TRANSPORT
ISSN 1648-4142 / eISSN 1648-3480
2016 Volume 31(3): 359–385
doi:10.3846/16484142.2015.1121517

REVIEW PAPER

MULTIPLE CRITERIA DECISION-MAKING TECHNIQUES IN TRANSPORTATION SYSTEMS: A SYSTEMATIC REVIEW OF THE STATE OF THE ART LITERATURE

Abbas Mardani[1], Edmundas Kazimieras Zavadskas[2], Zainab Khalifah[3], Ahmad Jusoh[4], Khalil MD Nor[5]

[1, 3, 4, 5]*Faculty of Management, Universiti Teknologi Malaysia (UTM), Skudai Johor, 81310, Malaysia*
[2]*Dept of Construction Technology and Management, Vilnius Gediminas Technical University, Lithuania*

Submitted 7 September 2015; resubmitted 4 November 2015; accepted 6 November 2015; first published online 18 December 2015

Abstract. The main goal of this review paper is to provide a systematic review of Multiple Criteria Decision-Making (MCDM) techniques in regard to transportation systems problems. This study reviewed a total of 89 papers, published from 1993 to 2015, from 39 high-ranking journals; most of which were related to transportation science and were extracted from the *Web of Science* and *Scopus* databases. Papers were classified into 10 main application areas and nine transport infrastructure. Furthermore, papers were categorized based on the author(s) and year, name of the journal in which they were published, technique and approach, author(s) nationality, application area and scope, study purpose, gap and research problem and results and outcome. The results of this study indicated that more papers on MCDM in 2013 than in any other year. AHP and Fuzzy-AHP methods in the individual methods and hybrid MCDM and fuzzy MCDM in the integrated methods were ranked as the first and second methods in use, respectively. The *Transportation Research Part A: Policy and Practice* was the most significant journal in this study, with 13 publications on the topic. Finally, service quality was ranked as the first application area and airline industry was ranked as the first transport infrastructure that applied MCDM techniques.

Keywords: multiple criteria decision-making techniques (MCDM); AHP; Fuzzy-AHP; decision-making; transportation systems.

Introduction

The development and management of transportation system is critical in economic and social development in any country. There many challenges, problems and issues relate to transportation system such as safety, cost and quality that require effective solutions and improvement. In assessing the effectiveness and the quality of the solutions, the ideas and inputs from the expert is vital particularly when we are operating with limited resources and constraints. Thus, the decision-making process must be based on factual approach. There are some approaches that can be used such as simulation, structural equation modeling and Multiple Criteria Decision-Making (MCDM). MCDM become one of the important decision-making techniques that has been used by many authorities, academicians and researchers in evaluation of the transportation systems (Pérez *et al.* 2015) as in Celik *et al.* (2013). Pérez *et al.* (2015), claim that 58 different MCDM techniques are applied in urban passenger transport systems between 1982 and 2014. Pérez *et al.* (2015), conclude that MCDM techniques become one of the very helpful techniques for the evaluation and decision-making projects in transportation systems in last decades. Tsamboulas *et al.* (1999), investigated important elements of the transport evaluation procedure for provide and associate the some, which applied MCDM methods for the evaluation of transportation systems. Changes in transportation systems and assessment of scenarios for the development of transport sectors could be based on economic, social and environmental principles (Joumard, Nicolas 2010; Kavaliauskas 2008). Assessment of transport to improve efficiency and improve customer gratification about the quality of service considered very significant. All of the transport subdivisions evaluate the superiority of service frequently (Awasthi *et al.* 2011). Using MCDM approaches and techniques, Decision Makers (DMs) must properly account for all significant criteria, which helps to decrease post-decision regret (Belton, Stewart 2002). The core of decision-making process related to transportation systems is the constructive discourse among the analysts, citizens, and decision makers. Today's de-

Corresponding author: Abbas Mardani
E-mail: *mabbas3@live.utm.my*

Taylor & Francis
Taylor & Francis Group

cision-making process is using a participatory approach, which involved all concerned citizens. To make citizen participation most productive, public discourse, which is often distracted and confused need to become more focused and possible consequences and uncertainty must be clearly presented. Understanding the requirement of transportation system from the perspective of users or customers point of view can lead to superior quality service delivery (Freitas 2013). Assessment on transportation system to improve efficiency service quality and customer satisfaction is substantial.

During the current review, the researchers attempted to offer an outline of a number of major MCDM approaches offered through the years and offers instances of the ways various approaches have been applied for transportation system problems. The examples were chosen in order to give an extensive overview of all techniques used to transportation system problems since 1993. This paper is the first review paper which investigated the role of MCDM techniques in transportation systems problems, although; some previous scholars reviewed papers in different perspectives of transportation systems such as; intra-household interactions (Ho, Mulley 2015); car-following models (Aghabayk *et al.* 2015; Brackstone, McDonald 1999); demand for high-speed rail (Givoni, Dobruszkes 2013); roundabout capacity modelling (Yap *et al.* 2013); level of service (Bhuyan, Nayak 2013); sociological perspectives (Cairns *et al.* 2014); bus transportation system (Ibarra-Rojas *et al.* 2015; Pelletier *et al.* 2011). Since there is no review paper on the application MCDM in transportation system, this paper provides the overall review of the past researches.

The rest of this review paper is structured as follows. Section 1 discuses on literature of MCDM and transportation systems. Section 2 describes the research method and the procedure of this study. Section 3 provides findings of this review based on the research objectives. Finally, last section presents our conclusions.

1. Literature Review

1.1. Multiple Criteria Decision-Making Techniques

Several MCDM and fuzzy MCDM approaches have been offered by previous scholars in the last three decades which are different in terms of the theoretical background, questions type and the achieved findings. Many approaches and techniques proposed for specific problems. In recent years, numerous MCDM and fuzzy MCDM approaches have been suggested to select the best compromise options. These approaches have been suggested for different problems in real world which need to consider as multi-criteria by decision makers for improving and solving in various fields of mathematical optimization, computer science and computer technology (Wiecek *et al.* 2008). Xu and Da (2002) categorized MCDM approach in two ways, classical and fuzzy MCDM. Furthermore in recent years some of previous scholars classified fuzzy MCDM and MCDM techniques in several application areas (Mardani *et al.* 2015a, 2015b). Recently, Mardani *et al.* (2015c) selected, summarized and reviewed 54 papers, which were related to renewable and sustainable energy and decision making techniques, these 54 papers published from 2003 to 2015. In addition, Mardani *et al.* (2015d) reviewed and classified fuzzy MCDM and classical MCDM techniques based on the service quality.

Decision makers employ the decision-making approaches in order to prioritize the important criteria or parameters, reduce uncertainty and enhance the quality of decisions. MCDM techniques have been suggested for solving different problems in real world. For the first time, MacCrimmon (1968) proposed Simple Additive Weighting (SAW) and two stages in weighting as complete aggregation, Multi-Attribute Utility Analysis (MAUA) (Keeney, Raiffa 1976), Order of Preference by Similarity to Ideal Solution (TOPSIS) (Hwang, Yoon 1981), VlseKriterijuska Optimizacija I Komoromisno Resenje (VIKOR) (Opricovic, Tzeng 2004), Weighted Aggregated Sum Product Assessment (WASPAS) (Zavadskas *et al.* 2012), Complex Proportional Assessment Method (COPRAS) (Zavadskas *et al.* 1994), Multi-Objective Optimization by Ratio Analysis (MOORA) (Brauers, Zavadskas 2006), COPRAS grey (COPRAS-G), fuzzy additive ratio assessment (ARAS-F), ARAS grey (ARAS-G) and MULTIMOORA (MOORA plus the full multiplicative form) (Brauers, Zavadskas 2010; Turskis, Zavadskas 2010a; Zavadskas, Turskis 2008), KEmeny Median Indicator Ranks Accordance (KEMIRA) (Krylovas *et al.* 2014), ARAS (Zavadskas, Turskis 2010). As examples of partial aggregation methods, Step-Wise Weight Assessment Ratio Analysis (SWARA) (Keršulienė *et al.* 2010), Analytic Hierarchy Process (AHP) are relied on as pair-wise comparisons (Saaty 1988, 2003, 2005; Saaty, Vargas 2013). ELimination and Choice Expressing REality (ELECTRE) (Roy 1996), and Novel Approach to Imprecise Assessment and Decision Environments (NAIADE) (Munda 1995) can be listed, which involve the pair-wise comparisons of alternatives.

In addition, Analytic Network Process (ANP) and Preference Ranking Organisation Method for Enrichment Evaluations (PROMETHEE) (Brans, Mareschal 1992). Xu and Da (2002) classified fuzzy MCDM in two different categorized including Fuzzy Multi-Attribute Decision-Making (FMADM) and Fuzzy Multi-Objective Decision-Making (FMODM). Liou and Tzeng (2012) examined the development of MADM techniques from 1738 to 2012 into three different ways: evaluating or choosing models, weighting models and normalizing models. Hwang and Yoon (1981), Zavadskas, and Turskis (2011) grouped MCDM techniques and approaches in various ways, in these investigations MCDM was classified into three kinds of information actors include no information, information about criteria and information of alternative. Zimmermann (1978), Bellman and Zadeh (1970) used fuzzy sets theory to MCDM field. According to Yager (1978), the fuzzy set of a decision is the intersection of the whole fuzzy goals. In addition, Kickert (1979), summarized the application of fuzzy set for apply to MADM problems. Many MCDM works were developed and published between 1950s and 1970s and growth during 1980s and early of 1990s (Köksalan *et al.* 2011). Furthermore, Köksalan *et al.* (2011) provided a

book, which discussed about history of MCDM development. Moreover, Hwang *et al.* (1979) reviewed development of MODM methods and approaches. Later, another review paper related to MADM techniques and methods such as LINMAP, SAW, ELECTRE and TOPSIS presented by Tzeng and Huang (2011). Keeneyet *al.* (1979) developed the basics of decision with multiple objectives for improvement the body of knowledge regarding to decision-making techniques and approaches.

1.2. Transportation Systems and MCDM

MCDM is described as a methodological tool for modeling and solving complex problems (Kahraman 2008) and defined as a common term for approaches that support decision makers in making decisions in cases where more than one decision criteria (Pérez *et al.* 2015). MCDM methods are very strong tools that can be applied to several areas. Any transportation infrastructure development project should begin with the recognition of an existing or projected need to meet the present and the growing demand in the future. Transport systems are designed to let people circulate though the systems; arrive their destinations; and achieve their trip purposes. As a result, it is essential to provide with an environment that makes road users feel convenient, secure, comfortable, and healthy when using the transportation system. Policy-makers of today's major transportation systems are engaged in debates and face arguments about whether to build a new or extend an existing transportation system, which transportation technologies should be considered, which transportation alternative is locally preferred, and which transit systems should be implemented. How to evaluate, present and recommend in a logical manner the most desirable transportation system that meets the purposes and needs from diverse standpoints and at the same time, satisfies multiple goals and objectives under uncertain information. Researchers view a transportation system a large-scale system. It is characterized by many elements that interact with each other. Planning a large-scale system is complicated because it must satisfy different groups of people with a wide range of views about benefits and needs, and about paying for its costs.

Decision-making about a transportation system is not straightforward and requires negotiations. Often times, the planning cannot be advanced because there is no consensus with regard to the goals and expected outcomes of a project. Traditional approaches to decision-making on transit systems are based on various unrealistic assumptions. For example, the decision problem is assumed to be well structured; the evaluation objectives are assumed to be independent; the evaluation criteria are assumed to be quantifiable; the decision makers are assumed to be from a consistent group of individuals; all possible alternatives are assumed to be clearly defined; the decision-makers have complete knowledge of information needed when analyzing transportation alternatives; and the alternative which gives the maximum utility is assumed to be the optimal solution. However in reality most transit decision makers have neither the complete information nor the rigid decision rules to make the 'correct' decision. In addition, traditional approaches seem to oversimplify the complex transit system by:

- aggregating performance measures and evaluating a system as a whole;
- omitting the analysts' ambiguity.

The proposed mechanism helps the participants to focus on specific causal relations. The integrity of the decision is related to how uncertainty is treated and how the participants understand uncertainties and ambiguities involved. Evaluation of transportation systems and reaching the recommended alternative is embedded in three stages: alternatives screening process; alternatives analysis process; and project evaluation process for funding recommendations. These processes are labyrinthine, because they deal with both demand and supply characteristics of transportation systems and their interactions. Different types of uncertainty require different mathematical representations of uncertainty treatment. Probability theory deals with uncertainty due to randomness (that is risk); fuzzy set theory deals with vagueness, and possibility theory and evidence theory deals with ambiguity. Traditionally, probability has been the approach used to connect with risk in decision-making process. Probability represents the degree of belief in terms of the frequency of occurrences based on the evidence presented. Nonetheless, in reality when analysts evaluate alternatives, they experience evidence in the form of data, information, opinions, and critiques, which are usually vague, incomplete, conflicting, and scattered.

The traditional probability theory may not be sufficient and appropriate to model and work with such weaker state (that is uncertainty) of information and knowledge. Transportation systems are strictly associated to its economy, humanity, setting, and policy-making. The structure of transportation systems are typically welcomed through local administrations because of several advantageous like better suitability and development in the local economy, and employment amount. Though, protection of environmental should be considered while those plans are offered, as poor in decision-making might not merely cause significant left-over about time as well as cash, but likewise might create long-term harm.

Several MCDM methods have been suggested to incorporate the needs of different stakeholders involved in decision-making process. MCDM methods use a numerical or analytical model to find the alternative that would best meet a wide variety of criteria. They transform both qualitative and quantitative measures into a single objective value. Yeh *et al.* (2000) applied fuzzy Multi-Criteria Analysis (MCA) technique for assessing the activity of transportation system in urban public. Hanaoka and Kunadhamraks (2009) applied Fuzzy-AHP to measure the performance in the transportation related to intermodal freight. Zak *et al.* (2009) applied MCA method based on named Light Beam Search and graphical amenities to optimizing the problems in transit vehicle. Campos and De Rus (2009) evaluated the sustainable mobility based weightage index in urban zones. Agusdinata *et al.* (2009) utilized a model for ex-

amine the doubt in intelligent speed adaptation strategy in urban transportation systems.

Previous investigations about transportation systems paid attention to the measurement of productivity as well as performance (Chang, Nojima 2001; Kanninen 1996; Watterson 1993). Furthermore, transportation performance comprises efficacy, success, output and finally quality of service (Eboli, Mazzulla 2011). Though most investigations applied outdated statistical methods to evaluate hypotheses, others utilized MCDM methods to examine service quality of transportation systems and making plans for development.

In the actual world, standards are seldom self-governing but usually have a grade of interactive association, occasionally with dependence and feedback effects, particularly about the very complicated combination of intangibles of service quality. Focus on customer satisfaction level in public transportation system is an essential task for the authorities and managers. Therefore, determining the efficiency and satisfactory levels of the services are needed to be assessed by the service provider(s) (Celik *et al.* 2013; Hassan *et al.* 2013). Correspondingly, Celik *et al.* (2013) and Hassan *et al.* (2013) argue that both the existing and predicted demand tendencies, apprehensions of shareholders, and unmet service requirements are needed to be taken into account in the evaluation framework. Evaluation criteria can be used to evaluate and display economic performances of the service provider, connect the service provider's achievements and difficulties that are faced, and improve the service quality standards. With the performance evaluation results, the management and service providers gain valuable directions for the future plans, such as transit line planning and finance.

In public transportation systems, multiple decision makers from both public and private sectors participate in decision-making process (Pérez *et al.* 2015) and multiple criteria are considered during this process. Therefore, MCDM become one of the important decision-making techniques that has been used by many authorities, academicians and researchers in customer satisfaction evaluation of the public transportation systems (Aydin *et al.* 2015; Liou *et al.* 2014).

Parkan (2002) applies operational competitiveness rating analysis to measure the productivity and performance of service quality in public transit company. Gerçek *et al.* (2004) analyze network of rail transit that are made for Istanbul. Hanaoka and Kunadhamraks (2009) apply Fuzzy-AHP to the intermodal freight transportation in order to evaluate the logistics performances. They prefer to use Fuzzy-AHP for evaluation of the factors in order to various judgment processes. In addition, Celik *et al.* (2013) apply an integrated model based on interval type-2, TOPSIS, FMCDM (fuzzy MCDM) and Grey Relational Analysis (GRA) to evaluate the satisfaction of customer regarding to public transportation systems in Istanbul, and give directions for the future improvements. Also Celik *et al.* (2014) evaluate the performances of five rail transit lines in Istanbul. The evaluation is calculated based on the survey that is conducted in 2012. Friman *et al.* (2001) presented empirical and theoretical analysis about improve of customer satisfaction in public transportation systems.

Hassan *et al.* (2013) suggest a multi-level outline for measuring the public transit service activity. Over their framework, a mixture of subjective and objective measures is applied for evaluating the service quality. Their work permits about the attitudes of different shareholders about public transit facilities to be used in a multi-criteria assessment procedure. Asakura and Kashiwadani (1991) conducted an investigation about the most significant issues, which have an influence on the reliability of public transportation systems. Bramel and Simchi-Levi (1996) assessed the optimal public bus station-locating problem.

2. Systematic Review Methodology

This review paper attempted to review and identify the published paper in popular international journals the presented the most significant information to scholars and researchers who examine the various application areas related to MCDM, FMCDM and transportation systems. Therefore, this review paper searched to identify the papers related to MCDM and FMCDM in various parts of published papers such as keywords, title, research method, results, conclusions and discussions. In relation to classification scheme, a reference repository has been established, which was included a total of 89 papers published in more than 39 journals published from 1993 to 2015. The papers were classified in terms of their author(s) and year, name of the journal in which they were published, technique and approach, author(s) nationality, application area and scope, study purpose, gap and research problem and results and outcome. Additionally, this review paper is consisted of a new perspective is taken into consideration to review the articles, namely the categorization of the articles into 10 different areas of transportation systems topics: service quality, transportation performance evaluation, customer and passengers satisfaction, financial assessment, sustainability, logistic management, strategic alliance, safety management, technology management and other areas Fig. 1 presented the systematic review of analysis and procedure.

In this review paper, we conduct a systematic review; a rigorous review methodology originally developed mainly within medical research and first outlined for the field of management and organization studies by Tranfield *et al.* (2003). The aim of such a systematic review is to locate relevant existing studies based on a prior formulated research question, to evaluate and synthesize their respective contributions and to report the evidence in a way that clear conclusions with regard to further research and managerial practice can be drawn (Denyer, Tranfield 2009). Systematic reviews exhibit significant advantages compared to traditional narrative approaches of literature reviews. Those traditional reviews generally do not follow a formal methodology, thus resulting in lacking transparency and replicability

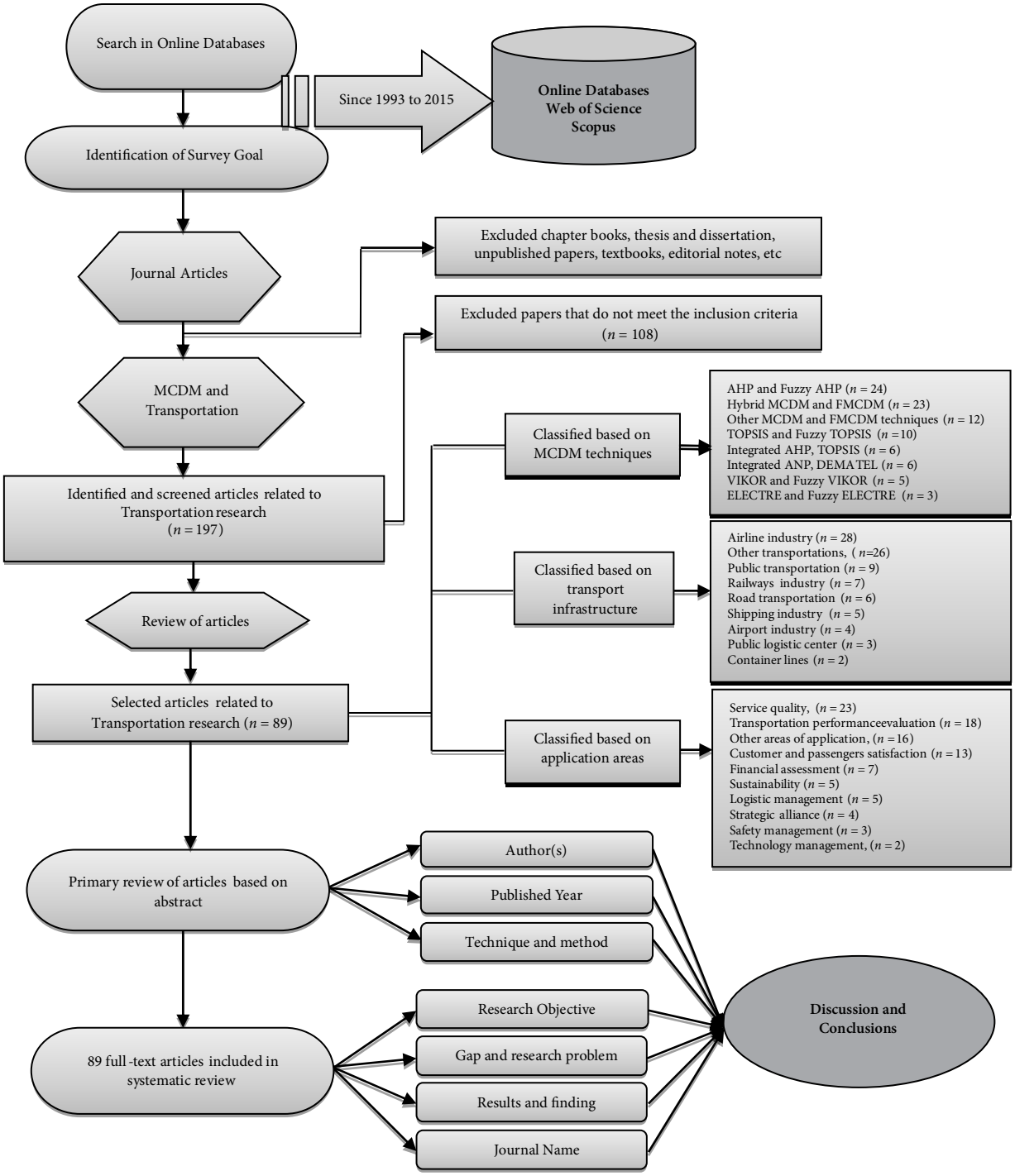

Fig. 1. Systematic review methodology of study

by others. Researchers can focus on 'preferred' literature sources and base their review on a personal, purposive selection of materials they believe to be important. Systematic reviews help to reduce those implicit researcher biases (Denyer, Tranfield 2009). Through the adoption of search strategies, predefined search strings as well as inclusion/exclusion criteria, systematic reviews effectively force researchers to search for all relevant studies beyond their own horizon of experience. Furthermore, the application and extensive documentation of a clear review protocol improves the methodological transparency of the review and enables future replication by other researchers. As the motivation and research questions of the review have already been outlined in the introduction, the remainder of this section will focus on how the review was conducted and describe in detail the search strategy, selection criteria and synthesis criteria applied in this paper. Our search strategy consisted of looking for relevant studies within scientific literature sources, represented by academic studies published in peer-reviewed journals. We searched online databases to identify all articles published on the topics of transpor-

tation systems issues enhancement between 1993 and 2015. We have chosen 1993 as a starting point for our review, as it was in this year, because, we found that; first paper published in transportation systems issues by in field of transportation investment (Kartam *et al.* 1993).

In addition; the majority of papers on transportation systems, MCDM applications and methodologies were published after 1993; as a result, 1993 was chosen as the starting date for this study. The major sources of information used to identify the studies eligible for this review were the scholarly database of Science Direct and Scopus, which identify relevant academic articles published in the domains of transportation systems issues (here definitely: MCDM and transportation, decision-making and transportation, MCDM and passenger, MCDM and airline industry) – domains in which articles on the topic of interest have appeared. We used two different search strings, which comprised MCDM + transportation and decision-making and transportation system as keywords to identify scientific articles. To ensure complete coverage, in a later step of the process, we also identified additional academic studies through manual screening of cross-referencing. Books, contributions to edited volumes, conference papers, periodicals, and working papers were not included in our review, as such, research usually goes through a less rigorous peer-review process, and they are less readily available (Podsakoff *et al.* 2005). The entire process of our search is illustrated in Fig. 1. Finally, 89 previous scientific papers were considered to be eligible for our systematic review.

3. Findings

3.1. Areas of Application and Transport Infrastructure

In recent decades, research on MCDM has continued, and many areas to which it can be applied have been found. MCDM provides effective decision-making methods in domains in which selection of the best alternative is highly complex. This survey reviews the main considerations of transportation systems problems in MCDM theory and practice. The main purpose is to identify various applications for MCDM in the transportation systems topics and to suggest robust and effective approaches for identifying the best solutions to complex problems. The MCDM method aids in identifying the best alternatives in situations with multiple criteria; the best choice can be obtained by analyzing different scopes and weights of the criteria. This survey comprehensively shows the development of various methods of MCDM and its applications in the transportation systems topics.

This survey investigates the developments of various methods of MCDM techniques and their applications in transportation systems issues. In our daily life, decisions are made based on various criteria; thus, a decision can be made by assigning weights to different criteria. The applications developed to solve multi-choice problems and the selected MCDM methods provide better performance in cases such as transportation systems, in which the 10 topics include: service quality, transportation performance evaluation, customer and passengers satisfaction, financial assessment, sustainability, logistic management, strategic alliance, safety management, technology management and other areas (Table 1). In addition, researchers classified all selected articles based on transport infrastructure, however, results of this classification provided in Table 2. Based on results of this table, transport infrastructure classified in nine various parts including, airline industry, public transportation, shipping industry, airport industry, railways industry, road transportation, public logistic center, container lines and other transportations.

Table 1. Distribution papers based on areas of application

Application fields	Number of papers	Percentage
Service quality	23	25.84%
Transportation performance evaluation	17	19.10%
Other areas of application	13	14.61%
Customer and passengers satisfaction	10	11.24%
Financial assessment	7	7.87%
Sustainability	5	5.62%
Logistic management	5	5.62%
Strategic alliance	4	4.49%
Safety management	3	3.37%
Technology management	2	2.25%
Total	89	100.00%

Table 2. Distribution papers based on transport infrastructure

Application fields	Number of papers	Percentage
Airline industry	28	31.46%
Other transportations	25	28.09%
Public transportation	9	10.11%
Railways industry	7	7.87%
Road transportation	6	6.74%
Shipping industry	5	5.62%
Airport industry	4	4.49%
Public logistic center	3	3.37%
Container lines	2	2.25%
Total	89	100.00%

3.2. Distribution Based on MCDM Techniques and Approaches

Table 3 provided the rate of fuzzy MCDM and MCDM techniques used in transportation systems topics. Based on results presented in this table, a total of 89 studies employed MCDM and fuzzy MCDM techniques and approaches. The first rank was the hybrid MCDM and FMCDM method (26.97%). This table shows that AHP and Fuzzy-AHP techniques (25.84%) and its applications have been used more than other individual approaches. Other MCDM and FMCDM techniques had the third rank with 12 papers. TOPSIS and fuzzy TOPSIS with

other techniques hold the fourth rank (11.24%) In addition, integrated AHP, TOPSIS and fuzzy set (6.74%) Moreover, integrated ANP, DEMATEL and fuzzy set with six paper, VIKOR and fuzzy VIKOR with other techniques (5.62%), and finally, ELECTRE, fuzzy ELECTRE was the last rank with three papers. The frequency of techniques and approaches are presented in Table 3.

Table 3. Summary of applications of the MCDM techniques

MCDM techniques	Frequency of application	Percentage
Hybrid MCDM and FMCDM	24	26.97%
AHP and Fuzzy-AHP	23	25.84%
Other MCDM and FMCDM techniques	12	13.48%
TOPSIS and fuzzy TOPSIS with other techniques	10	11.24%
Integrated ANP, DEMATEL and fuzzy set	6	6.74%
Integrated AHP, TOPSIS and fuzzy set	6	6.74%
VIKOR and fuzzy VIKOR with other techniques	5	5.62%
ELECTRE and fuzzy ELECTRE	3	3.37%
Total	89	100.00%

The following sections provide a systematic review of the 89 papers, categorizing them into the 10 MCDM techniques which presented in Table 3. This categorize were included, AHP and Fuzzy-AHP, hybrid MCDM and FMCDM, TOPSIS and fuzzy TOPSIS with other techniques, VIKOR and fuzzy VIKOR with other techniques, integrated AHP, TOPSIS and fuzzy set, integrated ANP, DEMATEL and fuzzy set, ELECTRE and fuzzy ELECTRE, PROMETHEE and fuzzy PROMETHEE, ANP and fuzzy ANP and finally, other MCDM and FMCDM techniques. All papers are then presented in tables, and MCDM techniques is summarized based on author(s) and year, technique and approach, transport infrastructure, study purpose, gap and research problem and the last column presents results and outcome in each paper.

3.2.1. Distribution Based on AHP and Fuzzy-AHP

AHP and Fuzzy-AHP have used for various and different application areas. In this section, we focused on those studies, which applied both AHP and Fuzzy-AHP to evaluate transportation systems in several application areas and transport infrastructure. Shiau (2013) assessment of sustainable transport strategies, results of this study found that, Istanbul District is importance convenient district related to container port. Mandic *et al.* (2014) improved original two-phase multi-criteria model in Serbian railways, results of this research found that priority project focused on restructuring and reform in Serbian railways despite of very poor technical subsystems. Chou *et al.* (2011) found that, assurance and reliability were the important criteria of service quality. Bruno *et al.* (2015) assessment aircraft for supporting of strategic decisions, finding of this paper showed that factor of cabin luggage compartment size in the best factor. Rezaei *et al.* (2014) evaluated and selected the supplier in the airline retail industry, finding of this article indicated that financial stability is significant criteria in supplier selection. Yedla and Shrestha (2003) evaluated and selected the best alternative in Delhi transportation system regarding to environmentally sustainable, results of this paper found, the importance quantitative criteria are cost energy and environment are significant criteria in Compressed Natural Gas (CNG) car, moreover, in case of qualitative result barriers, technology and adaptability are the importance criteria in CNG bus and CNG car. Jones *et al.* (2013) suggested a new framework for screening of projects regarding to urban transport based on sustainability criteria, results of this study demonstrated that the suggested framework is adequately present for priorities, local sustainable transport needs and perceptions. According to finding of Table 4, 23 of previous studies have used AHP and Fuzzy-AHP for evaluation of transportation system. Other information details such as author(s) and year, technique and approach, transport infrastructure, study purpose, gap and research problem and the last column presents results and outcome in each paper presented in Table 4.

Table 4. Articles based on AHP and Fuzzy-AHP

Author(s) and year	Technique and approach	Application area and scope	Study purpose	Gap and research problem	Results and outcome
Lupo (2013a)	Fuzzy-AHP	Public transport service	Proposed new methodology based on extended of SERVQUAL for analysis of performance in public transport service	There is need to handle uncertainty in analyses of service performance of public transport service	Results of this paper indicated perception of management of service quality positively influence of all levels of service performance
Shiau (2013)	AHP	Sustainable transport strategies	Assessment of sustainable transport strategies	Need to evaluation of strategies of sustainable transport in Taiwan	Finding of this study showed that measures of tailor are based on local circumstances
Mandic *et al.* (2014)	AHP	Railways	Improved original two-phase multicriteria model in Serbian railways	Need to propose new priority development projects in Serbia after war	Results of this research found that priority project focused on restructuring and reform in Serbian railways despite of very poor technical subsystems

Continue of Table 4

Author(s) and year	Technique and approach	Application area and scope	Study purpose	Gap and research problem	Results and outcome
Chou *et al.* (2011)	Fuzzy-AHP	Airline industry	Evaluate the quality of service international air travel transportation industry	There is lack in past studies which did not attention on assess service quality of airline based on weighted SERVQUAL measurement	Results of this paper found that, assurance and reliability were the important criteria of service quality
Lupo (2013b)	Fuzzy-AHP	Transit	Analysis service quality of customer satisfaction	Need to analysis of customer satisfaction in transit based on service quality measurements	The obtained results show that only few service attributes play an important role in performing a quality transit service
Bruno *et al.* (2015)	Fuzzy-AHP	Aircraft	Assessment of aircraft for supporting of strategic decisions	Need to further study regarding to service quality, environmental impact and attention on customer in aircraft evaluation	Finding of this paper showed that factor of cabin luggage compartment size in the best factor
Rezaei *et al.* (2014)	Fuzzy-AHP	Airline industry	Selection of supplier in the airline retail industry	There are conflicting in assessment of quantitative and qualitative criteria in supplier selection, therefore need to further study in this issue	Finding of this article indicated that financial stability is significant criteria in supplier selection
Yedla, Shrestha (2003)	AHP	Transport system	Selection of best alternative in Delhi transportation system regarding to environmentally sustainable	Due to problem in Delhi urban transportation need to further study related to environmentally sustainable	Results of this paper found, the importance quantitative criteria are cost energy and environment are significant criteria in CNG car, moreover, in case of qualitative result barriers, technology and adaptability are the importance criteria in CNG bus and CNG car
Tudela *et al.* (2006)	AHP	Urban transport	Compared results of two techniques including of AHP and (Cost-Benefit Analysis) CBA in unban transportation system	Need to study for further focuses on economic perspectives in unban transportation system	Results of this paper demonstrated that people are very sensitive about the available information in projects
Sohn (2008)	AHP	Overpasses	Identify of overpass for elimination in Korea	There is need to study for the useless overpasses elimination in Korea	Results of this study indicated the most systematic criterion to category of eliminable overpasses are based structural stability, traffic efficiency, environmental amenity, traffic safety and functionality
Zubaryeva *et al.* (2012)	AHP	Electrified vehicles	Identify and evaluation of potential market for electrified vehicles in Europe	There is need to integrate multiple criteria for ranking of various electric-drive vehicles market drivers	Results of this study showed, infrastructure availability, car density, state incentives, average winter temperatures, GDP per capita, Well-to-Whell (WTW) CO_2 emissions, diesel and gasoline fuel versus costs savings and share of Renewable Energy Sources (RES) are significant criteria of Electric Drive Vehicles (EDVs) lead markets
Jones *et al.* (2013)	AHP	Urban transport projects	Suggested a new framework for screening of projects regarding to urban transport based on sustainability criteria	Need to study for examine projects screening in urban transport systems based on sustainability criteria	Results of this study demonstrated that the suggested framework is adequately present for priorities, local sustainable transport needs and perceptions

End of Table 4

Author(s) and year	Technique and approach	Application area and scope	Study purpose	Gap and research problem	Results and outcome
Zietsman, Vander-schuren (2014)	AHP	Airport	Analysis and evaluation of development in multi-airport	Need to assessment of territorial competitiveness rather than economic activities and infrastructure in airport	Results of this paper indicated that, Cape Town city should developed to employ a single-airport system until passenger volumes per annum increase beyond the 27 million air passengers per annum level
Postorino, Praticò (2012)	AHP	Multi-airport system	Analysis of regional multi-airport system by employ of MCDM technique	There is problem related to identify the position and role of airports in multi-airport system	Results of this study found that, effectiveness and efficiency, location and facilities and classes have similar weight rather than outcome attributes
Podvezko, Sivile-vičius (2013)	AHP	Road transport	Examine the influence of interaction of transport system factors on the traffic accident rate	Need to attention to traffic safety in road for increasing of efficiency in the transport system	Outcomes of this paper showed that interaction between vehicle and traffic participants in the most significant elements
He *et al.* (2012)	Fuzzy-AHP	Transshipment	Improved a new model for increase of customer service level and decrease of logistic cost	Need to emphasize on service customers and deliverers for solving problems in transshipment	Outcome of this paper illustrated that reliability of order fulfillment is the best factor
Lirn *et al.* (2003)	Fuzzy-AHP	Transshipment Port Selection	Identification of significant criteria for selection of transshipment port	There is lack in previous studied which did not emphasize on selection of transshipment port	Outcome of this article found that, port geographical location is the best criteria selection of transshipment port
Tanad-tang *et al.* (2005)	AHP	Transportation demand	Proposed a new method for evaluation of transportation demand management	Need to evaluate the Transportation Demand Management (TDM) by considering of social, environmental and transportation impacts	Outcomes of this study indicated that, traffic impact is the most important in evaluation of TDM
Yeo, Song (2006)	AHP	Container port and terminal	Identify and evaluating the competitiveness of container ports	Due to important of service quality in logistics centers services and the efficient and effective integration in transport organizations presented by a port is the significant issue	The results of this study demonstrated that, the significant port was among the whole ports
Arslan (2009)	Fuzzy-AHP	Transportation projects	Presented a new decision support model for implementation of appropriate transportation projects	There is need to further study in project development and transportation planning in developed countries	Results of this study found that, this model is reasonable and can employ for achieve of public idea regarding on transportation projects in the development and planning steps
Teng *et al.* (2010)	Fuzzy-AHP	Transportation construction projects	Allocated budget for transportation construction projects	Need to more focus on budget allocation in transportation construction projects	Results of this paper found that the proposed model can divide the policy objectives of the transportation sector and real demands in the various demand levels
Liou, Chuang (2010)	Fuzzy-AHP	Airline market	Assessment of reputation and corporate image in airline market	Need to attention to corporate image for increase customer loyalty	Outcome of this study indicated that service emerge and safety record are the significant factors in the air transport market
Gerçek *et al.* (2004)	AHP	Rail transit network	Assessment of the rail transit networks	Need to investigate that, the investment in transport infrastructure has benefit in overall performance of transport system	Results of this paper indicated that, network construction costs, road vehicle operating costs, capacity and staging flexibility of the rail transit network are the significant criteria

3.2.2. Distribution Based on Hybrid MCDM and FMCDM

In this section, researchers provided some previous studies that integrated MCDM techniques and approaches to evaluate transportation systems in several application areas and transport infrastructure. Table 5 shows that, 30 of previous studies have integrated or combined various MCDM techniques and approaches to evaluate transportation systems in several application areas and transport infrastructure.

Chang *et al.* (2015) integrated ANP and fuzzy TOPSIS to evaluate of performance in for airport safety management system, results of this study showed that safety assurance, safety policy and objectives, safety promotion and safety risk management are importance criteria in evaluation of airport safety. Liou and Tzeng (2007) mixed AHP, GRA and SAW for assessment and enhance the service quality of airlines industry, results indicated that safety and reliability emerge as the critical factors of service quality. Tsai *et al.* (2011b) improved airport service quality by integrate VIKOR and AHP, empirical results were from the analysis in the airport of Taiwan and culture is a significant influence in marketing management, the results might not be generalized broadly. Chang and Yeh (2001) combined SAW, TOPSIS and Weighted Product Model (WPM) for evaluation of competitiveness performance in airline industry ,finding of this study found that management and service quality are the significant criteria in evaluation performance in Taiwan airline industry. Tsai *et al.* (2011a) integrated VIKOR, ANP and DEMATEL for assessment of websites effectiveness in airline industry. Aydin *et al.* (2015) mixed Fuzzy-AHP, Choquet integral and trapezoidal fuzzy sets for present a new framework to evaluating of customer satisfaction in rail transit systems. Based on the finding of Table 5, 24 of previous studies have integrated or combined for evaluation of transportation system. Other information details such as author(s) and year, technique and approach, transport infrastructure, study purpose, gap and research problem and the last column presents results and outcome in each paper presented in Table 5.

Table 5. Distribution based on hybrid MCDM and FMCDM

Author(s) and year	Technique and approach	Application area and scope	Study purpose	Gap and research problem	Results and outcome
Li *et al.* (2014)	TOPSIS and Entropy	Highway transportation	Evaluation of sustainable development in highway transportation	There is serious challenge in traffic system in China due to rapid development of the national economy	Outcomes of this study demonstrated that rate of cement highway to administrative village is the significant index
Bagočius *et al.* (2014)	COPRAS, SAW and TOPSIS	Gas terminal location	Gas terminal location by employed COPRAS, SAW and TOPSIS	There is problem in selection of construction sites for the Liquefied Natural Gas (LNG) pollutants	Having performed calculations in three methods, it was determined that the best alternative to build the LNG terminal is the Kiaulės Nugara island
Hashemkhani Zolfani *et al.* (2013)	SWARA and VIKOR	Tunnel pollutants	Employed SWARA and VIKOR for selection of mechanical longitudinal ventilation	There is a need to selection of the best model for the tunnel pollutants based on mechanical longitudinal ventilation	Final results illustrate that jet fans with spot extraction by axial fans is the best choice
Ramani *et al.* (2010)	AHP and MAUT	Transportation planning	Examine and improve the project selecting and evaluating with collaborating of a state-level transportation agency	There is need to evaluating of influence of accounting for nonlinearity for applications of transportation planning	Finding of this paper concluded that, utility nonlinearity positively effect on results in terms of the scaled value for a quantified measure
Kartam *et al.* (1993)	Entropy and ELECTRE I	Transportation investment	Integrated robust contingency plans and the planning process for evaluation of transportation investment planning	Large-scale planning of transportation investment deals with extensive areas and long time periods, therefore, it is necessary to robust contingency plan in each stage in order to mitigate the effects of uncertainty	Outcomes of this study found that evaluating the service level for mass transportation is the significant criteria in transportation investment
Liu *et al.* (2013)	VIKOR, ANP and DEMATEL	Metro–airport	Developed model of system evaluation of systems in airport connection service	Few of previous studies discussed about relationship between metro system and urban airports in tourism development	Outcomes of this study showed that, tangibles service encounters and re-ride are the significant criteria rather than other criteria

Continue of Table 5

Author(s) and year	Technique and approach	Application area and scope	Study purpose	Gap and research problem	Results and outcome
Celik *et al.* (2013)	TOPSIS and GRA	Public transportation	Improve and evaluation of customer satisfaction in public transportation	There is problem in level of customer satisfaction public transportation in Turkey, therefore need to improve and evaluation of customer satisfaction	Results of this paper found that Metrobus had the best customer satisfaction level in public transportation
Wang *et al.* (2015)	Entropy and GRA	Airline industry	Performance measurement evaluation based on corporate social responsibility in airline industry	Need to analysis of corporate social responsibility for improvement strategies in airline industry	The outcomes of this paper found that, the larger state-controlled airlines make better in corporate social responsibility performance and private airline has had better improvement regarding corporate social responsibility performance
Chao, Kao (2015)	Fuzzy-AHP and Fuzzy Delphi method	Airline industry	Selection and evaluation of strategic cargo alliance in airline industry	There is need to further study regarding to evaluation of cargo alliance in airline	Results of this paper indicated that increasing revenue, enhancing flight route and frequency and improving load factor are three important criteria
Barros, Wanke (2015)	TOPSIS and DEA	Airline industry	Evaluation of efficiency in African airlines	There is need to assessment of efficiency in African airlines	Outcomes of this paper indicated that network size-related variables economies of scope are significant criteria in efficiency assessment
Chen *et al.* (2014b)	TOPSIS and MGE	Railway station	Evaluation of performance of passenger transfer in railway station	There is need to performance evaluation of passengers through transfer facilities	Results of this article showed that, transfer facility capacity, level of service of transfer, transfer continuity and sustainable development are importance criteria in performance evaluation
Barfod, Salling (2015)	AHP and SMARTER	Transport infrastructure projects	Proposed new framework for evaluation of transport infrastructure projects based on CBA	There is lack in previous studies, which did not focus on sustainable and strategic transport evaluation	Finding of this paper indicated that DM framework is a valuable DSS and transport projects evaluation can be support significantly
Aydin *et al.* (2015)	Fuzzy-AHP, Choquet integral and trapezoidal fuzzy sets	Rail transit	Presented a new framework for evaluation of customer satisfaction in rail transit systems	There are problems in rail transit line systems regarding of evaluation of customers satisfaction	Outcomes of this study demonstrated that time; accessibility and safety are significant criteria in evaluation of customer satisfaction in Turkey
Tsai *et al.* (2011a)	VIKOR, ANP and DEMATEL	Airline industry	Assessment of websites effectiveness in airline industry	Effectiveness of information technology in airline industry is significant issue, which need further study in this issue	Result of this study showed that airline industry in Taiwan did not capitalized on webs marketing and need to further consideration regarding to managerial actions
Lee *et al.* (2012)	GRA and entropy	Shipping companies	Compared financial position in shipping companies in Taiwan and Korea	Due to financial crisis in two countries need to study to identify of various features for reflect financial crisis in shipping companies	Finding of this comparison demonstrated that cash flow, long-term debt to equity ratio, times interest earned ratio, working capital turnover are significant criteria in shipping companies

End of Table 5

Author(s) and year	Technique and approach	Application area and scope	Study purpose	Gap and research problem	Results and outcome
Wang (2008)	Fuzzy TOPSIS and GRA	Airline industry	Evaluation of financial performance in airline industry	Lack in previous studies, which did not focused on financial performance evaluation in Taiwanese airlines	Results of this paper can improve competitive advantage in airline industry in Taiwan
Wang (2009)	FMCGDM and GRA	Container lines	Evaluation of financial performance container lines	Lack in previous studies, which did not focused on financial performance in container lines which they need to large capitals	Results of this paper can improve competitive advantage in container lines in Taiwan
Chang, Yeh (2001)	SAW, TOPSIS and WPM	Airline industry	Evaluation of competitiveness performance in airline industry	Due to increase growth in competition after deregulation and passengers' traffic need to study for evaluation of performance	Finding of this study found that management and service quality are the significant criteria in evaluation performance in Taiwan airline industry
Tsai *et al.* (2011b)	VIKOR and AHP	Airport	Improving airport service quality	There is gap between passengers' perceptions and their expectations in airport	Empirical results were from the analysis in the airport of Taiwan and factor of culture is influenced on marketing management
Chou, Ding (2013)	MCDM and IPA	Transshipment	Assess the international ports service quality of in Asia	Few of previous studies emphasize of the service gap and expectation service in the shipping carries	The results show that the combined method is a suitable for evaluating and analyzing the service quality of ports
Liou, Tzeng (2007)	AHP, fuzzy integral GRA and SAW	Airlines industry	Assessment and enhance the service quality of airlines industry	Some of previous paper worked on service quality and they supposed the service quality attributes are independent	Results indicated that reliability and safety is the most important criteria of service quality
Chang *et al.* (2015)	ANP and Fuzzy TOPSIS	Airport safety	Evaluation of performance in for airport safety management systems	Few studies have attention on airport safety	Results of this study showed that safety assurance, safety policy and objectives, safety promotion and safety risk management are importance criteria in evaluation of airport safety
Ding, Liang (2005)	Entropy and fuzzy TOPSIS	liner shipping	Proposed new fuzzy MCDM method for selection strategic partner in shipping industry	There is problem in selection of strategic alliances in shipping industry	Finding of this study facilitated for implementation in system of computer-based decision support for selection of strategic partner in shipping industry
Wang *et al.* (2014)	Fuzzy Delphi and TOPSIS	Liner shipping companies	Selection of optimal bunkering ports in liner shipping companies	Need to study for selection of ports in shipping companies for reduce cost and maintain shipping schedules	Results of this study indicated that; port tariffs, bunker quality, bunkering safety and bunker price are important factors in choosing of bunkering ports

3.2.3. Distribution Based on TOPSIS and Fuzzy TOPSIS with Other Techniques

In this section we presented those papers that used both TOPSIS and fuzzy TOPSIS to evaluate transportation systems in several application areas and transport infrastructure such as; service quality, transportation performance evaluation, customer and passengers satisfaction, sustainability, logistic management, safety management, technology management and other areas, airline industry, public transportation, shipping industry, airport industry, railways industry, public logistic center, container lines and other transportations.

Awasthi *et al.* (2011) evaluated service quality in Metro transportation, results of this paper showed that

approach is the ability to perform assessment of quality of service of transportation systems under partial or lack of quantitative information. Kazançoğlu, Y. and Kazançoğlu, İ. (2013) finding service quality criteria of Turkish domestic airlines, from 23 sub-criteria, the important attributes were cleanliness of restrooms, personal attention, safety of aircraft and friendliness and helpfulness. Nejati *et al.* (2009) ranked the service quality criteria in the airline industry, the results show that offering highest possible quality service to customer, flight safety and good appearance of flight crew were the significant factors in airline industry. Fouladgar *et al.* (2012) assessed risk assessment in tunnel projects by using fuzzy TOPSIS, results of this article found that collapse is the most important risk in tunneling project in Iran. Wang and Chang (2007) developed model for evaluation of aircraft initial training, finding of this paper found that, stalling speed, maximum operating speed, fuel capacity, power plant and maximum G limits are the significant initial training. Hassan *et al.* (2013) indicated that, need to measure and evaluation of performance criteria for increase of service efficiency of service by public transit providers. ,finding of this paper showed that, involvement of each stakeholder and flexibility are the important criteria in assessment of public transportation system. Celik *et al.* (2013) combined fuzzy TOPSIS and GRA to improve and evaluate of customer satisfaction in public transportation, results of this paper found, that Metrobus had the best customer satisfaction level in public transportation. Wang (2014) evaluate financial performance in Taiwan container shipping companies, finding of this paper demonstrated that closeness coefficient values is best criteria in four categories. Chen *et al.* (2014a) presented a new model for selection of logistic center selection, this study mentioned that, there is problem in selection of location in logistics center of airline industry due to many multiple objectives, finding of this study showed that, investment cost criteria is the best criteria in selection of location in logistics center. Deng *et al.* (2007) demonstrated that, assessment of safety is important factor for success of business in airline industry, outcomes of this paper indicated that engineering and maintenance management, fleet planning and flight operations are important criteria in safety of airline industry. Based on the finding of Table 6, 10 of previous studies, used TOPSIS and fuzzy TOPSIS with other techniques to evaluate of transportation system. Other information details such as author(s) and year, technique and approach, transport infrastructure, study purpose, gap and research problem and the last column presents results and outcome in each paper presented in Table 6.

Table 6. Distribution based on TOPSIS and fuzzy TOPSIS with other techniques

Author(s) and year	Technique and approach	Application area and scope	Study purpose	Gap and research problem	Results and outcome
Deng *et al.* (2007)	Fuzzy TOPSIS	Airline safety	Evaluation of safety in airline industry	Assessment of Safety is important factor for success of business in airline industry	Outcomes of this paper indicated that engineering and maintenance management, fleet planning and flight operations are important criteria in safety of airline industry
Chen *et al.* (2014a)	TOPSIS	Airline industry	Presented a new model for selection of logistic center selection	There is problem in selection of location in logistics center of airline industry due to many multiple objectives	Finding of this study showed that, investment cost criteria is the best criteria in selection of location in logistics center
Wang (2014)	Fuzzy TOPSIS	Container shipping companies	Evaluation of financial performance in Taiwan container shipping companies	Need to further study for evaluation of financial performance in container shipping companies	Finding of this paper demonstrated that closeness coefficient values are best criteria in four categories
Hassan *et al.* (2013)	TOPSIS	Public transit service	Proposed new framework for evaluation performance of in public transit service	Need to measure and evaluation of performance criteria for increase of service efficiency of service by public transit providers	Finding of this paper showed that, involvement of each stakeholder and flexibility are the important criteria in assessment of public transportation system
Torlak *et al.* (2011)	Fuzzy TOPSIS	Airline industry	Assessment of business competition in airline industry	Due to importance of airline industry in Turkey need to evaluation business competition	Results of this paper indicated that the Turkish Airlines preserved its dominant role even after its entrance of newcomers and privatisation into the airline industry

End of Table 6

Author(s) and year	Technique and approach	Application area and scope	Study purpose	Gap and research problem	Results and outcome
Wang, Chang (2007)	Fuzzy TOPSIS	Aircraft	Developed model for evaluation of aircraft initial training	Need to present the optimal model for selection of training due to improve efficiency, shorten the training cycle, and save expenses	Finding of this paper found that, stalling speed, maximum operating speed, fuel capacity, power plant and maximum G limits are the significant initial training
Fouladgar *et al.* (2012)	Fuzzy TOPSIS	Tunneling projects	Evaluation of risk assessment in tunnel projects	Due to significant of tunneling need to study for assessment of risks	Results of this article found that collapse is the most important risk in tunneling project in Iran
Nejati *et al.* (2009)	Fuzzy TOPSIS	Airline industry	Ranking of service quality criteria in the airline industry	Need to identify and prioritizing Iranian customers' needs and expectations for airlines in the current competitive market	The results show that offering highest possible quality service to customer, flight safety and good appearance of flight crew were the significant factors in airline industry
Kazan-çoğlu, Y., Kazan-çoğlu, İ. (2013)	Fuzzy TOPSIS	Airline industry	Finding service quality criteria of Turkish domestic airlines	Need to focus on service quality as competitive advantage in airline industry	From 23 sub-criteria, the important attributes were cleanliness of restrooms, personal attention, safety of aircraft and friendliness and helpfulness
Awasthi *et al.* (2011)	fuzzy TOPSIS	Metro transportation	Evaluation of service quality in Metro transportation	Often it is difficult to assess service quality due to lack of quantifiable measures and limited data	Results showed that approach is the ability to perform assessment of quality of service of transportation systems under partial or lack of quantitative information

3.2.4. Distribution Based on Other MCDM and FMCDM Techniques

In this section of this study provided some previous studies that use several techniques and approaches which less in number of frequently, to evaluate of transportation systems several application areas and transport infrastructure such as transportation performance evaluation, customer and passengers satisfaction, sustainability, logistic management, safety management, technology management and other areas, airline industry, public transportation, shipping industry, airport industry, railways industry, public logistic center, container lines and other transportations.

Bouhana *et al.* (2013) proposed new model in search of personalized itinerary in systems of multimodal transportation by using Choquet integral, results of research presented the best solution regarding the personalized itinerary based on user's preferences in MCDM issue. Nigim *et al.* (2004) indicated that need to understand how the customer views their services relative to their competitors, the evaluation results would help airlines better manage their competitive advantages and provide an incentive for them to improve quality levels of specific services relative to their competitors. Liou (2011) evaluate service strategies by generating airline service decision rules, outcomes display that by developing both data and suitability, airlines might evade a poor service assessment, though good information, baggage management and check-in procedures would guarantee at least a good rating. On-board ease, operative service, being on-time and schedule are not significant qualities to obtain customer gratification in Taiwan's local marketplace. Cheng *et al.* (2005) presented a novel aggregation model for service quality evaluation based on fuzzy OWA (Ordered Weighted Averaging), results of this study show that if the alternative perform stable in each attribute, the evaluating results obtained by proposed model will also robust. Hickman *et al.* (2012) investigated sustainability impacts for future lower CO_2 emissions in the transportation system by employ MCA, the geography of the county, the historic and compact central city, and a surrounding periphery which is much more dispersed and car dependent, are all typical to many city-regions in the UK and elsewhere. Brauers *et al.* (2008) applied MULTIMOORA for evaluation of road design, The results revealed that the important alternative is construction of road. Turskis and Zavadskas (2010b) selected of suitable site for logistic center based on multiple criteria employ ARAS-F, outcomes of this paper found that investment cost, operation time, expansion possibility and closeness to the demand market are important criteria in selection of site. Based on the finding of Table 7, 12 of previous studies employed MCDM and FMCDM techniques to evaluate of transportation system. Other information details such as author(s) and year, technique and approach, transport infrastructure, study purpose, gap and research problem and the last column presents results and outcome in each paper presented in Table 7.

Table 7. Distribution based on other MCDM and FMCDM techniques

Author(s) and year	Technique and approach	Application area and scope	Study purpose	Gap and research problem	Results and outcome
Turskis, Zavadskas (2010b)	ARAS-F	Logistic center	Selection of suitable site for logistic center based on multiple criteria	Proposed new method as ARAS-F for solving problems in civil engineering fields such as transportation	Outcomes of this paper found that investment cost, operation time, expansion possibility and closeness to the demand market are important criteria in selection of site
Onut *et al.* (2011)	Fuzzy ANP	Container port	Applied fuzzy ANP for solve problems in selection of container port	There are some quality problems related to logistics firm in a production company in the Turkey	Results of this study found that, Istanbul District is importance convenient district related to container port
Brauers *et al.* (2008)	MULTIMOORA	Road design	Applied MULTIMOORA for evaluation of road design	Need to present the model based on multiobjective optimization for road construction	The results revealed that the important alternative is construction of road
Mouter *et al.* (2013)	MCA	Spatial infrastructure projects	Assess role of Cost–Benefit Analysis for spatial-infrastructure projects	There is lack in previous studies, which did not emphasize on CBA in process of decision-making for transport projects	Results of this study indicated that, there is agreement which CBA must have role in the assessment of process in the projects regarding to spatial-infrastructure
Sevkli *et al.* (2012)	Fuzzy ANP	Airline industry	Evaluation of SWOT analysis in airline industry	Need to study for develop airport infrastructure and civil aviation in Turkey due to rapid urbanization, growing population and growing of tourism industry	Results of this study showed that the SWOT FANP is the best method for decision of strategic management in the airline industry
Hickman *et al.* (2012)	MCA	Transport sector	Investigated sustainability impacts for future lower CO_2 emissions in the transport sector	Need to identify the best ways for future in regarding of reduces CO_2 emissions	Finding of this paper indicated that the surrounding periphery, compact and historic central city
Cheng *et al.* (2005)	Fuzzy OWA	Airline industry	Present a novel aggregation model for service quality evaluation	Need to show how to achieve parameter feasible value in evaluation of service quality	The finding of this study indicated that obtain results by presented model are robust
Chou (2012)	Fuzzy MCDM	Airport	Assessment of the quality of airport service	Need to evaluation the quality of airport service	Results of this paper indicated that airport of Kaohsiung and airport of Taoyuan should emphasize on some service quality items specifically
Liou (2011)	Dominance-based Rough Set Approach	Airline industry	Evaluate service strategies by generating airline service decision rules	This lack in previous studies, which did not focus on evaluation of service strategies in airline industry	Finding of this paper indicated that baggage handling, good information and check-in processes had the best rating
Liou *et al.* (2011b)	Fuzzy ANP	Airline industry	Presented a new model strategic alliance selection in airline industry	There are few studies focused on how firms selected partner which emphasis on interrelationship and main firm at the same time	Outcomes of this study found that one-world alliance is the best choice in specific time

End of Table 7

Author(s) and year	Technique and approach	Application area and scope	Study purpose	Gap and research problem	Results and outcome
Nigim *et al.* (2004)	Multicriteria analysis	Airline industry	Evaluation of all customers on service quality levels	Need to understand how the customer views their services relative to their competitors	These evaluation results would help airlines better manage their competitive advantages and provide an incentive for them to improve quality levels of specific services relative to their competitors
Bouhana *et al.* (2013)	Choquet integral	Public transit	Proposed new model in search of personalized itinerary in systems of multimodal transportation	There is problem in suggest the personalized itinerary in the multimodal transportation due to changing information, transportation means diversity and destinations multitude and itinerary	Results of research presented the best solution regarding the personalized itinerary based on user's preferences in MCDM issue

3.2.5. Distribution Based on VIKOR and Fuzzy VIKOR with Other Techniques

Celik *et al.* (2014) demonstrated that Focus of customer satisfaction is important task for municipalities and government in case of public transportation like rail transit, the important factors related to customer satisfaction are noise level and vibration, crowdedness and density, air-conditioning system and phone services. Kuo and Liang (2011) provided an effective method to assessing service quality of Northeast Asian international airports, the study results showed that this approach is an effective means for tackling MCDM problems involving subjective assessments of qualitative attributes in a fuzzy environment. Liou *et al.* (2011a) enhance service quality among domestic airlines in Taiwan by applied VIKOR and GRA, finding of this paper isolated that the important factors of airlines may wish to focus and those in which airlines have already done well and can reduce their efforts without affecting the overall service level. Based on the finding of Table 8, five of previous studies used VIKOR and fuzzy VIKOR with other techniques to evaluate of transportation systems. Other information details such as author(s) and year, technique and approach, transport infrastructure, study purpose, gap and research problem and the last column presents results and outcome in each paper presented in Table 8.

3.2.6. Distribution Based on Integrated AHP, TOPSIS and Fuzzy Set

In this section, this study provided some previous studies that combined AHP, TOPSIS and fuzzy set to evaluate of transportation systems several application areas and transport infrastructure such as transportation performance evaluation, customer and passengers satisfaction, sustainability, logistic management, safety management, technology management and other areas, airline industry, public transportation, shipping industry, airport industry, railways industry, public logistic center, container lines and other transportations.

Yazdani-Chamzini and Yakhchali (2012) proposed new method for selection tunnel boring machine, finding of this paper found the cost factor is most important factor in selection of tunnel boring machine in Iran. Toosi and Kohanali (2011) assessing service quality of Iranian airlines; results show that the important criteria are comfort flight safety, knowledgeable employees to answer customer questions, without delay flights, convenient air-condition of plane and announcing schedule flights rapidly and availability of flight options to cancel or delay cases. John *et al.* (2014) integrated fuzzy TOPSIS and Fuzzy-AHP for selection an appropriate model for evaluation of performance efficiency in seaports, finding of this study demonstrated that increasing reliability is the best investment strategy in seaports. Yeo *et al.* (2013) combined Fuzzy-AHP and fuzzy TOPSIS for assessment of competitiveness of the aerotropolises in East Asia with FMCDM, outcomes of this paper showed that, two important criteria are basic infrastructure and convenience operation. Based on the finding of Table 9, 6 of previous studies combined AHP and TOPSIS with fuzzy set to assess of transportation systems. Other information details such as author(s) and year, technique and approach, transport infrastructure, study purpose, gap and research problem and the last column presents results and outcome in each paper presented in Table 9.

3.2.7. Distribution Based on Integrated ANP, DEMATEL and Fuzzy Set

In this section, study provided some previous studies that integrated ANP and DEMATEL with fuzzy set to evaluate of transportation systems several application areas and transport infrastructure such as transportation performance evaluation, customer and passengers satisfaction, sustainability, logistic management, safety management, technology management and other areas, airline industry, public transportation, shipping industry, airport industry, railways industry, public logistic center,

Table 8. Distribution based on VIKOR and Fuzzy VIKOR with other techniques

Author(s) and year	Technique and approach	Application area and scope	Study purpose	Gap and research problem	Results and outcome
Kabir (2015)	Fuzzy VIKOR	Transportation firm	Selection and evaluation of hazardous industrial waste transportation firm	Evaluation of the proper and most appropriate hazardous industrial waste transportation firm is an important problem for hazardous waste generators	Finding of this paper not only enables us to determine the outranking order of HIW transportation firms, but also assess and rate the firms
Kuo (2011)	Fuzzy VIKOR and GRA	Airline industry	Evaluate the quality of service in Chinese cross-strait passenger airlines	Previous studies cannot effectively measure and handle service levels of air travel passenger services	According to the empirical example, though this study can obtain a best alternative A1 by using the proposed approach, this study can also obtain that the priority improvement criterion is C2 in alternative A1
Liou *et al.* (2011a)	VIKOR	Airline industry	Enhance service quality among domestic airlines in Taiwan	In a competitive environment, delivering high-quality service is important but from 2008 the global economic downturn saw airlines are struggling just to survive	Finding isolated that the important factors of airlines may wish to focus and those in which airlines have already done well and can reduce their efforts without affecting the overall service level
Kuo, Liang (2011)	VIKOR with GRA	Airports	Provide an effective method to assessing service quality of Northeast Asian international airports	Need to investigate the service level of each service presented by in international airport services	The finding of this paper indicated that, presented approach is very significant for solving of MCDM problems, including subjective assessments of qualitative attributes in a fuzzy environment
Celik *et al.* (2014)	VIKOR and interval type-2 fuzzy sets	Rail transit	Evaluation of customer satisfaction in rail transit in Turkey	Focus of customer satisfaction is important task for municipalities and government in case of public transportation like rail transit	The important factors related to customer satisfaction are noise level and vibration, crowdedness and density, air-conditioning system and phone services

container lines and other transportations. Liou *et al.* (2014) combined fuzzy DEMATEL and ANP for assess and enhance the service quality of transport systems, this study illustrates that how to improve transportation service quality and thus attract more passengers to use public transportation systems is an important concern for city governments around the world, the empirical example of this study indicates that the interdependent effect among criteria is significant. Liou (2012) combined ANP, DEMATEL and fuzzy preference programming to develop model for selection of partners in strategic alliance, results of this study demonstrated that service network, risk sharing and relationship are significant criteria. Hsu *et al.* (2010) integrated ANP and DEMATEL for propose a new model to identify the critical success factors of safety management in airline industry, finding of this paper demonstrated that organization is the significant factor in safety management system. Based on the finding of Table 10, 6 of previous studies combined AHP and TOPSIS with fuzzy set to assess of transportation systems.

Other information details such as author(s) and year, technique and approach, transport infrastructure, study purpose, gap and research problem and the last column presents results and outcome in each paper presented in Table 10.

3.2.8. Distribution Based on ELECTRE and Fuzzy ELECTRE

Lupo (2015) evaluate the quality of service in international airports employ fuzzy ELECTRE III, results of this paper showed that only few key service aspects played a focal role in quality airport service. Freitas (2013) indicated that, due to facing growing competition of public transportation with other transportation need to assessment of road transportation quality of passengers, outcomes of this study found that vehicle condition and vehicle cleanliness are the significant items in evaluation of quality in road transportation. Based on the finding of Table 11, 3 of previous studies used ELECTRE and fuzzy ELECTRE to evaluate of transportation systems. Other information details such as author(s) and year, technique and approach, transport infrastructure, study purpose, gap and research problem and the last column presents results and outcome in each paper presented in Table 11.

Table 9. Distribution based on integrated AHP, TOPSIS and fuzzy set

Author(s) and year	Technique and approach	Application area and scope	Study purpose	Gap and research problem	Results and outcome
Bilişik *et al.* (2013)	Fuzzy-AHP and fuzzy TOPSIS	Public transportation	Evaluation of customer satisfaction based on SERVQUAL measurement	Need to examine service quality in public transportation due to solve many problems	Results of this paper showed that, fee and tangibles factors are the greatest weights in evaluation of service quality
Yayla *et al.* (2015)	Fuzzy-AHP and fuzzy TOPSIS	3PL transportation	Presented a new decision support tool for evaluation of 3PL transportation	Selection of 3PL service providers is difficult decision with complexity and uncertainty	Results of this paper indicated that proposed model can reflects expectations of 3PL transportation service provider
Yeo *et al.* (2013)	Fuzzy-AHP and Fuzzy TOPSIS	Aerotropolis	Assessment of competitiveness of the aerotropolises in east Asia with FMCDM	There is lack in previous empirical studies which did not focused on advantages and disadvantages of specific aerotropolis	Outcomes of this paper showed that, two important criteria are basic infrastructure and convenience operation
John *et al.* (2014)	Fuzzy TOPSIS and Fuzzy-AHP	Seaport	Selection an appropriate model for evaluation of performance efficiency in seaports	Need to choose the best model for investment strategy to increase of performance in seaports	Finding of this study demonstrated that increasing reliability is the best investment strategy
Toosi, Kohanali (2011)	Fuzzy-AHP and fuzzy TOPSIS	Airline industry	Assessing service quality of Iranian airlines	There is lack for evaluation of airlines service quality in Iran	Results show that the important criteria are comfort flight safety, knowledgeable employees to answer customer questions, without delay flights, convenient air-condition of plane and announcing schedule flights rapidly and availability of flight options to cancel or delay cases
Yazdani-Chamzini, Yakhchali (2012)	Fuzzy-AHP and fuzzy TOPSIS	Tunnel boring machine	Proposed new method for selection tunnel boring machine	Need to study for selection of tunnel boring machine due to reduce time and increase speed	Finding of this paper found the cost factor is most important factor in selection of tunnel boring machine in Iran

Table 10. Distribution based on integrated ANP, DEMATEL and fuzzy set

Author(s) and year	Technique and approach	Application area and scope	Study purpose	Gap and research problem	Results and outcome
Hsu *et al.* (2010)	ANP and DEMATEL	Airline industry	Proposed new model for identify the critical success factors of safety management in airline industry	There is need to development and implementation of safety management system in airline industry	Finding of this paper demonstrated that organization is the significant factor in safety management system
Liou *et al.* (2007)	ANP and DEMATEL	Airline industry	Assessment of safety management in airline industry	There is lack in previous studies, which did not attention on safety in airline industry	Results of this paper shoed that, accident rate flight crew competence, compliance with aviation task procedures the training status of pilots, compliance with maintenance task procedures; training status of maintenance personnel; number of certified technicians/number of maintenance crew and the managers' attitude/commitment are important criteria in safety management

End of Table 10

Author(s) and year	Technique and approach	Application area and scope	Study purpose	Gap and research problem	Results and outcome
Tsai, Hsu (2008)	ANP and DEMATEL	Airline industry	Evaluation and selection of corporate social responsibility criteria	Due to the important of corporate social responsibility in airline business strategies need to further study in this regard	Results of this study indicated that organization image improvements is the important criterion in Corporate Social Responsibility (CSR)
Hsu, Liou (2013)	ANP and DEMATEL	Airline industry	Evaluation of outsourcing provider in airline industry	Outsourcing is critical issue in airline industry and need to further studies in evaluation of that	Results of this study indicated that, knowledge skills can help for improving service quality, there is good relationship between airlines and their partners and risk factor is the most importance in outsourcing evaluation
Liou (2012)	ANP, DEMATEL and fuzzy preference program-ming	Airline industry	Developed model for selection of partners in strategic alliance	There is lack in previous studies which did not emphasize on how select partners and lack of interrelationship analysis among them	Results of this study demonstrated that service network, risk sharing and relationship are significant criteria
Liou *et al.* (2014)	Fuzzy DEMATEL and ANP	Public transportation	Assessment and enhance the service quality of transport systems	How to improve transportation SQ and thus attract more passengers to use public transportation systems is an important concern for city governments around the world	The empirical example indicates that the interdependent effect among criteria is significant. We believe that the results of our method's application are promising

Table 11. Distribution based on ELECTRE and fuzzy ELECTRE

Author(s) and year	Technique and approach	Application area and scope	Study purpose	Gap and research problem	Results and outcome
Sawadogo, Anciaux (2011)	ELECTRE TRI	Intermodal transportation	Presented a model for evaluation of performance in intermodal transportation system of goods within the green supply chain	Need to attention to environmental impact in green supply chain and intermodal transportation system	Results of this study found that two criteria of cost and time are the significant in industrial scenario
Freitas (2013)	ELECTRE TRI	Road transportation	Evaluation of quality in road transportation in Brazil	Due to facing growing competition of public transportation with other transportation need to assessment of road transportation quality of passengers	Outcomes of this study indicated that vehicle condition and vehicle cleanliness are the significant items in evaluation of quality in road transportation
Lupo (2015)	Fuzzy ELECTRE III	Airline industry	Evaluate the quality of service in international airports	It is important to have an accurate and reliable assessment of passenger service quality	The results showed that only few key service aspects played a focal role in quality airport service

3.3. Distribution of Papers Based on Title of Journal

Table 12 provides the distribution based on the name of the journals, which was used in this paper. The articles, which were related to the MCDM methods and transportation systems are published in 39 international journals, which cover an extensive range of the *Web of Science* and *Scopus* databases. From these 39 journals, the first rank was the *Transportation Research Part A: Policy and Practice*, with 13 papers. This result indicates that this journal has the most significant role in MCDM issues and transportation systems fields. *Journal of Air Transport Management* and *Expert Systems with Applications* had the second and third rank with 11 and 10 papers respectively; in addition, *Transport Policy,* with 6 papers, had fourth rank. In other journal rankings, *Transportation* with 5 papers had fifth rank, *Transport* and *Applied Soft Computing* journal had the sixth and seventh rank, respectively, with five publications; finally, *Transportation Research Part E: Logistics and Transportation Review*, with three studies, had eighth rank. The frequency of other published journals is shown in Table 12.

Table 12. Distribution of papers based on the name of journals

Title of journal	Number	Percentage [%]
Transportation Research Part A: Policy and Practice	13	14.61
Journal of Air Transport Management	11	12.36
Expert Systems with Applications	10	11.24
Transport Policy	6	6.74
Transportation	5	5.62
Transport	5	5.62
Applied Soft Computing	4	4.49
Transportation Research Part E: Logistics and Transportation Review	3	3.37
Total Quality Management & Business Excellence	2	2.25
Computers & Industrial Engineering	1	1.12
Transportation Research Part C: Emerging Technologies	1	1.12
Safety Science	1	1.12
Omega: The International Journal of Management Science	1	1.12
Journal of Applied Mathematics	1	1.12
Modeling Decisions for Artificial Intelligence	1	1.12
Expert Systems	1	1.12
Mathematical Problems in Engineering	1	1.12
Intelligence and Security Informatics	1	1.12
Information Sciences	1	1.12
Archives of Civil and Mechanical Engineering	1	1.12
The International Journal of Logistics Management	1	1.12
Journal of Traffic and Transportation Engineering	1	1.12
International Journal of Data Analysis Techniques and Strategies	1	1.12
Eskişehir Osmangazi Üniversitesi İktisadi ve İdari Bilimler Dergisi	1	1.12
IEEE Transactions on Systems, Man and Cybernetics	1	1.12
Sustainability	1	1.12
Quality & Quantity	1	1.12
Knowledge-Based Systems	1	1.12
Tourism Management Perspectives	1	1.12
European Transport – Trasporti Europei	1	1.12
International Journal of Quality & Reliability Management	1	1.12
Renewable Energy	1	1.12
Research in Transportation Business & Management	1	1.12
IEEE Transactions on Engineering Management	1	1.12
International Journal of Business Performance and Supply Chain Modelling	1	1.12
The Journal of Mathematics and Computer Science	1	1.12
Journal of Advanced Transportation	1	1.12
International Journal of Production Research	1	1.12
Tunnelling and Underground Space Technology	1	1.12

3.4. Distribution of Papers Based on Publication Year

Fig. 2 provided the significant data based on the frequency of distribution by the year of publication. The finding of this figure found that, from 1993 to 2015, using of MCDM method has significant growth in field of transportation systems and MCDM techniques. According to the findings of this section, the use of these techniques and approaches in 1993 was found in only one paper, and this number increased to three papers in 2005; the number of publications increased to 10 and 17 papers in 2012 and 2013. Accordingly, it can be indicated that researchers in different fields and categories of transportation systems use the MCDM techniques and approaches nowadays in their research, and it can be predicted that in coming years, these numbers will increase. Results of publication years are shown in Fig. 2.

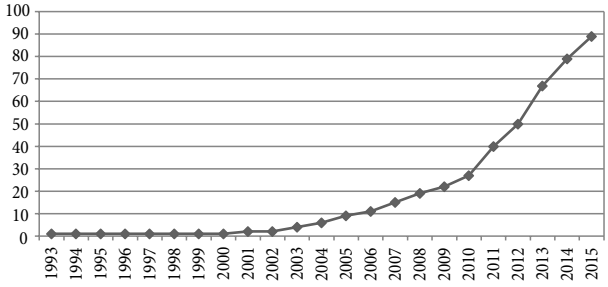

Fig. 2. Distribution papers based on year of publication

3.5. Distribution of Papers Based on Nationality of Authors

Table 13 shows that authors from 25 nationalities and countries applied MCDM issues in the transportation systems areas. Most of the published papers were from Taiwan (34.83%). However, findings of this paper indicate that Turkey, Italy and Iran have published papers regarding transportation systems areas by using MCDM techniques and applications. Table 13 presents details regarding the nationality of authors.

Table 13. Distribution of papers based on the authors' nationality

Country	Number	Percentage [%]
Taiwan	31	34.83
Turkey	11	12.36
Italy	5	5.62
Iran	4	4.49
UK	4	4.49
China	4	4.49
Lithuania	3	3.37
Republic of Korea	3	3.37
Netherlands	3	3.37
US	3	3.37
Canada	2	2.25
Thailand	2	2.25
Serbia	1	1.12
Tunisia	1	1.12
UAE	1	1.12
Brazil	1	1.12
Denmark	1	1.12
South Africa	1	1.12
Portugal	1	1.12
Belgium	1	1.12
Slovenia	1	1.12
France	1	1.12
Hong Kong	1	1.12
Croatia	1	1.12
Poland	1	1.12
Hungary	1	1.12
Brazil	1	1.12
Malaysia	1	1.12

Conclusions

This review paper contributes to existing literature by demonstrating the possibility of combining decision-making and transportation systems areas in the MCDM procedure. The potential for finding the most feasible MCDM method under the influence of changing transportation systems conditions is promising. In an age of increasing globalization and increasing flows of information, decision makers and scientists are trying to better understand how to construct of decision-making systems to address a range of multi-level problems. These complexities in generating the desired transportation systems decisions may be exacerbated by uncertainties existing in the related system components. For many decades, transportation systems problems, which have been accompanied by rapid economic, environment and social developments, have been of great importance for both local and national governments worldwide. Recognition of decision schemes, with sound socio-economic and environmental efficiencies, is necessary for promoting effectual practices in transportation management. Still, transportation management systems are generally associated with various uncertainties and complexities that are being further amplified due not only to dynamics and interactions amongst different sub-systems, but also their association with economic penalties at the time that different overriding policies are violated. Consequently, it is desired to develop robust and efficient systems analysis methodologies that can address the above-mentioned complexities. Results obtained from this review show that MCDM approaches and techniques are appropriate for transportation systems. This study shows that a large number of MCDM approaches and techniques exist and many of these methods are applicable to the solution of problems in the transportation systems fields. Various DMs generally disagree regarding that approach and technique is most valid and suitable. This paper provided several examples of the way various MCDM approaches and techniques have been applied to the transportation systems fields.

Results of this paper indicated that, hybrid MCDM and FMCDM in the integrated approaches and AHP and Fuzzy-AHP in the individual methods in the rank order weighting methods are increasingly prevalent because of their understandability in theory and the simplicity in application. The objective and combination weighting methods rise in decision-making progressively. They will be mainly used to transportation systems decision-making as they assess the comparative significance accurately minus decision makers. MCDM techniques and approaches were extensively used in transportation systems decision-making that considers multi-criteria. Usually hybrid MCDM and FMCDM in the integrated approaches and AHP and Fuzzy-AHP in the individual methods are the most prevalent widespread technique so that the basic biased sum technique is still simple in multi-criteria decision-making difficulties. In addition this review paper found that, previous studies in various fields of transportation systems more attention on service quality rather than other application areas. As a result of evaluation of service quality, improvements can attract further users to use public transportation. The inclusive procedure to develop service quality needs to the identify the clients' priorities and requirements, the measurement of clients' gratification applying suitable indices, the usage of this reaction to assess the related service issues and lastly the description and application of measures to develop the services improve to the clients. Fuzzy set methodology was progressively used for caring the qualitative standards and the vagueness or fuzziness characteristic in the data. The evaluation and calculation in transportation systems decision-making is usually obtained in a MCDM techniques and approaches. It is essential that a few dissimilar classes of techniques and approaches are used to get the ranking instructions of transportation systems' substitutes and ensure that the validity of MCDM approaches is confirmed. It is supposed that the consequences got by the other mathematics approaches are more balanced and more mathematics approaches will help in the transportation systems problems in the future. As long as criteria selection and weights are used, MCDM techniques and approaches are appropriate and suitable to the precise decision difficulties, and MCDM can develop an influential instrument for solve problems in the transportation systems.

References

Aghabayk, K.; Sarvi, M.; Young, W. 2015. A state-of-the-art review of car-following models with particular considerations of heavy vehicles, *Transport Reviews* 35(1): 82–105. http://dx.doi.org/10.1080/01441647.2014.997323

Agusdinata, D.; Van Der Pas, J. W. G. M.; Walker, W. E.; Marchau, V. A. W. J. 2009. Multi-criteria analysis for evaluating the impacts of intelligent speed adaptation, *Journal of Advanced Transportation* 43(4): 413–454. http://dx.doi.org/10.1002/atr.5670430402

Arslan, T. 2009. A hybrid model of fuzzy and AHP for handling public assessments on transportation projects, *Transportation* 36(1): 97–112. http://dx.doi.org/10.1007/s11116-008-9181-9

Asakura, Y.; Kashiwadani, M. 1991. Road network reliability caused by daily fluctuation of traffic flow, in *Transportation Planning Methods: Proceedings of Seminar G Held at the PTRC Transport Highways and Planning Summer Annual Meeting*, 9–13 September 1991, Sussex, UK, 73–84.

Awasthi, A.; Chauhan, S. S.; Omrani, H.; Panahi, A. 2011. A hybrid approach based on SERVQUAL and fuzzy TOPSIS for evaluating transportation service quality, *Computers & Industrial Engineering* 61(3): 637–646. http://dx.doi.org/10.1016/j.cie.2011.04.019

Aydin, N.; Celik, E.; Gumus, A. T. 2015. A hierarchical customer satisfaction framework for evaluating rail transit systems of Istanbul, *Transportation Research Part A: Policy and Practice* 77: 61–81. http://dx.doi.org/10.1016/j.tra.2015.03.029

Bagočius, V.; Zavadskas, E. K.; Turskis, Z. 2014. Selecting a location for a liquefied natural gas terminal in the Eastern Baltic Sea, *Transport* 29(1): 69–74. http://dx.doi.org/10.3846/16484142.2014.897996

Barfod, M. B.; Salling, K. B. 2015. A new composite decision support framework for strategic and sustainable transport appraisals, *Transportation Research Part A: Policy and Practice* 72: 1–15. http://dx.doi.org/10.1016/j.tra.2014.12.001

Barros, C. P.; Wanke, P. 2015. An analysis of African airlines efficiency with two-stage TOPSIS and neural networks, *Journal of Air Transport Management* 44–45: 90–102. http://dx.doi.org/10.1016/j.jairtraman.2015.03.002

Bellman, R. E.; Zadeh, L. A. 1970. Decision-making in a fuzzy environment, *Management Science* 17(4): 141– 164. http://dx.doi.org/10.1287/mnsc.17.4.B141

Belton, V.; Stewart, T. J. 2002. *Multiple Criteria Decision Analysis: an Integrated Approach*. Springer. 372 p. http://dx.doi.org/10.1007/978-1-4615-1495-4

Bhuyan, P. K.; Nayak, M. S. 2013. A review on level of service analysis of urban streets, *Transport Reviews* 33(2): 219–238. http://dx.doi.org/10.1080/01441647.2013.779617

Bilişik, Ö. N.; Erdoğan, M.; Kaya, İ.; Baraçlı, H. 2013. A hybrid fuzzy methodology to evaluate customer satisfaction in a public transportation system for Istanbul, *Total Quality Management & Business Excellence* 24(9–10): 1141–1159. http://dx.doi.org/10.1080/14783363.2013.809942

Bouhana, A.; Fekih, A.; Abed, M.; Chabchoub, H. 2013. An integrated case-based reasoning approach for personalized itinerary search in multimodal transportation systems, *Transportation Research Part C: Emerging Technologies* 31: 30–50. http://dx.doi.org/10.1016/j.trc.2013.02.014

Brackstone, M.; McDonald, M. 1999. Car-following: a historical review, *Transportation Research Part F: Traffic Psychology and Behaviour* 2(4): 181–196. http://dx.doi.org/10.1016/S1369-8478(00)00005-X

Bramel, J.; Simchi-Levi, D. 1996. Probabilistic analyses and practical algorithms for the vehicle routing problem with time windows, *Operations Research* 44(3): 501–509. http://dx.doi.org/10.1287/opre.44.3.501

Brans, J. P.; Mareschal, B. 1992. PROMETHEE V: MCDM problems with segmentation constraints, *INFOR: Information Systems and Operational Research* 30(2): 85–96.

Brauers, W. K. M.; Zavadskas, E. K. 2010. Project management by MULTIMOORA as an instrument for transition economies, *Technological and Economic Development of Economy* 16(1): 5–24. http://dx.doi.org/10.3846/tede.2010.01

Brauers, W. K. M.; Zavadskas, E. K. 2006. The MOORA method and its application to privatization in a transition economy, *Control and Cybernetics* 35(2): 445–469.

Brauers, W. K. M.; Zavadskas, E. K.; Peldschus, F.; Turskis, Z. 2008. Multi-objective decision-making for road design, *Transport* 23(3): 183–193. http://dx.doi.org/10.3846/1648-4142.2008.23.183-193

Bruno, G.; Esposito, E.; Genovese, A. 2015. A model for aircraft evaluation to support strategic decisions, *Expert Systems with Applications* 42(13): 5580–5590. http://dx.doi.org/10.1016/j.eswa.2015.02.054

Cairns, S.; Harmer, C.; Hopkin, J.; Skippon, S. 2014. Sociological perspectives on travel and mobilities: a review, *Transportation Research Part A: Policy and Practice* 63: 107–117. http://dx.doi.org/10.1016/j.tra.2014.01.010

Campos, J.; De Rus, G. 2009. Some stylized facts about high-speed rail: a review of HSR experiences around the world, *Transport Policy* 16(1): 19–28. http://dx.doi.org/10.1016/j.tranpol.2009.02.008

Celik, E.; Aydin, N.; Gumus, A. T. 2014. A multiattribute customer satisfaction evaluation approach for rail transit network: a real case study for Istanbul, Turkey, *Transport Policy* 36: 283–293. http://dx.doi.org/10.1016/j.tranpol.2014.09.005

Celik, E.; Bilisik, O. N.; Erdogan, M.; Gumus, A. T.; Baracli, H. 2013. An integrated novel interval type-2 fuzzy MCDM method to improve customer satisfaction in public transportation for Istanbul, *Transportation Research Part E: Logistics and Transportation Review* 58: 28–51. http://dx.doi.org/10.1016/j.tre.2013.06.006

Chang, S. E.; Nojima, N. 2001. Measuring post-disaster transportation system performance: the 1995 Kobe earthquake in comparative perspective, *Transportation Research Part A: Policy and Practice* 35(6): 475–494. http://dx.doi.org/10.1016/S0965-8564(00)00003-3

Chang, Y.-H.; Shao, P.-C.; Chen, H. J. 2015. Performance evaluation of airport safety management systems in Taiwan, *Safety Science* 75: 72–86. http://dx.doi.org/10.1016/j.ssci.2014.12.006

Chang, Y.-H.; Yeh, C.-H. 2001. Evaluating airline competitiveness using multiattribute decision making, *Omega: The International Journal of Management Science* 29(5): 405–415. http://dx.doi.org/10.1016/S0305-0483(01)00032-9

Chao, C.-C.; Kao, K.-T. 2015. Selection of strategic cargo alliance by airlines, *Journal of Air Transport Management* 43: 29–36. http://dx.doi.org/10.1016/j.jairtraman.2015.01.004

Chen, K.-H.; Liao, C.-N.; Wu, L.-C. 2014a. A selection model to logistic centers based on TOPSIS and MCGP methods: the case of airline industry, *Journal of Applied Mathematics* 2014: 1–10. http://dx.doi.org/10.1155/2014/470128

Chen, S.; Leng, Y.; Mao, B.; Liu, S. 2014b. Integrated weight-based multi-criteria evaluation on transfer in large transport terminals: a case study of the Beijing south railway station, *Transportation Research Part A: Policy and Practice* 66: 13–26. http://dx.doi.org/10.1016/j.tra.2014.04.015

Cheng, C.-H.; Chang, J.-R.; Ho, T.-H.; Chen, A.-P. 2005. Evaluating the airline service quality by fuzzy OWA operators, in V. Torra, Y. Narukawa, S. Miyamoto (Eds.). *Modeling Decisions for Artificial Intelligence*, 77–88. http://dx.doi.org/10.1007/11526018_9

Chou, C.-C. 2012. Evaluating the quality of airport service using the fuzzy multi-criteria decision-making method: a case study of Taiwanese airports, *Expert Systems* 29(3): 246–260. http://dx.doi.org/10.1111/j.1468-0394.2010.00574.x

Chou, C.-C.; Ding, J.-F. 2013. Application of an integrated model with MCDM and IPA to evaluate the service quality of transshipment port, *Mathematical Problems in Engineering* 2013: 1–7. http://dx.doi.org/10.1155/2013/656757

Chou, C.-C.; Liu, L.-J.; Huang, S.-F.; Yih, J.-M.; Han, T.-C. 2011. An evaluation of airline service quality using the fuzzy weighted SERVQUAL method, *Applied Soft Computing* 11(2): 2117–2128. http://dx.doi.org/10.1016/j.asoc.2010.07.010

Deng, Y.; Xiong, J.; Fu, P. 2007. Airline safety evaluation based on fuzzy TOPSIS, in C. C. Yang, D. Zeng, M. Chau, K. Chang, Q. Yang, X. Cheng, J. Wang, F.-Y. Wang, H. Chen (Eds.). *Intelligence and Security Informatics*, 282–287. http://dx.doi.org/10.1007/978-3-540-71549-8_29

Denyer, D.; Tranfield, D. 2009. Producing a systematic review, in D. A. Buchanan, A. Bryman (Eds.). *The Sage Handbook of Organizational Research Methods*, 671–689.

Ding, J.-F.; Liang, G.-S. 2005. Using fuzzy MCDM to select partners of strategic alliances for liner shipping, *Information Sciences* 173(1–3): 197–225. http://dx.doi.org/10.1016/j.ins.2004.07.013

Eboli, L.; Mazzulla, G. 2011. A methodology for evaluating transit service quality based on subjective and objective measures from the passenger's point of view, *Transport Policy* 18(1): 172–181. http://dx.doi.org/10.1016/j.tranpol.2010.07.007

Fouladgar, M. M.; Yazdani-Chamzini, A.; Zavadskas, E. K. 2012. Risk evaluation of tunneling projects, *Archives of Civil and Mechanical Engineering* 12(1): 1–12. http://dx.doi.org/10.1016/j.acme.2012.03.008

Freitas, A. L. P. 2013. Assessing the quality of intercity road transportation of passengers: an exploratory study in Brazil, *Transportation Research Part A: Policy and Practice* 49: 379–392. http://dx.doi.org/10.1016/j.tra.2013.01.042

Friman, M.; Edvardsson, B.; Gärling, T. 2001. Frequency of negative critical incidents and satisfaction with public transport services. I., *Journal of Retailing and Consumer Services* 8(2): 95–104. http://dx.doi.org/10.1016/S0969-6989(00)00003-5

Gerçek, H.; Karpak, B.; Kılınçaslan, T. 2004. A multiple criteria approach for the evaluation of the rail transit networks in Istanbul, *Transportation* 31(2): 203–228. http://dx.doi.org/10.1023/B:PORT.0000016572.41816.d2

Givoni, M.; Dobruszkes, F. 2013. A Review of ex-post evidence for mode substitution and induced demand following the introduction of high-speed rail, *Transport Reviews* 33(6): 720–742. http://dx.doi.org/10.1080/01441647.2013.853707

Hanaoka, S.; Kunadhamraks, P. 2009. Multiple criteria and fuzzy based evaluation of logistics performance for intermodal transportation, *Journal of Advanced Transportation* 43(2): 123–153. http://dx.doi.org/10.1002/atr.5670430204

Hashemkhani Zolfani, S.; Esfahani, M. H.; Bitarafan, M.; Zavadskas, E. K.; Arefi, S. L. 2013. Developing a new hybrid MCDM method for selection of the optimal alternative of mechanical longitudinal ventilation of tunnel pollutants during automobile accidents, *Transport* 28(1): 89–96. http://dx.doi.org/10.3846/16484142.2013.782567

Hassan, M. N.; Hawas, Y. E.; Ahmed, K. 2013. A multi-dimensional framework for evaluating the transit service performance, *Transportation Research Part A: Policy and Practice* 50: 47–61. http://dx.doi.org/10.1016/j.tra.2013.01.041

He, T.; Ho, W.; Man, C. L. K.; Xu, X. 2012. A fuzzy AHP based integer linear programming model for the multi-criteria transshipment problem, *The International Journal of Logistics Management* 23(1): 159–179. http://dx.doi.org/10.1108/09574091211226975

Hickman, R.; Saxena, S.; Banister, D.; Ashiru, O. 2012. Examining transport futures with scenario analysis and MCA, *Transportation Research Part A: Policy and Practice* 46(3): 560–575. http://dx.doi.org/10.1016/j.tra.2011.11.006

Ho, C.; Mulley, C. 2015. Intra-household interactions in transport research: a review, *Transport Reviews* 35(1): 33–55. http://dx.doi.org/10.1080/01441647.2014.993745

Hsu, C.-C.; Liou, J. J. H. 2013. An outsourcing provider decision model for the airline industry, *Journal of Air Transport Management* 28: 40–46. http://dx.doi.org/10.1016/j.jairtraman.2012.12.009

Hsu, Y.-L.; Li, W.-C.; Chen, K.-W. 2010. Structuring critical success factors of airline safety management system using a hybrid model, *Transportation Research Part E: Logistics and Transportation Review* 46(2): 222–235. http://dx.doi.org/10.1016/j.tre.2009.08.005

Hwang, C.-L.; Masud, A. S. M.; Paidy, S. R.; Yoon, K. 1979. *Multiple Objective Decision Making – Methods and Applications: a State-of-the-Art Survey*. Springer. 358 p. http://dx.doi.org/10.1007/978-3-642-45511-7

Hwang, C.-L.; Yoon, K. 1981. *Multiple Attribute Decision Making: Methods and Applications a State-of-the-Art Survey*. Springer. 270 p. http://dx.doi.org/10.1007/978-3-642-48318-9

Ibarra-Rojas, O. J.; Delgado, F.; Giesen, R.; Muñoz, J. C. 2015. Planning, operation, and control of bus transport systems: a literature review, *Transportation Research Part B: Methodological* 77: 38–75. http://dx.doi.org/10.1016/j.trb.2015.03.002

John, A.; Yang, Z.; Riahi, R.; Wang, J. 2014. Application of a collaborative modelling and strategic fuzzy decision support system for selecting appropriate resilience strategies for seaport operations, *Journal of Traffic and Transportation Engineering (English Edition)* 1(3): 159–179. http://dx.doi.org/10.1016/s2095-7564(15)30101-x

Jones, S.; Tefe, M.; Appiah-Opoku, S. 2013. Proposed framework for sustainability screening of urban transport projects in developing countries: a case study of Accra, Ghana, *Transportation Research Part A: Policy and Practice* 49: 21–34. http://dx.doi.org/10.1016/j.tra.2013.01.003

Joumard, R.; Nicolas, J.-P. 2010. Transport project assessment methodology within the framework of sustainable development, *Ecological Indicators* 10(2): 136–142. http://dx.doi.org/10.1016/j.ecolind.2009.04.002

Kabir, G. 2015. Selection of hazardous industrial waste transportation firm using extended VIKOR method under fuzzy environment, *International Journal of Data Analysis Techniques and Strategies* 7(1): 40–58. http://dx.doi.org/10.1504/IJDATS.2015.067700

Kahraman, C. 2008. *Fuzzy Multi-Criteria Decision Making: Theory and Applications with Recent Developments*. Springer. 590 p. http://dx.doi.org/10.1007/978-0-387-76813-7

Kanninen, B. J. 1996. Intelligent transportation systems: an economic and environmental policy assessment, *Transportation Research Part A: Policy and Practice* 30(1): 1–10. http://dx.doi.org/10.1016/0965-8564(95)00014-3

Kartam, N.; Tzeng, G.-H.; Teng, J.-Y. 1993. Robust contingency plans for transportation investment planning, *IEEE Transactions on Systems, Man and Cybernetics* 23(1): 5–13. http://dx.doi.org/10.1109/21.214763

Kavaliauskas, P. 2008. A concept of sustainable development for regional land use planning: Lithuanian experience, *Technological and Economic Development of Economy* 14(1): 51–63. http://dx.doi.org/10.3846/2029-0187.2008.14.51-63

Kazançoğlu, Y.; Kazançoğlu, İ. 2013. Benchmarking service quality performance of airlines in Turkey, *Eskişehir Osmangazi Üniversitesi İktisadi ve İdari Bilimler Dergisi* 8(1): 59–91.

Keeney, R. L.; Raiffa, H. 1976. *Decision Analysis with Multiple Conflicting Objectives*. Wiley & Sons.

Keeney, R. L.; Raiffa, H.; Rajala, D. W. 1979. Decisions with multiple objectives: preferences and value trade-offs, *IEEE Transactions on Systems, Man and Cybernetics* 9(7): 403–403. http://dx.doi.org/10.1109/TSMC.1979.4310245

Keršulienė, V.; Zavadskas, E. K.; Turskis, Z. 2010. Selection of rational dispute resolution method by applying new stepwise weight assessment ratio analysis (SWARA), *Journal of Business Economics and Management* 11(2): 243–258. http://dx.doi.org/10.3846/jbem.2010.12

Kickert, W. J. M. 1979. *Fuzzy Theories on Decision Making: A Critical Review*. Springer. 182 p.

Köksalan, M.; Wallenius, J.; Zionts, S. 2011. *Multiple Criteria Decision Making: From Early History to the 21st Century*. World Scientific Publishing Company. 212 p.

Krylovas, A.; Zavadskas, E. K.; Kosareva, N.; Dadelo, S. 2014. New KEMIRA method for determining criteria priority and weights in solving MCDM problem, *International Journal of Information Technology & Decision Making* 13(6): 1119–1133. http://dx.doi.org/10.1142/S0219622014500825

Kuo, M.-S. 2011. A novel interval-valued fuzzy MCDM method for improving airlines' service quality in Chinese cross-strait airlines, *Transportation Research Part E: Logistics and Transportation Review* 47(6): 1177–1193. http://dx.doi.org/10.1016/j.tre.2011.05.007

Kuo, M.-S.; Liang, G.-S. 2011. Combining VIKOR with GRA techniques to evaluate service quality of airports under fuzzy environment, *Expert Systems with Applications* 38(3): 1304–1312. http://dx.doi.org/10.1016/j.eswa.2010.07.003

Lee, P. T.-W.; Lin, C.-W.; Shin, S.-H. 2012. A comparative study on financial positions of shipping companies in Taiwan and Korea using entropy and grey relation analysis, *Expert Systems with Applications* 39(5): 5649–5657. http://dx.doi.org/10.1016/j.eswa.2011.11.052

Li, Y.; Zhao, L.; Suo, J. 2014. Comprehensive assessment on sustainable development of highway transportation capacity based on entropy weight and TOPSIS, *Sustainability* 6(7): 4685–4693. http://dx.doi.org/10.3390/su6074685

Liou, J. J. H. 2012. Developing an integrated model for the selection of strategic alliance partners in the airline industry, *Knowledge-Based Systems* 28: 59–67. http://dx.doi.org/10.1016/j.knosys.2011.11.019

Liou, J. J. H. 2011. Variable consistency dominance-based rough set approach to formulate airline service strategies, *Applied Soft Computing* 11(5): 4011–4020. http://dx.doi.org/10.1016/j.asoc.2011.03.002

Liou, J. J. H.; Chuang, M.-L. 2010. Evaluating corporate image and reputation using fuzzy MCDM approach in airline market, *Quality & Quantity* 44(6): 1079–1091. http://dx.doi.org/10.1007/s11135-009-9259-2

Liou, J. J. H.; Hsu, C.-C.; Chen, Y.-S. 2014. Improving transportation service quality based on information fusion, *Transportation Research Part A: Policy and Practice* 67: 225–239. http://dx.doi.org/10.1016/j.tra.2014.07.007

Liou, J. J. H.; Tsai, C.-Y.; Lin, R.-H.; Tzeng, G.-H. 2011a. A modified VIKOR multiple-criteria decision method for improving domestic airlines service quality, *Journal of Air Transport Management* 17(2): 57–61. http://dx.doi.org/10.1016/j.jairtraman.2010.03.004

Liou, J. J. H.; Tzeng, G.-H.; Tsai, C.-Y.; Hsu, C.-C. 2011b. A hybrid ANP model in fuzzy environments for strategic alliance partner selection in the airline industry, *Applied Soft Computing* 11(4): 3515–3524. http://dx.doi.org/10.1016/j.asoc.2011.01.024

Liou, J. J. H.; Tzeng, G.-H. 2012. Comments on "Multiple criteria decision making (MCDM) methods in economics: an overview", *Technological and Economic Development of Economy* 18(4): 672–695. http://dx.doi.org/10.3846/20294913.2012.753489

Liou, J. J. H.; Tzeng, G.-H. 2007. A non-additive model for evaluating airline service quality, *Journal of Air Transport Management* 13(3): 131–138. http://dx.doi.org/10.1016/j.jairtraman.2006.12.002

Liou, J. J. H.; Tzeng, G.-H.; Chang, H.-C. 2007. Airline safety measurement using a hybrid model, *Journal of Air Transport Management* 13(4): 243–249. http://dx.doi.org/10.1016/j.jairtraman.2007.04.008

Lirn, T.-C.; Thanopoulou, H. A.; Beresford, A. K. C. 2003. Transhipment port selection and decision-making behaviour: analysing the Taiwanese case, *International Journal of Logistics Research and Applications: a Leading Journal of Supply Chain Management* 6(4): 229–244. http://dx.doi.org/10.1080/1367556032000162699O

Liu, C.-H.; Tzeng, G.-H.; Lee, M.-H.; Lee, P.-Y. 2013. Improving metro–airport connection service for tourism development: using hybrid MCDM models, *Tourism Management Perspectives* 6: 95–107. http://dx.doi.org/10.1016/j.tmp.2012.09.004

Lupo, T. 2015. Fuzzy ServPerf model combined with ELECTRE III to comparatively evaluate service quality of international airports in Sicily, *Journal of Air Transport Management* 42: 249–259. http://dx.doi.org/10.1016/j.jairtraman.2014.11.006

Lupo, T. 2013a. Handling stakeholder uncertain judgments in strategic transport service analyses, *Transport Policy* 29: 54–63. http://dx.doi.org/10.1016/j.tranpol.2013.04.002

Lupo, T. 2013b. Strategic analysis of transit service quality using fuzzy AHP methodology, *European Transport – Trasporti Europei* (53): 1–18.

MacCrimmon, K. R. 1968. *Decisionmaking among Multiple-Attribute Alternatives: a Survey and Consolidated Approach*. Memorandum RM-4823-ARPA. Prepared for Advanced Research Projects Agency. The RAND Corporation. 63 p. Available from Internet: http://www.rand.org/pubs/research_memoranda/RM4823.html

Mandic, D.; Jovanovic, P.; Bugarinovic, M. 2014. Two-phase model for multi-criteria project ranking: Serbian Railways case study, *Transport Policy* 36: 88–104. http://dx.doi.org/10.1016/j.tranpol.2014.08.002

Mardani, A.; Jusoh, A.; Nor, K.; Khalifah, Z.; Zakwan, N.; Valipour, A. 2015a. Multiple criteria decision-making techniques and their applications – a review of the literature from 2000 to 2014, *Economic Research – Ekonomska Istraživanja* 28(1): 516-571. http://dx.doi.org/10.1080/1331677X.2015.1075139

Mardani, A.; Jusoh, A.; Zavadskas, E. K. 2015b. Fuzzy multiple criteria decision-making techniques and applications: two decades review from 1994 to 2014, *Expert Systems with Applications* 42(8): 4126–4148. http://dx.doi.org/10.1016/j.eswa.2015.01.003

Mardani, A.; Jusoh, A.; Zavadskas, E. K.; Cavallaro, F.; Khalifah, Z. 2015c. Sustainable and renewable energy: an overview of the application of multiple criteria decision making techniques and approaches, *Sustainability* 7(10): 13947–13984. http://dx.doi.org/10.3390/su71013947

Mardani, A.; Jusoh, A.; Zavadskas, E. K.; Khalifah, Z.; Nor, K. 2015d. Application of multiple-criteria decision-making techniques and approaches to evaluating of service quality: a systematic review of the literature, *Journal of Business Economics and Management* 16(5): 1034–1068.

Mouter, N.; Annema, J. A.; Van Wee, B. 2013. Attitudes towards the role of cost–benefit analysis in the decision-making process for spatial-infrastructure projects: a Dutch case study, *Transportation Research Part A: Policy and Practice* 58: 1–14. http://dx.doi.org/10.1016/j.tra.2013.10.006

Munda, G. 1995. *Multicriteria Evaluation in a Fuzzy Environment: Theory and Applications in Ecological Economics*. Physica-Verlag Heidelberg. 255 p. http://dx.doi.org/10.1007/978-3-642-49997-5

Nejati, M.; Nejati, M.; Shafaei, A. 2009. Ranking airlines' service quality factors using a fuzzy approach: study of the Iranian society, *International Journal of Quality & Reliability Management* 26(3): 247–260. http://dx.doi.org/10.1108/02656710910936726

Nigim, K.; Munier, N.; Green, J. 2004. Pre-feasibility MCDM tools to aid communities in prioritizing local viable renewable energy sources, *Renewable Energy* 29(11): 1775–1791. http://dx.doi.org/10.1016/j.renene.2004.02.012

Onut, S.; Tuzkaya, U. R.; Torun, E. 2011. Selecting container port via a fuzzy ANP-based approach: a case study in the Marmara Region, Turkey, *Transport Policy* 18(1): 182–193. http://dx.doi.org/10.1016/j.tranpol.2010.08.001

Opricovic, S.; Tzeng, G.-H. 2004. Compromise solution by MCDM methods: a comparative analysis of VIKOR and TOPSIS, *European Journal of Operational Research* 156(2): 445–455. http://dx.doi.org/10.1016/S0377-2217(03)00020-1

Parkan, C. 2002. Measuring the operational performance of a public transit company, *International Journal of Operations & Production Management* 22(6): 693–720. http://dx.doi.org/10.1108/01443570210427695

Pelletier, M.-P.; Trépanier, M.; Morency, C. 2011. Smart card data use in public transit: a literature review, *Transportation Research Part C: Emerging Technologies* 19(4): 557–568. http://dx.doi.org/10.1016/j.trc.2010.12.003

Pérez, J. C.; Carrillo, M. H.; Montoya-Torres, J. R. 2015. Multi-criteria approaches for urban passenger transport systems: a literature review, *Annals of Operations Research* 226(1): 69–87. http://dx.doi.org/10.1007/s10479-014-1681-8

Podsakoff, P. M.; MacKenzie, S. B.; Bachrach, D. G.; Podsakoff, N. P. 2005. The influence of management journals in the 1980s and 1990s, *Strategic Management Journal* 26(5): 473–488. http://dx.doi.org/10.1002/smj.454

Podvezko, V.; Sivilevičius, H. 2013. The use of AHP and rank correlation methods for determining the significance of the interaction between the elements of a transport system having a strong influence on traffic safety, *Transport* 28(4): 389–403. http://dx.doi.org/10.3846/16484142.2013.866980

Postorino, M. N.; Praticò, F. G. 2012. An application of the Multi-Criteria Decision-Making analysis to a regional multi-airport system, *Research in Transportation Business & Management* 4: 44–52. http://dx.doi.org/10.1016/j.rtbm.2012.06.015

Ramani, T. L.; Quadrifoglio, L.; Zietsman, J. 2010. Accounting for nonlinearity in the MCDM approach for a transportation planning application, *IEEE Transactions on Engineering Management* 57(4): 702–710. http://dx.doi.org/10.1109/TEM.2009.2037743

Rezaei, J.; Fahim, P. B. M.; Tavasszy, L. 2014. Supplier selection in the airline retail industry using a funnel methodology: conjunctive screening method and fuzzy AHP, *Expert Systems with Applications* 41(18): 8165–8179. http://dx.doi.org/10.1016/j.eswa.2014.07.005

Roy, B. 1996. *Multicriteria Methodology for Decision Aiding*. Springer. 293 p. http://dx.doi.org/10.1007/978-1-4757-2500-1

Saaty, R. W. 2003. *Decision Making in Complex Environments: the Analytic Hierarchy Process (AHP) for Decision Making and the Analytic Network Process (ANP) for Decision Making with Dependence and Feedback*. Pittsburgh: Super Decisions. 122 p.

Saaty, T. L. 2005. *Theory and Applications of the Analytic Network Process: Decision Making with Benefits, Opportunities, Costs, and Risks*. 3rd edition. RWS Publications. 352 p.

Saaty, T. L. 1988. What is the analytic hierarchy process?, in G. Mitra, H. J. Greenberg, F. A. Lootsma, M. J. Rijkaert, H. J. Zimmermann (Eds.). *Mathematical Models for Decision Support*, 109–121. http://dx.doi.org/10.1007/978-3-642-83555-1_5

Saaty, T. L.; Vargas, L. G. 2013. *Decision Making with the Analytic Network Process: Economic, Political, Social and Technological Applications with Benefits, Opportunities, Costs and Risks*. 2nd edition. Springer. 363 p. http://dx.doi.org/10.1007/978-1-4614-7279-7

Sawadogo, M.; Anciaux, D. 2011. Intermodal transportation within the green supply chain: an approach based on ELECTRE method, *International Journal of Business Performance and Supply Chain Modelling* 3(1): 43–65. http://dx.doi.org/10.1504/IJBPSCM.2011.039973

Sevkli, M.; Oztekin, A.; Uysal, O.; Torlak, G.; Turkyilmaz, A.; Delen, D. 2012. Development of a fuzzy ANP based SWOT analysis for the airline industry in Turkey, *Expert Systems with Applications* 39(1): 14–24. http://dx.doi.org/10.1016/j.eswa.2011.06.047

Shiau, T.-A. 2013. Evaluating sustainable transport strategies for the counties of Taiwan based on their degree of urbanization, *Transport Policy* 30: 101–108. http://dx.doi.org/10.1016/j.tranpol.2013.09.001

Sohn, K. 2008. A systematic decision criterion for the elimination of useless overpasses, *Transportation Research Part A: Policy and Practice* 42(8): 1043–1055. http://dx.doi.org/10.1016/j.tra.2008.03.003

Tanadtang, P.; Park, D.; Hanaoka, S. 2005. Incorporating uncertain and incomplete subjective judgments into the evaluation procedure of transportation demand management alternatives, *Transportation* 32(6): 603–626. http://dx.doi.org/10.1007/s11116-005-0645-x

Teng, J.-Y.; Huang, W.-C.; Lin, M.-C. 2010. Systematic budget allocation for transportation construction projects: a case in Taiwan, *Transportation* 37(2): 331–361. http://dx.doi.org/10.1007/s11116-009-9239-3

Toosi, N. M.; Kohanali, R. A. 2011. The study of airline service quality in the Qeshm free zone by fuzzy logic, *The Journal of Mathematics and Computer Science* 2(1): 171–183.

Torlak, G.; Sevkli, M.; Sanal, M.; Zaim, S. 2011. Analyzing business competition by using fuzzy TOPSIS method: an example of Turkish domestic airline industry, *Expert Systems with Applications* 38(4): 3396–3406. http://dx.doi.org/10.1016/j.eswa.2010.08.125

Tranfield, D.; Denyer, D.; Smart, P. 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review, *British Journal of Management* 14(3): 207–222. http://dx.doi.org/10.1111/1467-8551.00375

Tsai, W.-H.; Chou, W.-C.; Leu, J.-D. 2011a. An effectiveness evaluation model for the web-based marketing of the airline industry, *Expert Systems with Applications* 38(12): 15499–15516. http://dx.doi.org/10.1016/j.eswa.2011.06.009

Tsai, W.-H.; Hsu, W.; Chou, W.-C. 2011b. A gap analysis model for improving airport service quality, *Total Quality Management & Business Excellence* 22(10): 1025–1040. http://dx.doi.org/10.1080/14783363.2011.611326

Tsai, W.-H.; Hsu, J.-L. 2008. Corporate social responsibility programs choice and costs assessment in the airline industry: a hybrid model, *Journal of Air Transport Management* 14(4): 188–196. http://dx.doi.org/10.1016/j.jairtraman.2008.04.003

Tsamboulas, D.; Yiotis, G.; Panou, K. 1999. Use of multicriteria methods for assessment of transport projects, *Journal of Transportation Engineering* 125(5): 407–414. http://dx.doi.org/10.1061/(ASCE)0733-947X(1999)125:5(407)

Tudela, A.; Akiki, N.; Cisternas, R. 2006. Comparing the output of cost benefit and multi-criteria analysis: an application to urban transport investments, *Transportation Research Part A: Policy and Practice* 40(5): 414–423. http://dx.doi.org/10.1016/j.tra.2005.08.002

Turskis, Z.; Zavadskas, E. K. 2010a. A novel method for multiple criteria analysis: grey additive ratio assessment (ARAS-G) method, *Informatica* 21(4): 597–610.

Turskis, Z.; Zavadskas, E. K. 2010b. A new fuzzy additive ratio assessment method (ARAS-F). Case study: The analysis of fuzzy multiple criteria in order to select the logistic centers location, *Transport* 25(4): 423–432. http://dx.doi.org/10.3846/transport.2010.52

Tzeng, G.-H.; Huang, J.-J. 2011. *Multiple Attribute Decision Making: Methods and Applications*. CRC Press. 352 p.

Wang, Q.; Wu, C.; Sun, Y. 2015. Evaluating corporate social responsibility of airlines using entropy weight and grey relation analysis, *Journal of Air Transport Management* 42: 55–62. http://dx.doi.org/10.1016/j.jairtraman.2014.08.003

Wang, T.-C.; Chang, T.-H. 2007. Application of TOPSIS in evaluating initial training aircraft under a fuzzy environment, *Expert Systems with Applications* 33(4): 870–880. http://dx.doi.org/10.1016/j.eswa.2006.07.003

Wang, Y.-J. 2014. The evaluation of financial performance for Taiwan container shipping companies by fuzzy TOPSIS, *Applied Soft Computing* 22: 28–35. http://dx.doi.org/10.1016/j.asoc.2014.03.021

Wang, Y.-J. 2009. Combining grey relation analysis with FMCGDM to evaluate financial performance of Taiwan container lines, *Expert Systems with Applications* 36(2): 2424–2432. http://dx.doi.org/10.1016/j.eswa.2007.12.027

Wang, Y.-J. 2008. Applying FMCDM to evaluate financial performance of domestic airlines in Taiwan, *Expert Systems with Applications* 34(3): 1837–1845. http://dx.doi.org/10.1016/j.eswa.2007.02.029

Wang, Y.-J.; Lee, H.-S.; Lin, K. 2003. Fuzzy TOPSIS for multicriteria decision-making, *International Mathematical Journal* 3(4): 367–379.

Wang, Y.; Yeo, G.-T.; Ng, A. K. Y. 2014. Choosing optimal bunkering ports for liner shipping companies: a hybrid Fuzzy-Delphi–TOPSIS approach, *Transport Policy* 35: 358–365. http://dx.doi.org/10.1016/j.tranpol.2014.04.009

Watterson, W. T. 1993. Linked simulation of land use and transportation systems: developments and experience in the Puget Sound region, *Transportation Research Part A: Policy and Practice* 27(3): 193–206. http://dx.doi.org/10.1016/0965-8564(93)90059-t

Wiecek, M. M.; Ehrgott, M.; Fadel, G.; Rui Figueira, J. 2008. Multiple criteria decision making for engineering, *Omega: The International Journal of Management Science* 36(3): 337–339. http://dx.doi.org/10.1016/j.omega.2006.10.001

Xu, Z. S.; Da, Q. L. 2002. The ordered weighted geometric averaging operators, *International Journal of Intelligent Systems* 17(7): 709–716. http://dx.doi.org/10.1002/int.10045

Yager, R. R. 1978. Fuzzy decision making including unequal objectives, *Fuzzy Sets and Systems* 1(2): 87–95. http://dx.doi.org/10.1016/0165-0114(78)90010-6

Yap, Y. H.; Gibson, H. M.; Waterson, B. J. 2013. An international review of roundabout capacity modelling, *Transport Reviews* 33(5): 593–616. http://dx.doi.org/10.1080/01441647.2013.830160

Yayla, A. Y.; Oztekin, A.; Gumus, A. T.; Gunasekaran, A. 2015. A hybrid data analytic methodology for 3PL transportation provider evaluation using fuzzy multi-criteria decision making, *International Journal of Production Research* 53(20): 6097–6113. http://dx.doi.org/10.1080/00207543.2015.1022266

Yazdani-Chamzini, A.; Yakhchali, S. H. 2012. Tunnel boring machine (TBM) selection using fuzzy multicriteria decision making methods, *Tunnelling and Underground Space Technology* 30: 194–204. http://dx.doi.org/10.1016/j.tust.2012.02.021

Yedla, S.; Shrestha, R. M. 2003. Multi-criteria approach for the selection of alternative options for environmentally sustainable transport system in Delhi, *Transportation Research Part A: Policy and Practice* 37(8): 717–729. http://dx.doi.org/10.1016/s0965-8564(03)00027-2

Yeh, C.-H.; Deng, H.; Chang, Y.-H. 2000. Fuzzy multicriteria analysis for performance evaluation of bus companies, *European Journal of Operational Research* 126(3): 459–473. http://dx.doi.org/10.1016/S0377-2217(99)00315-X

Yeo, G.-T.; Song, D.-W. 2006. An application of the hierarchical fuzzy process to container port competition: policy and strategic implications, *Transportation* 33(4): 409–422. http://dx.doi.org/10.1007/s11116-005-6000-4

Yeo, G.-T.; Wang, Y.; Chou, C.-C. 2013. Evaluating the competitiveness of the aerotropolises in East Asia, *Journal of Air Transport Management* 32: 24–31. http://dx.doi.org/10.1016/j.jairtraman.2013.06.004

Zak, J.; Jaszkiewicz, A.; Redmer, A. 2009. Multiple criteria optimization method for the vehicle assignment problem in a bus transportation company, *Journal of Advanced Transportation* 43(2): 203–243. http://dx.doi.org/10.1002/atr.5670430207

Zavadskas, E. K.; Turskis, Z. 2011. Multiple criteria decision making (MCDM) methods in economics: an overview, *Technological and Economic Development of Economy* 17(2): 397–427. http://dx.doi.org/10.3846/20294913.2011.593291

Zavadskas, E. K.; Turskis, Z. 2010. A new additive ratio assessment (ARAS) method in multicriteria decision-making, *Technological and Economic Development of Economy* 16(2): 159–172. http://dx.doi.org/10.3846/tede.2010.10

Zavadskas, E. K.; Turskis, Z. 2008. A new logarithmic normalization method in games theory, *Informatica* 19(2): 303–314.

Zavadskas, E. K.; Kaklauskas, A.; Šarka, V. 1994. The new method of multicriteria complex proportional assessment of projects, *Technological and Economic Development of Economy* 1(3): 131–139.

Zavadskas, E. K.; Turskis, Z.; Antucheviciene, J.; Zakarevicius, A. 2012. Optimization of weighted aggregated sum product assessment, *Elektronika ir Elektrotechnika – Electronics and Electrical Engineering* (6): 3–6. http://dx.doi.org/10.5755/j01.eee.122.6.1810

Zietsman, D.; Vanderschuren, M. 2014. Analytic hierarchy process assessment for potential multi-airport systems – the case of Cape Town, *Journal of Air Transport Management* 36: 41–49. http://dx.doi.org/10.1016/j.jairtraman.2013.12.004

Zimmermann, H.-J. 1978. Fuzzy programming and linear programming with several objective functions, *Fuzzy Sets and Systems* 1(1): 45–55. http://dx.doi.org/10.1016/0165-0114(78)90031-3

Zubaryeva, A.; Thiel, C.; Zaccarelli, N.; Barbone, E.; Mercier, A. 2012. Spatial multi-criteria assessment of potential lead markets for electrified vehicles in Europe, *Transportation Research Part A: Policy and Practice* 46(9): 1477–1489. http://dx.doi.org/10.1016/j.tra.2012.05.018