Applications of Fuzzy Analytic Hierarchy Process in Urban Mobility System

Uroš KRAMAR, Darja TOPOLŠEK

Abstract: Importance of urban mobility system is increasing from year to year. This is the reason why decision making process is increasingly complex requiring taking into account more and more different criteria. One of the important and commonly used techniques that support decision making processes is Analytic Hierarchy Process (AHP) while for the purpose of supporting a more realistic way of decision making, fuzzy logic is used. The paper examines the use of fuzzy analytical hierarchy process (FAHP) in the urban mobility system. With the use of systematic literature review (SLR) it categorises peer reviewed journals' articles related to the applications of FAHP in urban mobility system and extracted from Scopus and Web of science database, and analyses them methodologically. Papers were classified based on basic attributes of research papers, features of urban mobility system (UMS) where the FAHP was used, and use characteristics of the fuzzy analytic hierarchy process (FAHP). The results of this study indicated that the use of FAHP in urban mobility system is increasing with the first published paper in 2009. Our review has found that FAHP is used for very different purposes such as evaluation of customer expectations or citing a selection problem. Most often it is used in combination with other methods. Interestingly, there is only one paper that uses FAHP for decision making in the whole urban mobility system.

Keywords: fuzzy analytic hierarchy process; systematic literature review; urban mobility system; urban transport system

1 INTRODUCTION

Modern society depends on mobility. As pointed out by [1] mobility is a significant scope of social improvement both for individuals and for the whole country. The increasing dependence on high-quality mobility system also brings negative consequences that are evident through environment problems, traffic jams and congestion, which in turn reduces the degree of mobility. According to the United Nations, actions should be taken so that the transport system becomes more sustainable and that the provision of mobility becomes a priority of every transport policy [2].

For the efficient and effective operation of the mobility of the system it is necessary to provide complex and complete solutions, which will enable sustainable development. Such solutions, however, require the adoption of complex decisions, taking into account the various and also conflicting criteria. For creating productive judgments that satisfy all the appropriate gauges for judgment at various levels, Multi-Criteria Decision-Making (MCDM) methods are commonly applied. Between the various MCDM techniques recommended, the Analytic Hierarchy Process (AHP) suggested by Saaty [3] is well-known. When making a decision it is much easier for decision makers to articulate themselves through linguistic terms. As is claimed in [4] a decision-making approach can be considerably upgraded with a fuzzy linguistic model, and be applicable for individual judgements and assessment preferences. According to [5], fuzzy logic makes a more realistic way for such issues and to better deal with undetermined human judgments.

We can find many applications that use fuzzy AHP technique to solve various situations [4]. In Scopus database there are more than 2.479 papers that apply FAHP. Considering these circumstances, an analysis of usefulness of FAHP in particular areas becomes important.

However, to the best of our knowledge there has not been a study that has reviewed FAHP applications in urban mobility system. We consider this as an important gap in the literature and aim to contribute an up-to-date review of

FAHP applications in urban mobility system to fill the gap. So the purpose of this research is to explore the use of FAHP in the urban mobility system as one of frequently used methods for MCDM problems. It provides an overall review of the past researches and shows how FAHP can be used in urban mobility system. It also provides cases of the use of FAHP in urban mobility system, combined in one place, which can be useful for different practices and policies.

The structure of the paper is as follows. In the next section urban mobility is briefly described. Then we introduce FAHP in Section 3. In section four the methodology used is explained. Findings are introduced in section five. The paper finishes with research conclusions.

2 URBAN MOBILITY

Oxford English Dictionary defines "mobility" as "the ability to move or be moved freely and easily" [6]. According to [8], in the field of transport mobility is described as "the *potential for movement*" and the capability to get from point A to point B. Some authors [1] use the term *transport mobility* in conjunction with the gains derived from travel activities.

There is not a clear distinction between transport and mobility. In literature mobility and transport are often used together (see [9]). Generally speaking, though, "mobility is a broader concept than transport, as it refers not only to actual movement, always referring to the latter. When we talk about urban mobility it can be understood as urban transport of passengers and freight in relation to conurbations [10]. It includes users and their interaction, the transport system, vehicles and infrastructure and their interaction, impacts of transport and relevant tools in an urban context [10]. It is the ability to move between different activities sites [11] and represents a complex system with many subsystems. A comprehensive discussion on the difference between the transport and mobility goes beyond the intention of this research paper. For the purpose of our research, we will use the term mobility and focus on urban mobility.

Modern approaches for regulating urban mobility systems require a holistic strategic approach with a mixed strategy between 'hardware' and 'software' oriented measures (see [12]) and with focus on more sustainable modes of travel such as public transport, walking and cycling. All this demonstrates the need for the adoption of integrated strategic decisions, which may be significantly more difficult because decisions are often complex and objectives contradictory.

3 FUZZY AHP

AHP, proposed by [3] and presented in 1970s', is one of widely used MCDM tools [13]. It consists of three basics parts: model structure, comparisons of the alternatives and the criteria and combined preferences. Besides AHP, there are several well-established MCDM models [13]; most popular ones are ELECTRE, PROMETHEE and TOPSIS [14]. AHP has been broadly used in solving various complex decision-making problems such as planning, defining the best alternative, resource allocation and customer expectations [13]. It has also been used in many different fields, for example technology and engineering, marketing, business, government, education and medicine which highlights the importance of research of AHP usage in different fields [13]. Regardless of its recognition, acceptance and simplicity in handling MCDM problems, the AHP is often criticized for its incapability to appropriately tackle the inherent unpredictability and unclearness [7]. Similarly, [14] emphasizes that the traditional AHP is not able to reflect the unclearness in human thinking style.

Uncertainty in preferences can be modelled using fuzzy set theory which was first introduced by Zadeh [15]. The fuzzy set theory uses linguistic terms to express decision maker preferences and has the ability and capacity to point out vague data. In fuzzy set terminology, the ratio supplied by the decision maker is a fuzzy number described by a membership function. Here, a membership function describes the degree with which elements in the judgment interval belong to the preference set [16]. Introduction of fuzzy linguistic factors instead of exact, crisp values can help a decision maker to use non-numerical terms for his/her subjective judgments and it can include the inexactness related to the decision maker's priorities. Therefore, it will remove the disadvantages of the static form of the basic scale in capturing uncertainty in the comparisons [7]. In order to include fuzzy linguistics factors in solving hierarchical multi-decision problems, FAHP, extension of AHP, is presented.

In FAHP pairwise comparison judgments are usually expressed by two different ordinary fuzzy numbers, i.e., triangular and trapezoidal fuzzy numbers [7]. An important part of the FAHP method is the process of determining weights to each criterion. To determine the weights, different approaches are used, such as Van Laarhoven and Pedrycz's approach, Buckley's fuzzy AHP or Chang's extent analysis method.

4 METHODOLOGY

Given the importance of mobility in urban environments and the complexity of the decision-making process, this paper examines scientific literature that uses FAHP in urban mobility system. To do such a research we used the systematic literature review (SLR) technique.

According to [17] and [18] from a methodological perspective, a literature review is a methodical, organized, straightforward, and consistent approach for analysing, assessing, and explaining the existing body of documents. Systematic reviews are described as literature reviews that are attached closely to a series of scientific approaches that strictly and exactly aim to limit systematic error (bias), primarily by trying to recognize, evaluate and incorporate all relevant research studies with the purpose of answering a specific question (or set of questions).

The SLR method was first presented in the 1990s in the field of medicine. It involves documenting all the procedures undertaken [19], [18] and as pointed out by [20], SLR can support the development of guidelines, as it encompasses the search, selection, critical evaluation and synthesis of primary research results. It differs from heavily statistics methods such as meta-analysis [19] and from traditional narrative reviews by being more systematic and explicit in the selection of the studies and employing rigorous and reproducible evaluation methods [21]. As argued by [22] one of the strengths of a SLR is its systematic methodology, therefore providing the required criticism in the performance of all research steps.

Following [18] the following stages are adopted in this review: 1. Formulation of clear and answerable research question; 2. determination of research database; 3. A detailed search of scientific papers with a help of a series of keywords; 4. Review and the elimination of irrelevant articles; 5. Examination of selected papers more thoroughly and analysis and classifications of articles; 6. Concluding Remarks.

First stage in implementation of a systematic review is defining understandable and answerable question. According to [17] a research question is a precisely stated question that guides the review. To meet the needs of our research paper we formulated the following question: In what extent has the FAHP approach been used in the scientific literature to assist decision making in urban mobility system? More in detail, we wanted to answer the following two groups of sub questions: features of UMS where FAHP was used and use characteristics of FAHP.

For the purpose of answering the predefined research question, our search strategy has been composed of looking for relevant papers within extensive scientific literature, presented in peer-reviewed journals. For an initial generic search of the topic the articles were searched from Scopus Citation Databases using their web-based user interface at http://www.scopus.com. We chose Scopus database because *"Scopus is the largest abstract and citation database of peer-reviewed literature"* [23]. It covers over 20,500 headings from 5,000 publishers throughout the world, ensuring high quality and comprehensive search results [18]. As [19] claims Scopus holds a large number of established, eminent and widely-known journals with more than 41 million entries in its database and in terms of search functionality, it offers the opportunity to search simultaneously for keywords in an article title, abstract and keyword list thereby assuring that researcher can locate the required word within the above mentioned elements of a published paper. The same database has already been used

by other researchers (see [23]). Additionally, we have also used Web of Science (WoS) database for a wider scope of articles.

After defining the database, we use "fuzzy AHP", "fuzzy analytic* hierarchy process" and FAHP, as keywords for searching in the field title, abstract or keywords. We found 3105 results in Scopus and 1092 in WOS. After limiting to document type: article, article in press, source type: journals and English language we found 1533 results in Scopus and 943 in WoS. In second stage we limited our research to next group of words: mobility, transport and transportation and we found 557 results in Scopus and 77 in WoS. According to our research question in the third stage we limited our results to urban and found 91 final results in Scopus and 6 in WOS.

This basic selection of references was first reviewed in order to evaluate their real importance for the topic of this research [18]. Thus, we excluded those that did not refer to any part of the mobility system or FAHP was not used or the paper was not related to the urban environment. Finally, a total of 19 papers published between 2009 and July 2016 were considered to be acceptable and suitable for our SLR. These papers were then analysed more thoroughly and classified according to some key elements which are shown in the next section.

5 DISCUSSION

According to our research question we analysed features of UMS where FAHP was used and characteristics of FAHP were used. Below key findings are presented.

Table 1 Source of research papers per year

Source of research papers	Year
International Journal of Environmental Science And Technology	2009
Construction Management and Economics	2010
International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems	2012
European Transport Trasporti Europei	2013
Transport Policy	2013
Total Quality Management and Business Excellence	2013
Advances in Environmental Biology	2014
Computational Intelligence and Neuroscience	2014
European Transport Research Review	2014
Journal of Applied Mathematics	2014
Promet Traffic Traffico	2014
Safety Science	2014
Advances in Civil Engineering	2014, 2015
Habitat International	2015
Transportation Research Part A Policy And Practice	2015
Environmental Impact Assessment Review	2016
International Journal of Pavement Research And Technology	2016
Mathematical Problems in Engineering	2016
Total	19 research papers

Interestingly, the articles using FAHP in the field of urban mobility appear only in the last few years. First paper published in year 2009 was from [5]. It used FAHP with preference ranking organization method for classifying the transportation modes according to the environmental effects of them. The suggested methodology was used and tested in Marmara Region of Turkey. The increase in the number of research papers is visible from 2013 onwards. Most of them were published in 2014 [7]. In 2013, 2015

and 2016 there were three published research papers per year. It is expected that the number of papers in 2016 will increase.

Papers were published in 18 different publications (Tab. 1). Only in Advances in Civil Engineering there were two published papers (in year 2014 in 2015).

According to country/territory FAHP was most often used in Turkey (five research papers), four of them were used in Istanbul. Three research papers were used for urban mobility system in China and two in Iran, Kenya, United Kingdom and United States. All together FHAP was used in ten different countries.

Tab. 2 shows how many times individual research paper was cited. All together there were 112 citations. Most cited was [5] which ranked the transportation modes according to the environmental effects of them. Four research papers had more than 10 citations and three research papers were not cited.

Table 2 Number of citations of research papers

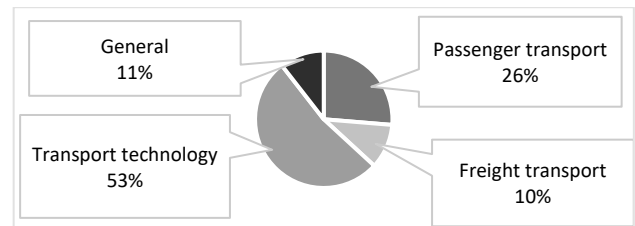| Reference no	No of citations	Reference no	No of citations
[5]	24	[28]	3
[27]	18	[38]	3
[42]	13	[34]	3
[29]	12	[36]	3
[35]	9	[4]	2
[26]	6	[37]	1
[25]	5	[41]	1
[39]	5	[33]	0
[40]	4	[30]	0
		[32]	0

Figure 1 Analysis of research papers per main category

In Fig. 1, research papers are arranged according to categories of urban mobility system as in [24]. Regarding passenger transport, some papers used FAHP and SERVQUAL to evaluate customer satisfaction [25, 26], or to estimate the values of service gaps in delivered public transport service [27]. In category of freight transport, one paper used integrated FAHP and FTOPSIS for choosing central business district logistics scenario [28] and the other paper used FAHP to facilitate the employment of unpredictability in seaport operations [29]. Some paper examples for transport technology are: [36] used FAHP and VIKOR for prioritization of pavement maintenance, [30] used FAHP and GIS to determine the location of subsurface parking. Within the 'general' category there are papers which cannot be classified among the remaining three categories. Among them there is also one paper that is focusing on the whole system, namely to rank the transportation modes according to their environmental effects [5].

In regard to the classification in [24] and [31] further analysis was done according to the mobility sub-category. One can notice that the main subcategory where FAHP was used is public transport with 10 research papers (among them 5 in public bus system). Despite that, there is a strong

tendency to present an integrated holistic approach in UMS that simultaneously requires complex decisions making, only one research paper used FAHP to comprehensively address the mobility system.

Table 3 Research papers according to transport sub-category

Research papers according to transport sub-category	Number of papers	%
Public transport - bus	5	26
Public transport - rail	2	11
Public transport - metro or subway	3	16
Walking and cycling	0	0
Road transport (flowing and stationary, cars)	1	5
Road technology	4	21
Urban logistics	1	5
General (whole system, intermodality,…)	2	11
Water	1	5
Air	0	0

Table 4 The use of FAHP in conjunction with soft and hard measures in UMS

Soft measures	11 papers	58%
Hard measures	8 papers	42%

We analysed research papers regarding soft and hard measures (Tab. 4) and according to which criteria they used (Fig. 2). We used similar criteria classification as in [18]. Among research papers there are eleven papers in the field of soft measures and eight papers that cover hard measures, which shows that the use of FAHP was not limited only to the decision making process in combination with developing transport infrastructure.
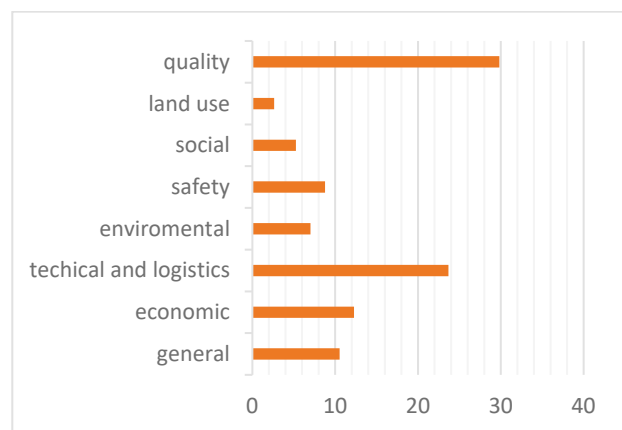

Figure 2 Type of criteria for decision-making in UMS

Diversification is also evident in the choice of criteria, where predominant criteria are in the field of quality and technical logistics. Quality criteria are present in a large number of papers (16 research papers). Technical and logistics criteria are also present in a large number of research papers (14 research papers). At least one economic criterion is present in 12 research papers. In the general group there are decision criteria like social-cultural criteria [30] or government support level [32]

We also analysed research papers according to the use of FHAP. The summary of use characteristics is shown in Tabs. 4, 5, 6 and 7.

Table 5 The use of fuzzy numbers

Fuzzy numbers used	Triangular	Trapezoidal	Not specified	Other
No. of papers	13	1	4	1

Table 6 Method for weight computation

Method for weight computation	Buckley's (1985) FAHP algorithm	Computing fuzzy eigenvalue	Not specified	Chang's (1992) extent analysis	Other
No. of papers	7	4	1	4	3

Table 7 Use of consistency check

Use of consistency check	Not used	Used with results shown	Used but results not shown	Not needed
No. of papers	10	5	3	1

Table 8 Use of defuzzification

Use of defuzzification	Used	Not used	Not specified
No. of papers	8	10	1

The most commonly used fuzzy numbers were triangular fuzzy numbers, which does not differ from applications in other fields. For weight computation the most used method was Buckley's (1985) FAHP algorithm, followed by Chang's (1992) extent analysis and Computing fuzzy eigenvalue. It is interesting that ten research papers did not use consistency check, five used it and showed the results. One research paper explains that consistency check for their research was not needed [34]. Eight from 19 research papers used defuzzification for changing fuzzy into crisp numbers.

Tab. 10 shows that there is quite a wide variation of the use of FAHP in urban mobility system, from customer satisfaction [34, 35], infrastructure projects [30, 37, 38, 36], treatment of uncertainties [29] to environment impact evaluations [5, 4].

Regarding method combination FHAP was independently used two times namely to set up an assessment index system for the development level of urban public transport [32] and to make the multi-criteria evaluation of the existing rail systems for the assignment of the scarce sources [39]. Five times FAHP was used with TOPSIS [4, 28, 34, 40, 41] three times with SERVQUAL [27, 25, 26] and two times with GIS [30], [37].

Regarding the selection of decision makers two research papers used users of UMS [27, 26], four research papers did not specify decision makers [34, 32, 30, 38] and 13 research papers used different type of experts.

According to the review of scientific papers we can conclude that the use of FAHP in urban mobility system increases through the years, which means that its useful value in multi-criteria decision-making problems is recognized. Its useful value is very wide, which means it can be used for taking simple or complex decisions to tackle various segments of the urban mobility system. Its utility is in its simplicity and convenience, but it is a sufficiently accurate method that may be used for significant managerial decisions.

Table 9 Rewiewd papes according to authors and purpose of the research

Authors	Purpose
Tadić, Zečević and Krstić, 2014 [28]	A new proposal of choosing the central business district logistics scenario, which is composed of different city logistics initiatives.
Ouma, Yabann, Kirichu and Tateishi, 2014 [37]	To take into account the vagueness type uncertainty detected and experienced in alternative bypass location determination
Aydin, Celik and Gumus, 2015 [35]	To assess level of customer satisfaction for the rail transit lines of Istanbul
Zhao, Tang and Ning, 2016 [33]	To solve group decision-making support problem of emergency alternatives in Unattended Train Operation metro system of China
Bilişik, Erdoğan, Kaya and Baraçli, 2013 [36]	To evaluate customer satisfaction of public transportation system
Pashmakian and Saeed Izadi 2014 [30]	To determine the location of subsurface parking selection in reducing the loss of historic neighbourhoods identification surrounding central area of Hamedan and appropriate response to the problem of citizen space and spatial needs
Lupo, 2013 [26]	To conquer constraints of the traditional service assessment methods and to evaluate customer satisfaction with the public urban transit service which is supplied in the city of Palermo
Zou, Dai, Yao, Jiang and Guo, 2014 [32]	To establish an assessment index system for the development level of urban public transport consisting of a target layer, a criterion layer, and an index layer
Ouma, Opudo and Nyambenya, 2015 [40]	to evaluate and compare FAHP and Fuzzy TOPSIS method for the subjective analysis of the pavement conditions for automated maintenance prioritization
Zou and Li, 2010 [42]	To develop a comprehensive risk checklist associated with subway projects and a methodology to assess the risks at the early stage of a project
Wey, 2015 [38]	To find a solution for a site selection problem by employing the FAHP as the assurance region's weights
Shafabakhsh, Hadjihoseinlou and Taghizadeh, 2014 [41]	To select an appropriate public transportation system to access airport
Bilisik, Demirtaş, Tuzkaya and Baraçl, 2014 [34]	To establish the best locations for bus garages to manage the maintenance and repair activities.
John, Paraskevadakis, Bury, Yang, Riahi and Wang, 2014 [29]	To facilitate the employment of unpredictability in seaport operations and to optimize its performance effectiveness in a systematic manner
Tuzkaya, 2009 [5]	To rank the transportation modes according to the environmental effects of them
Babashamsi, Golzadfar, Yusoff, Ceylan and Nor, 2016 [25]	Prioritization of pavement maintenance alternatives
Ruiz-Padillo, Ruiz, Torija and Ramos-Ridao, 2016 [4]	To select appropriate options against traffic noise in each of the road stretches included in the noise action plans
Lupo, 2013 [26]	To estimate the values of service gaps in public urban transport service delivered
Sari, Behret, Kahraman, 2012 [39]	To make the multi-criteria evaluation of the existing rail systems for the assignment of the scarce sources

Table 10 Features of FAHP use in UMS

Authors	Combination method/technique	No. of criteria/sub criteria	Selection of alternatives	No. of decision makers/Definition of experts
Tadić, Zečević and Krstić, 2014 [28]	Integrated FAHP-FTOPSIS method	10/0	3 scenarios of the Central Business Danube District logistics system	More than one / A number of stakeholders: residents, shippers and receivers, logistics providers and city government
Ouma, Yabann, Kirichu and Tateishi, 2014 [37]	FAHP and GIS-based least cost path (LCP) analysis	3/9	1 road	More than one / Large number of experts: Transportation engineers and planners
Aydin, Celik and Gumus, 2015 [35]	FAHP, Statistical analysis and fuzzy-Choquet integral	9/0	6 rail transit lines	More than one / Professionals and academicians
Zhao, Tang and Ning, 2016 [33]	FAHP and Enhanced WOWA operator	3/0	5 Emergency alternatives of train fire.	5 groups of decision makers / Traffic dispatcher, Environment dispatcher, Passenger Dispatcher, Vehicle Dispatcher, Power dispatcher
Bilişik, Erdoğan, Kaya and Baraçli, 2013 [36]	FAHP, SERVQUAL, the Delphi method and TOPSIS	5/33	4 public transport companies	3 experts and more transport users / One working in Istanbul Electric Tramway and Tunnel company, the second an academician offering studies on this topic, and the third one both working in IETT company at an administrative level and having academic publications
Pashmakian and Saeed Izadi 2014 [30]	FAHP and GIS	7/17	4 urban locations for under subsurface parking	Not specified
Lupo, 2013 [26]	FAHP and SERVQUAL discrepancy paradigm	5/18	1 Palermo transit service	300 random customers
Zou, Dai, Yao, Jiang and Guo, 2014 [32]	Only FAHP	6/22	1 present public transport development	More than one / Not specified
Ouma, Opudo and Nyambenya, 2015 [40]	FAHP and FTOPSIS	4/0	7 pavement maintenance alternatives	10 / Pavement engineers, inspectors, and transport planners

Table 11 Features of FAHP use in UMS (continuation)

Authors	Combination method/technique	No. of criteria/sub criteria	Selection of alternatives	No. of decision makers/Definition of experts
Zou and Li, 2010 [42]	FAHP and Risk checklist	6/30	1 city subway line	5 / different weights for experts Contract Manager Consultant Department head Project manager Senior engineer. Two criteria: (1) each must have more than five years' working experience in subway projects; and (2) each must be a member of senior management staff or a senior engineer
Wey, 2015 [38]	FAHP and Data Envelopment Analysis (DEA) model with assurance region approach	9/0	7 possible transit station sites	6 / not specified
Shafabakhsh, Hadjihoseinlou and Taghizadeh, 2014 [41]	FAHP and TOPSIS	9/0	3 modes to access airport: train, bus with 25 passenger capacity and van shuttle with 5 seats and a space for passengers' luggage	3 groups of decision makers / involving transportation experts, airport operators and employees beside passengers inhabited in city of Sari that have used this airport as a point of their travel at least 5 times
Bilisik, Demirtaş, Tuzkaya and Baraçl, 2014 [34]	FAHP and Integrated MCDM technique and fuzzy axiomatic design (AD) technique	6/18	6 different urban garage locations	More than one / not specified
John, Paraskevadakis, Bury, Yang, Riahi and Wang, 2014 [29]	FAHP and An evidential reasoning (ER) approach, fuzzy set theory and expected utility.	5/20	0	3 / A senior operations manager who has been involved with port operational services for over 20 years. A senior marine and safety engineer who has been involved in maritime and port operational management for over 20 years. A chief superintendent of maritime transportation systems who has been involved with maritime operations for over 20 years.
Tuzkaya, 2009 [5]	FAHP and Preference ranking organization method	9/0	5 alternatives: Road, Railway, Sea, Air and Multimodal	More than one / Decision makers: academicians, government, municipality, environmental associations and logistics firms
Babashamsi, Golzadfar, Yusoff, Ceylan and Nor, 2016 [25]	FAHP and VIKOR method	5/0	3 examples of pavements	25 / Experts in pavement design and management
Ruiz-Padillo, Ruiz, Torija and Ramos-Ridao, 2016 [4]	FAHP, Discrete multi-criteria analysis methods (weighted sum) and ELECTRE and TOPSIS	5/17	5 alternatives and more sub alternatives Noise barriers, Low noise pavements, Traffic management, Building insulation, Covering the road	65 / Technical staff from public administration, technical staff from engineering consulting firms, academic experts
Lupo, 2013 [26]	FAHP and SERVQUAL	5/18	Bus urban transport system in Palermo	About 300 customers and a total of 50 respondents between decision-makers and service employers have been interviewed
Sari, Behret, Kahraman, 2012 [39]	Only FAHP	4/13	4 main rail systems of Istanbul	5 experts (2 academicians and 3 managers from public companies).

6 CONCLUSIONS

Throughout the paper, we reviewed articles published in recognized journals that used FAHP methodology for solving problems in the field of urban mobility systems. More in detail we analysed features of UMS where FAHP was used and used characteristics of FAHP. We note that this methodology was started rather late to be applied in this field (since 2009), but its usefulness increases throughout the years. The purpose of FAHP methodology is diverse. Most often it was used in transport technology and in the sub-category of public urban transport. It was used for decision making in combination with both soft as hard measures. Interestingly only one research paper used FAHP on whole UMS, despite the fact that the political guidelines highlight the holistic problem solving in UMS with inclusion of all transport modes. The features of FAHP use show that most often employed type of criteria were quality, technical and logistics. When we analysed the use of the consistency check, we found that eight research papers have used consistency check and ten research papers were not checked for decision consistency.

This paper presents a new systematic review of applications of FAHP in the field of urban mobility system, which can be used for further research. It would be interesting to investigate what Fuzzy MCDM methods still exist in the field of urban mobility, what is the frequency of these methods and for which purpose they are being used.

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Contact information:

Uroš KRAMAR, M.C.A, Assistant
University of Maribor,
Faculty of Logistics,
Mariborska cesta 7, 3000 Celje, Slovenia
uros.kramar@um.si

Darja TOPOLŠEK, Assoc. Prof. PhD
University of Maribor,
Faculty of Logistics,
Mariborska cesta 7, 3000 Celje, Slovenia
darja.topolsek@um.si