first expert, DM1, has logistics sector experience exceeding ten years. DM2 has experience for the smart systems projects in the logistics sector. DM3 is working on supply chain and logistics management and smart systems for city transportation in the academy. All three experts are sufficiently knowledgeable and experienced in the field of smart city logistics.

Step 1: Customer requirements of smart city logistics in House of Quality matrix are determined with a detailed literature survey and expert opinions.

Step 2: Technological requirements of smart city logistics in House of Quality components are determined with a detailed literature survey and expert opinions.

Step 3: DMs evaluated customer requirements using linguistic terms in Table 2 to calculate weights. These evaluations with linguistic expressions are shown in Table 3.

Table 3: DMs' evaluation for customer requirements.

	DM1	DM2	DM3
CR1	M	H	VH
CR2	VL	M	L
CR3	L	L	VL
CR4	VH	M	L
CR5	N	N	L
CR6	H	H	H
CR7	P	VH	VH
CR8	M	L	M

Step 4: The equations (1) – (4) are applied and the weights of customer requirements are calculated as shown in Table 4.

Table 4: The weights of customer requirements.

	Aggregated Fuzzy Weights	Defuzzified Weights	Normalized Weights
CR1	(0.50,0.67,0.83)	0.667	0.168
CR2	(0.17,0.33,0.50)	0.333	0.084
CR3	(0.11,0.28,0.44)	0.278	0.070
CR4	(0.39,0.55,0.72)	0.556	0.140
CR5	(0.06,0.11,0.28)	0.149	0.038
CR6	(0.50,0.67,0.83)	0.667	0.168
CR7	(0.72,0.89,1)	0.870	0.220

CR8	(0.28,0.44,0.61)	0.444	0.112
------------	-------------------------	--------------	--------------

Step 5: DMs made a collective decision and formed the relationship matrix. For each actor group such as customer requirements, technological requirements, comparison matrices between them, weights and relationship matrix are placed in the House of Quality as Table 5.

Step 6: The importance degree of each technological requirement by multiplying the weight of the customer requirement and the relationship matrix values are found as follows:

$$\text{Weight of TR1} = [(0.168 \times 9) + (0.084 \times 9)] / 16.112 = 0.141$$

Table 5: House of quality.

		Technological Requirement										Sum	
		TR1	TR2	TR3	TR4	TR5	TR6	TR7	TR8	TR9	TR10		
Customer Requirements	CR1	0.168	9	3		3	1						
	CR2	0.084	9			3				1			
	CR3	0.070		3	3		3	9				3	
	CR4	0.140		3			9	3		1	1		
	CR5	0.038		1		3			9	3	1		
	CR6	0.168		3		9						3	
	CR7	0.220		3	9			3					
	CR8	0.112			3	3					3	9	
			2.271	2.336	2.522	1.963	2.229	0.827	1.051	0.338	0.673	1.902	16.112
Importance degree			0.141	0.145	0.157	0.122	0.138	0.051	0.065	0.021	0.042	0.118	1.000
Ranking			3	2	1	5	4	8	7	10	9	6	

The final importance degrees are shown in Table 5. As a result of the evaluation, the priority order of the technological requirements is as follows: security and emergency systems (TR3), full adaptive traffic management system (TR2), demand and access management (TR1), intelligent public transport systems (TR5), variable message system (TR4), communication systems (TR10), lane control systems (TR7), road and meteorological observation sensors (TR6), electronic detection system (TR9) and parking guidance systems (TR8).

According to this result, the first issue to focus is on smart city logistics solutions is security and emergency systems. It is the most critical solution because it has the highest evaluation of the relationship between customer requirements and technological requirements. At all times, human safety is a critical element. Thanks to smart systems in the case of emergency, fast and direct interventions protect passenger and driver's health. With the developed brake and speed control systems, a more secure logistics system will establish.

5 Conclusion

Countries with high economic levels make great strides in smart city logistics area and use the technology at the highest level. The critical need for smart city logistics may be understood if the material and spiritual losses that are caused by traffic accidents and congestions in our country are taken into account. It is vital to integrate the right technology to implement the required system.

This study aims to identify and evaluate smart city logistics solutions with fuzzy analytic methods. Fuzzy analytic methods are enables to decide where to start the development of a more sustainable, mobile, and livable city. In this reason, an integrated methodology is proposed. The components of the House of Quality determined by the literature survey and the expert opinions are prioritized by the proposed methodology. In this combined work, the priority ranking is made for all technologies without focusing on only one smart technology. According to the results obtained, safety and emergency systems have ranked first in importance.

With these systems, events that require any kind of emergency response are identified, the center concerned are informed, the incident is intervened, and the destruction caused by the incident is managed. Preventing the loss of life and minimizing material damage depends on the effective management of this process. In general, one of the most effective methods of event detection is camera monitoring and automatic alerting [41, 46].

In future studies, the number of customer and technological requirements can be increased, and the problem can be solved using aggregation operators for group decision making to aggregate DMs' evaluations. Another perspective can be to consider uncertainty using an advanced fuzzy approach such as hesitant fuzzy linguistic term sets, intuitionistic fuzzy sets, etc.

6 References

- [1] Taniguchi E, Thompson RG, Yamada T. "Modelling city logistics". *International Conference on City Logistics*, 1st, Cairns, Queensland, Australia, 1999.
- [2] Nowicka K. "Smart city logistics on cloud computing model". *Procedia-Social and Behavioral Sciences*, 151, 266-281, 2014.
- [3] BVRLA Policy Paper. "Intelligent Mobility". 2016.
- [4] UNECE. "Intelligent Transport Systems (ITS) for sustainable mobility". 2012.
- [5] Kirch M, Poenicke O, Richter K. "RFID in Logistics and Production-Applications, Research and Visions for Smart Logistics Zones". *Procedia Engineering*, 178, 526-533, 2017.
- [6] Hwang CL, Yoon K. *Methods for Multiple Attribute Decision Making*. In *Multiple Attribute Decision Making*. Springer, Berlin, Heidelberg, 58-191, 1981.
- [7] Roszkowska, E., Kacprzak, D. "The fuzzy SAW and fuzzy TOPSIS procedures based on ordered fuzzy numbers". *Information Sciences*, 369, 564-584, 2016.
- [8] Tufan H. Akilli Ulaşım Sistemleri Uygulamaları ve Türkiye için bir AUS Mimarisi Önerisi. Ulaştırma ve Haberleşme Uzmanlığı Tezi, TC Ulaştırma Denizcilik ve Haberleşme Bakanlığı. 2014.
- [9] T. C. Ministry of Transport, Maritime Affairs and Communications. "National Intelligent Transportation Systems Strategy Document and Action Plan: 2014-2023", 2014.
- [10] Zanelli P. "Intelligent Mobility., CATAPULT Transport Systems Report, 2016.
- [11] Viecznicki P, Khuperkar A, Fishman T, Eggers W. "Smart mobility: Reducing congestion and fostering faster, greener, and cheaper transportation options". Deloitte Smart Mobility Research Report. 2015.
- [12] Buyukozkan G, Göçer F. "Prioritizing the Strategies to Enhance Smart City Logistics by Intuitionistic Fuzzy CODAS". Conference of the International Fuzzy Systems Association and the European Society for Fuzzy Logic and Technology (EUSFLAT 2019), Prague, Czechia, 09-13 September 2019.
- [13] Korczak J, Kijewska K. "Smart Logistics in the development of Smart Cities". *Transportation Research Procedia*, 39, 201-211, 2019.
- [14] Taniguchi E, Thompson RG. "Future developments modelling information and. Urban Logistics: Management". *Policy and Innovation in a Rapidly Changing Environment*, 336, 2018.
- [15] Stoller CW, Wan W. "Smart City Logistics-Ein Besuch in Schanghai". *Internationales Verkehrswesen*, 70(4), 2018.
- [16] Kaźmierczak J, Hilarowicz A, Wolny M. "Introduction to the research project "smart city: a holistic approach", *International Multidisciplinary Scientific Conference on Social Sciences and Arts (SGEM)*, Albena, Bulgaria, 26 August-01 September 2018.
- [17] Bachanek KH. "Development of IT Services in Urban Space-Smart City Logistics". *European Journal of Service Management*, 28, 27, 2018.
- [18] Gruler AC. Simheuristics to support efficient and sustainable freight transportation in smart city logistics, PhD Thesis, University of Catalonia, 2018.
- [19] Eitzen H, Lopez-Pires F, Baran B, Sandoya F, Chicaiza JL. "A multi-objective two-echelon vehicle routing problem. An urban goods movement approach for smart city logistics". *XLIII Latin American Computer Conference (CLEI)*, 1-10, Cordoba, Argentina, 04-08 September 2017.
- [20] Shuai L, Hong-chun W. "Discussion on the problems and countermeasures of smart city logistics system". *IEEE Control and Decision Conference (CCDC)*, Chongqing, China, 28-30 May 2017.
- [21] Bektaş T, Crainic TG, Van Woensel T. "From managing urban freight to smart city logistics networks". *Network Design and Optimization for Smart Cities*, 143-188, 2017.
- [22] Melo S, Macedo J, Baptista P. "Guiding cities to pursue a smart mobility paradigm: An example from vehicle routing guidance and its traffic and operational effects". *Research in transportation economics*, 65, 24-33, 2017.
- [23] Kauf S. "City logistics-A Strategic Element of Sustainable Urban Development". *Transportation Research Procedia*, 16, 158-164, 2016.
- [24] Nocerino R, Colorni A, Lia F, Luè A. "E-bikes and E-scooters for smart logistics: environmental and economic sustainability in pro-E-bike Italian pilots". *Transportation Research Procedia*, 14, 2362-2371, 2016.
- [25] Nathanail E, Gogas M, Adamos G. "Smart interconnections of interurban and urban freight transport towards achieving sustainable city logistics". *Transportation Research Procedia*, 14, 983-992, 2016.
- [26] Baudel T, Dablanc L, Alguar-Melgarejo P, Ashton J. "Optimizing urban freight deliveries: from designing and testing a prototype system to addressing real life challenges". *Transportation Research Procedia*, 12, 170-180, 2016.
- [27] Guerlain C, Cortina S, Renault S. "Towards a collaborative Geographical Information System to support collective decision making for urban logistics initiative". *Transportation Research Procedia*, 12, 634-643, 2016.
- [28] Navarro C, Roca-Riu M, Furió S, Estrada M. "Designing new models for energy efficiency in urban freight transport for smart cities and its application to the Spanish case". *Transportation Research Procedia*, 12, 314-324, 2016.
- [29] Małeckı K, Iwan S, Kijewska K. "Influence of intelligent transportation systems on reduction of the environmental negative impact of urban freight transport based on Szczecin example". *Procedia-Social and Behavioral Sciences*, 151, 215-229, 2014.
- [30] Taniguchi E. "Concepts of city logistics for sustainable and liveable cities". *Procedia-social and behavioral sciences*, 151, 310-317, 2014.
- [31] Thompson RG, Hassall K. "Implementing high productivity freight vehicles in urban areas". *Procedia-Social and Behavioral Sciences*, 151, 318-332, 2014.
- [32] Zidi A, Bouhana A, Fekih A, Abed M. "Personalization of Itineraries search using Ontology and Rules to Avoid Congestion in Urban Areas". *IFAC Proceedings Volumes*, 47(3), 4196-4200, 2014.
- [33] Cagliano AC, Gobbato L, Tadei R, Perboli G. "Its for e-grocery business: the simulation and optimization of urban logistics project". *Transportation Research Procedia*, 3, 489-498, 2014.
- [34] Lu M. "Advanced Logistics for Sustainable Urban Areas". Second International Conference on Traffic and Transport Engineering (ICTTE). 2014.

- [35] Tesch C, Clausen U, Wohlgemuth S. "Logistics for decision support in the operation of both terminals and the corresponding yards", *15th World Multi-Conference on Systemics, Cybernetics and Informatics (WMSCI)*, Orlando, USA, 19-22 July 2011.
- [36] Oliveira LK, Nunes NTR, Novaes AGN. "Assessing model for adoption of new logistical services: An application for small orders of goods distribution in Brazil". *Procedia-Social and Behavioral Sciences*, 2(3), 6286-6296, 2010.
- [37] Ambrosini C, Routhier JL. "Objectives, methods and results of surveys carried out in the field of urban freight transport: an international comparison". *Transport Reviews*, 24(1), 57-77, 2004.
- [38] Akao Y, King B, Mazur GH. *Quality function deployment: integrating customer requirements into product design*. Cambridge, MA: Productivity press, 1990.
- [39] Hauser JR, Clausing D. *The house of quality*. 1988.
- [40] Chan LK, Wu, ML. "Quality function deployment: A literature review". *European journal of operational research*, 143(3), 463-497, 2002.
- [41] Civitas, Policy Note. "Intelligent Transport Systems and traffic management in urban areas". 2015.
- [42] Cohen B. "Smart city wheel. Retrieved from SMART & SAFE CITY". 2013.
- [43] Deloitte. "Akıllı Şehirler, Teknolojideki Hızlı İlerlemeler Ekonomimizi ve Toplumunu Nasıl Yeniden Şekillendiriyor?". 2015.
- [44] Ilıcalı M, Toprak T, Özen H, Tapkın S, Öngel A, Camkesen N, Kantarcı M. "Akılcı-Güvenli Trafik için Akıllı Ulaşım Sistemleri". 2016.
- [45] Goldman T, Gorham R. "Sustainable urban transport: Four innovative directions". *Technology in society*, 28(1-2), 261-273, 2006.
- [46] ASCIMER (Assessing Smart Cities in the Mediterranean Region). "Assessment Methodology for Smart City Projects-Application to the Mediterranean Region". Universidad Politecnica de Madrid (UPM), 2017.
- [47] Chang YH, Yeh CH. "Evaluating airline competitiveness using multiattribute decision making". *Omega*, 29(5), 405-415, 2001.
- [48] Chou SY, Chang YH, Shen CY. "A fuzzy simple additive weighting system under group decision-making for facility location selection with objective/subjective attributes". *European Journal of Operational Research*, 189(1), 132-145, 2008.
- [49] Beg I, Rashid T. "TOPSIS for hesitant fuzzy linguistic term sets". *International Journal of Intelligent Systems*, 28(12), 1162-1171, 2013.