ISSN 1648-4142 / eISSN 1648-3480

TRANSPORT

2024
Volume 39
Issue 3
Pages 264–286
https://doi.org/10.3846/transport.2024.22915

*Review Article*

# MULTI-CRITERIA DECISION-MAKING FOR SOLVING TRANSPORT SUSTAINABILITY ISSUES: AN OVERVIEW

Indrė ŠIKŠNELYTĖ-BUTKIENĖ[1], Dalia ŠTREIMIKIENĖ[2],
Tomas BALEŽENTIS[3]✉, Leonardo AGNUSDEI[4]

[1,2,3] *Institute of Economics and Rural Development, Lithuanian Centre for Social Sciences, Vilnius, Lithuania*
[4] *Dept of Innovation Engineering, University of Salento, Lecce, Italy*

**Highlights:**

- the SALSA framework and the PRISMA statement are employed for analysis;
- studies are categorized according to the application area and technique applied;
- advantages and disadvantages of the most popular MCDM techniques are discussed;
- thematic areas for criteria of transport sustainability are proposed.

**Article History:**

- submitted 2 November 2022;
- resubmitted 21 December 2023;
- accepted 4 January 2024.

**Abstract.** With the recognition of the impact of the transport sector on climate change and human health, decision-makers are under the pressure to shape the transport sector in a more sustainable way, considering more sustainable options and technologies. Besides that, it is also important to ensure such aspects as affordability, security, reliability and convenience of transport services and the effective functioning of the whole system. Therefore, transport-related policy actions require not only an economic point of view, but also environmental and social actions. The article aims to overview the application of Multi-Criteria Decision-Making (MCDM) techniques for solving sustainability issues in the transport sector and to provide the main insights for methods and sustainability criteria selection. The Search, Appraisal, Synthesis and Analysis (SALSA) framework and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement were applied as the basis for the research. The detailed content analysis of studies is arranged according to the application areas and the methods applied. In order to increase the applicability of the performed analysis and to simplify the decision-making for further studies, the thematic areas for criteria selection are proposed, the most popular MCDM techniques alongside their advantages and disadvantages are briefly discussed.

**Keywords:** transport sustainability, sustainable development, multi-criteria, MCDM, SALSA, PRISMA.

✉Corresponding author. E-mail: *tomas.balezentis@ekvi.lt*

## Notations

AHP – analytical hierarchy process;
ANP – analytic network process;
ARAS – additive ratio assessment;
BMW – best worst method;
CBA – cost–benefit analysis;
COCOSO – combined compromise solution;
CODAS – combinative distance-based assessment;
COMET – characteristic objects method;
COPRAS – complex proportional assessment;
DEA – data envelopment analysis;
DEMATEL – decision-making trial and evaluation laboratory;
DSS – decision support system;
EDAS – evaluation based on distance from average solution;
ELECTRE – elimination and choice translating reality (in French: *ÉLimination Et Choix Traduisant la REalité*);
FST – fuzzy set theory;
FUCOM – full consistency method;
GHG – greenhouse gas;
GIS – geographic information system;
MABAC – multi-attribute border approximation area comparison;
MACBETH – measuring attractiveness by a category based evaluation technique;

MAJA – general equilibrium analysis (in Swedish: *Modell för Allmän JämviktsAnalys*);
MAMCA – multi-actor multi-criteria analysis;
MAVT – multi-attribute value theory;
MAUT – multi-attribute utility theory;
MCDM – multi-criteria decision-making;
MEW – multiplicative exponential weighting;
MIVES – integrated value model for sustainability assessment (in Spanish: *Modelo Integrado de Valor para una Evaluación Sostenible*);
MULTIMOORA – full multiplicative form of multi-objective optimization ratio analysis;
NAIADE – novel approach to imprecise assessment and decision environments;
PRISMA – preferred reporting items for systematic reviews and meta-analyses;
PROMETHEE – preference ranking organization method for enrichment evaluation;
TOPSIS – technique for order of preference by similarity to ideal solution;
SALSA – search, appraisal, synthesis and analysis;
SAW – simple additive weighting;
SIMUS – sequential interactive modelling for urban systems;
SMART – simple multi-attribute rating technique;
SMARTER – SMART exploiting ranks;
SUATAIN – sustainable transportation assessment;
SWARA – step-wise weight assessment ratio analysis;
TODIM – interactive MCDM (in Portuguese: *Tomada de Decisão Interativa Multicritério*);
VIKOR – multi-criteria optimization and compromise solution (in Serbian: *Višekriterijumska optimizacija I KOmpromisno Rešenje*);
WoS – *Clarivate Analytics Web of Science* database;
WSM – weighted sum method.

## 1. Introduction

More than a quarter of generated energy is consumed in the transport sector globally. In Europe, the share is even higher and stands at more than 30%. Accordingly, there is a need to predict and plan the flows of transport (Zhao *et al.* 2022). The externalities linked with energy generation and consumption are given special attention today in transport development decisions. In the last decade, serious attention was paid to technological progress and development of micro and shared mobility options. The development of the transport sector should be aligned with development of the urban systems (Zhang, Qi 2021). As transport sector is responsible for more than a quarter of the EU's GHG emissions and energy demand in transport has a trend to rise each year, the smart, competitive, safe, accessible, and affordable transport systems is among the main policy goals in EU. According to the statistical data, only the 3 countries of EU have a negative change in total GHG emissions from transport in the years 1990–2017. These countries are Liechtenstein (–20.7%), Sweden (–5%) and Lithuania (–2.7%). At the same time, the total GHG emissions in EU-28 have risen by 28% since 1990. The growth of pollution from the transport sector tends to increase each year, in 2018 an increase to 29% is observed (Eurostat 2024). The *European Green Deal* (EC 2019) has ambitions to reduce these emissions by 2050 by 90%. Nevertheless, transport development is not related to reducing pollution only. Many people of the world, especially in cities and living near major roads, are exposed to high transport noise due to road traffic, which is the biggest source of noise, followed by railway noise, air noise and industrial noise. Emissions from public and private transport are the main source of air pollution in cities. Therefore, health issues also become particularly important (Tang *et al.* 2020; Spadaro, Pirlone 2021). The aforementioned issues comprise only a fragment of the problematic that is relevant for decision-makers when ensuring the smooth operation of the everyday transport sector.

Some of the objectives relevant for the transport sector are conflicting among themselves (Brůhová Foltýnová *et al.* 2020; Delibasic 2022). This means that decision-makers must propose more environmentally friendly options, but at the same time offer consumers reliable, affordable, clean, and convenient solutions for transport systems development. Various studies emphasize the involvement of stakeholders for the sustainable transport planning (for example, Lee *et al.* 2021; Rześny-Cieplińska *et al.* 2021; Karolemeas *et al.* 2021). Amid these challenges, it has become very complicated to measure sustainable transport alternatives considering multidimensional needs of mobility providers, passengers, logistic companies, and decision-makers. The involvement of stakeholders can help to look at transport issues from different perspectives. Based on stakeholder input, a set of indicators to assess the sustainable development of transport systems in a specific context can be selected, reflecting the related challenges and priorities. In this way, the responsibility of stakeholders for the indicators obtained and their adoption and implementation can be increased. A comprehensive set of transport sustainability criteria and indicators can be used to monitor progress, develop policies, communicate, and address challenges. As many stakeholders are involved in the decision-making process of transport development, it forces decision-makers to look for new instruments and techniques to deal with the complex decision-making processes to evaluate the conflicting aspects.

MCDM allows to involve various stakeholders in the decision-making process and gives the possibility to successfully achieve the balance between multiple conflicting social, economic and environmental issues framing sustainability of transport systems. Due to their capabilities and convenience, different MCDM methods are increasingly used to solve various decision-making problems dealing with sustainable transport development. The article aims to overview the application of multi-criteria analysis for solving sustainability issues in the transport sector and to provide the main insights for sustainability criteria and MCDM techniques selection. The SALSA framework (Del Amo *et al.* 2018) and the PRISMA statement (Moher *et al.* 2010) were used as the basis for literature review and analysis. All the studies selected for the analysis were categorized according to the application area and technique used. 6 application areas were singled out, which are the following: sustainability assessment, transport policy, public transport planning, project selection, logistics, and methods selection studies. Also, the current study proposes the thematic areas for criteria selection in order follow the concept of sustainability in decision-making process, as well as briefly discusses the most common used MCDM approaches and their advantages and disadvantages for sustainable transport decision-making. The performed research can serve as a basis for further studies dealing with decision-making in transport and will simplify the process of criteria selection and will make it easier to select the most appropriate instrument for the assessment.

The article proceeds as follows. Section 1 – introduction. Section 2 presents the methodology of the research. Literature review is provided in Section 3, where an overview of studies in the field is provided and the detailed analysis of selected publications for the research is presented categorizing them by the application area and by the techniques applied. Section 4 outlines the thematic areas for criteria selection in order to consider all the dimensions of sustainability, discusses the most commonly applied MCDM approaches and briefly distinguishes their main advantages and disadvantages. Finally, in Section 5 the conclusions of the study are provided.

## 2. Methodology

A systematic scientific literature search and analysis was carried out following the SALSA framework. The SALSA proposes a methodological system, which allows to minimize subjectivity in the search and analysis processes and is recognized as preferable tool for literature identification, systemization, and evaluation (Del Amo *et al.* 2018). The framework allows to ensure the completeness and precision of the literature review methodology (Grant, Booth 2009). The completeness of the literature review is assured by the PRISMA statement (Moher *et al.* 2010). Table 1 provides the framework of this research:

The search of publications in the WoS database was carried out. The search was made on the 2 combinations of topics "sustainable transport" AND "multi-criteria decision-making" and "sustainable transport" AND "multi-criteria decision analysis" in all WoS categories. For the selection of articles, the recommendations of PRISMA statement were followed. The 2 inclusion criteria for the articles were determined: the relevant phrases must appear in the title, keywords, or abstract of the publication; also, article must be published in a scientific peer-reviewed journal. All non-research articles (review publications, editorial letters, not primary research) and non-English publications were excluded from the detailed analysis. The detailed content analysis was carried out for 130 publications. During the content analysis 24 articles were excluded, because the content of these articles did not correspond to the topic of this research. The logical scheme of the research is presented in Figure 1.

All the publications identified (172) were overviewed according to the main characteristics such as: publication year, WoS categories, institutions, countries, and journals. The detailed analysis of publications was made only for those publications (130), which met inclusion criteria selected. In the detailed analysis, all the selected publications were categorized into 6 categories by application area: transport policy studies, sustainability assessment studies, project selection studies, public transport planning studies, logistics studies and methods selection studies. The studies were assigned to a certain category depending on the main purpose of the study. It should be emphasized that this classification is based on the authors' subjective expertise and further research may offer different modifications of the proposed grouping. However, this does not have a significant impact on the final goal of this study, since the research conclusions are formed for all the analysed studies in general and criteria selection guidelines are presented for solving all tasks of the transport sector in general, leaving room for the interpretation of the specifics of the problem under analysis. Also, all the selected articles were categorized by the method applied.

## 3. Literature review

### 3.1. General trends

There has been a significant increase in articles dealing with transport sustainability issues over the last 2 decades. Also, it can be said that the trend of growth each year is more and more notable. There were more than 2000 publications on the topic "sustainable transport" found in the WoS database (considering publications that appeared in the period 1990–2020). Multi-criteria decision analysis is a very popular approach in different areas of decision-making. Also, it is one of the most popular tools to solve energy-related sustainability issues. Since 1990,

**Table 1.** The framework for the overview of MCDM for solving transport sustainability issues (source: created by the authors)

| Step | Search | Appraisal | Synthesis | Analysis |
|---|---|---|---|---|
| Actions | ▪ identification of keywords;<br>▪ database search | ▪ selection of articles (following the PRISMA statement) | ▪ data extraction;<br>▪ data categorization | ▪ data analysis;<br>▪ comparison of the results;<br>▪ conclusions of the research |

more than 2600 publications have been published on the topics "multi-criteria decision-making" or "multi-criteria decision analysis" in the WoS database (Figure 2). Significant growth in the number of studies, which apply MCDM techniques for the sustainable transport development issues in the last few years (Figure 3).

The highest number of publications that address the issues related to transport sustainability by means of the MCDM approaches fall into the subject areas (in WoS) of Environmental Sciences (58) and *Green & Sustainable Science & Technology* (54) categories. Less pronounced yet still numerous are the publications falling within the areas of *Environmental Studies* (37), *Transportation* (30) and *Transportation Science & Technology* (30) (Table 2). The *Vrije Universiteit Brussel* (9), *University of London* (8), *Vilnius Gediminas Technical University* (8) are the leading scientific institutions in the field (Table 3). This suggests that the European institutions currently dominate the debate on sustainable transportation from the viewpoint of the multi-criteria analysis.

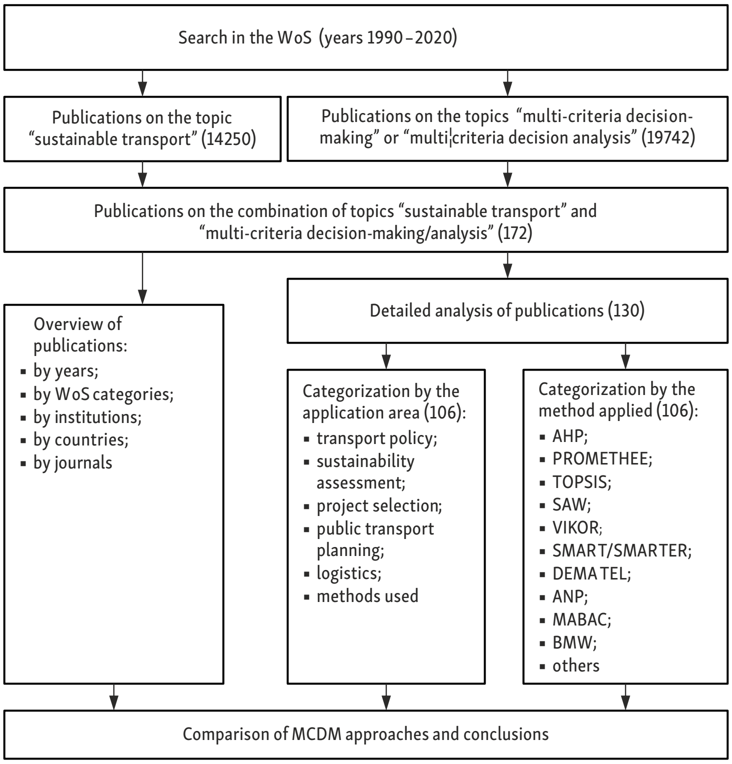



**Figure 1.** The organization of the research (source: created by the authors)

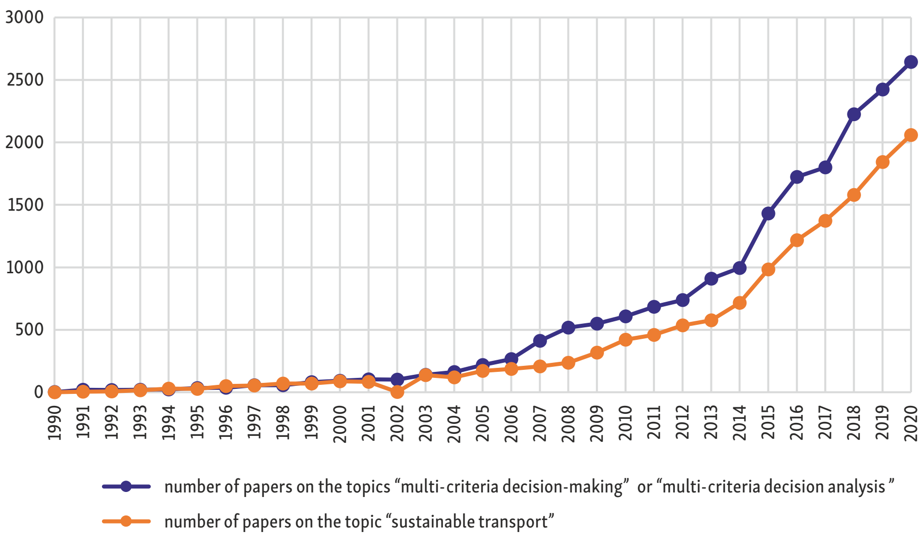



**Figure 2.** Articles on topics related to the sustainable transport and multi-criteria analysis (source: prepared by the authors based on data from the WoS database as of 16 April 2021)

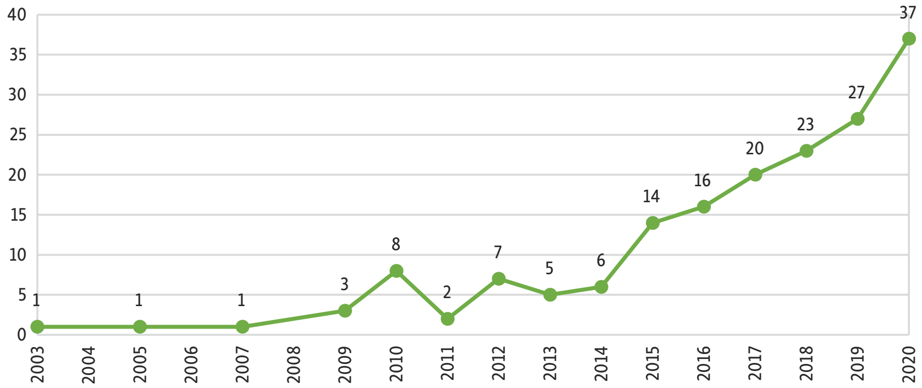
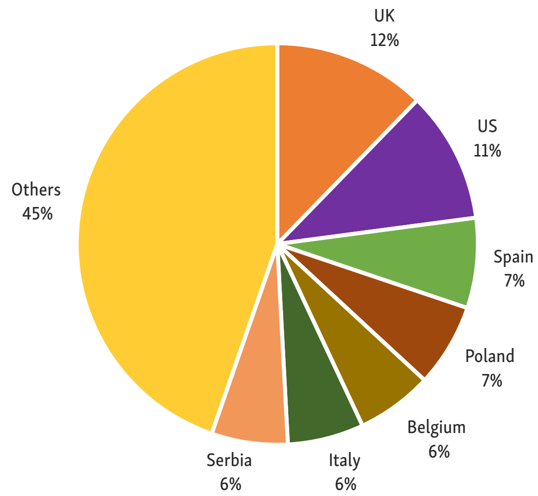



**Figure 3.** Articles on combination of topics "sustainable transport" and "multi-criteria decision-making/analysis" (source: prepared by the authors based on data from the WoS database as of 16 April 2021)

Researchers from the UK, US, Spain, Poland, Belgium, Italy, and Serbia are the most active in application of different MCDM methods for solving sustainable transport issues. Figure 4 shows the distribution of articles across the countries. Researchers from England have published 22 articles, those from the US – 19, those from Spain – 13, those from Poland – 12, and those from Belgium, Italy, and Serbia – 11 each. *Sustainability* and *Journal of Cleaner Production* are the most popular scientific journals publishing articles on analysed topics (Table 4).

### 3.2. Detailed analysis with focus on the methodological issues

Articles that met the inclusion criteria were selected for the detailed analysis. After the content analysis, 24 articles that do not completely correspond to the topic under analysis were eliminated. Finally, 106 publications were analysed with respect to the selected categories. 1st, the MCDM methods used for the analysis were identified in the retained articles. Figure 5 shows the range of MCDM methods that are used to address sustainable transport issues.




*Note*: The figure shows countries with more than 10 publications.

**Figure 4.** Distribution of the articles related to "sustainable transport" and "multi-criteria decision-making/analysis" across the countries (source: prepared by the authors based on data from the WoS database as of 16 April 2021)

**Table 2.** Distribution of the articles related to "sustainable transport" and "multi-criteria decision-making/analysis" across the subject areas (source: prepared by the authors based on data from the WoS database as of 16 April 2021)

| WoS category | Articles [count] | Articles [%] |
|---|---|---|
| Environmental sciences | 58 | 32.4 |
| Green & sustainable science & technology | 54 | 30.2 |
| Environmental studies | 37 | 20.7 |
| Transportation | 34 | 19 |
| Transportation science & technology | 30 | 16.8 |
| Economics | 19 | 10.6 |
| Energy & fuels | 16 | 8.9 |
| Engineering, environmental | 16 | 8.9 |

*Note*: the table shows categories, which have more than 10 publications.

**Table 3.** Distribution of the articles related to "sustainable transport" and "multi-criteria decision-making/analysis" across the research institutions (source: Prepared by the authors based on data from the WoS database as of 16 April 2021)

| Institution | Articles [count] | Articles [%] |
|---|---|---|
| Vrije Universiteit Brussel | 9 | 5 |
| University of London | 8 | 4.5 |
| Vilnius Gediminas Technical University | 8 | 4.5 |
| Budapest University of Technology Economics | 7 | 3.9 |
| Technical University of Denmark | 7 | 3.9 |
| University College London | 6 | 3.4 |
| University of Belgrade | 6 | 3.4 |

*Note*: the table shows institutions with more than 5 publications.

**Table 4.** Distribution of the articles related to "sustainable transport" and "multi-criteria decision-making/analysis" across the outlets (source: prepared by the authors based on data from the WoS database as of 16 April 2021)

| Journal | Articles[count] | Articles [%] |
|---|---|---|
| Sustainability | 26 | 14.5 |
| Journal of Cleaner Production | 11 | 6.2 |
| Transport | 7 | 3.9 |
| Transportation Research Part A: Policy and Practice | 6 | 3.4 |
| Transportation Research Procedia | 6 | 3.4 |

*Note*: The table shows journals with more than 5 publications.

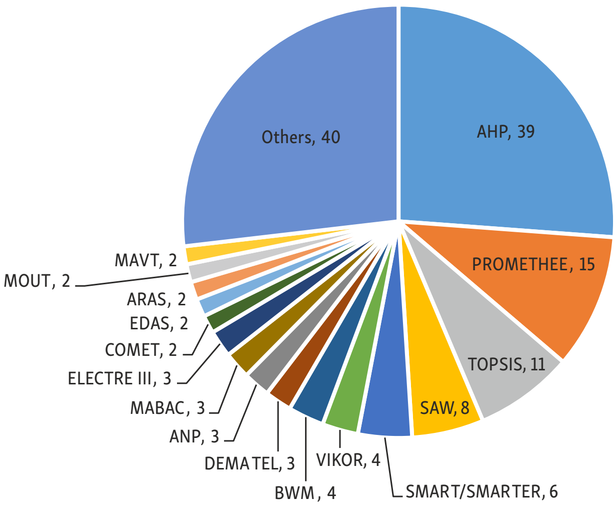



**Figure 5.** Manifestations of the MCDM methods in the articles on transport sustainability issues in 2005–2020 (number of studies) (source: created by the authors based on data from the WoS database as of 16 April 2021)

Different methods were applied for solving various transport sustainability issues. The most popular MCDM technique is AHP (Saaty 1980), which was applied in 39 studies. The high prevalence of applications of the latter technique can be explained by its versatility: it can be used as a tool or eliciting the weights through expert assessments in hybrid frameworks, and it can also be used for the utility measurement of multiple alternatives. This technique has also seen extensive development with extensions to the fuzzy sets and integration with various MCDM tools.

A group of methods show the frequencies that are lower compared to that of the AHP. This group includes the PROMETHEE (Brans, Mareschal 1992), the TOPSIS (Hwang, Yoon 1981), SAW (MacCrimmon 1968). These techniques represent the 3 approaches used for the MCDM, namely the value function represented by SAW, the reference point approach represented by TOPSIS, and the outranking approach represented by PROMETHEE. The problems in the domain of sustainable transportation can involve any of the discussed approaches to obtain the optimum solutions whether assuming compensatory or non-compensatory nature of the criteria.

Several studies applied the SMART (Edwards 1977), the SMARTER (Edwards, Barron 1994), VIKOR (Opricović 1998), the BWM (Rezaei 2015), DEMATEL (Gabus, Fontela 1972), ANP (Saaty 2001), MABAC (Pamučar, Ćirović 2015), ELECTRE (Roy 1968; Vallée, Zielniewicz 1994), the COMET (Sałabun 2015), the EDAS (Keshavarz Ghorabaee *et al.* 2015), ARAS (Zavadskas, Turskis 2010), MAVT (Fishburn 1967; Keeney, Raiffa 1993), MAUT (Keeney 1982; Raiffa 1997). Also, a lot of methods were used only once during the period analysed, these are: MAJA (Jacyna 2006), CODAS (Keshavarz Ghorabaee *et al.* 2016), COPRAS (Zavadskas *et al.* 1994), WSM (Zadeh 1963), TODIM (Gomes, Lima 1991), the MIVES (San-José Lombera, Cuadrado 2010), SIMUS (Munier 2016), FUCOM (Pamučar *et al.* 2018), MACBETH (Bana e Costa *et al.* 2012), MEW (Zanakis *et al.* 1998), SWARA (Keršulienė *et al.* 2010), COCOSO (Yazdani *et al.* 2019), MULTIMOORA (Brauers, Zavadskas 2010), NAIADE (Munda 1995). These techniques are rather diverse in their nature and requirements for the MCDM problems. They are also developed in different time periods with MAVT and MAUT belonging to the oldest generation of the MCDM methods and such methods as COCOSO and CODAS being developed much more recently.

Also, it should be noted, that a lot of supporting methods were combined with multi-criteria analysis, such as: CBA, FST, DEA, system dynamics simulation model, GIS, quality function deployment, MAMCA, prospect theory, goal programming, Monte Carlo simulation, Delphi method, pairwise comparison, swing weights, Kendall's coefficient of concordance, etc. The use of the additional techniques allows for involving a more comprehensive approach towards the problems under analysis. Indeed, it often allows to introduce additional axioms (e.g., economic ones) in the problem under analysis.

Also, during the content analysis, the articles were categorized by application area and by the used method. According to the results, the most popular is to use MCDM techniques for public transport planning and sustainability assessment issues. Table 5 provides categorization of studies by the used method and application area.

The detailed content analysis of scientific studies and the categorization by the methods and problem areas revealed that mostly MCDM methods were applied to solve questions related to sustainable transport planning and sustainability assessment. The AHP, PROMETHEE and MOUT techniques are commonly used to solve sustainable transport policy issues. The AHP method is commonly used in all application areas. The most popular MCDM techniques in transport sustainability assessment category were AHP, PROMETHEE and SAW. The predominant MCDM methods in the transport project selection category are AHP, TOPSIS, SMART/SMARTER and ANP. The widest range of methods applied were in the public transport planning category. AHP and TOPSIS can be distinguished as the dominant methods in this category.

**Table 5.** Categorization of the studies by used method and application area (source: created by the authors)

| Method | Transport policy | Sustainability assessment | Project selection | Public transport planning | Logistics | Methods selection |
|---|---|---|---|---|---|---|
| AHP | ■ Kramar *et al.* (2019);<br>■ Ullah *et al.* (2018);<br>■ Soria-Lara, Banister (2018);<br>■ Vermote *et al.* (2013);<br>■ Phdungsilp (2010) | ■ Zapolskytė *et al.* (2020);<br>■ Kumar, Anbanandam (2021);<br>■ Nowakowski, Król (2021);<br>■ Jasti, Ram (2019a, 2019b);<br>■ Alzouby *et al.* (2019);<br>■ Jones *et al.* (2013);<br>■ Oltean-Dumbrava *et al.* (2013);<br>■ Castillo, Pitfield (2010) | ■ Henke *et al.* (2020);<br>■ Broniewicz, Ogrodnik (2020);<br>■ Erdogan, Kaya (2019);<br>■ Salling *et al.* (2018);<br>■ Cadena, Magro (2015);<br>■ Barfod, Salling (2015) | ■ Ortega *et al.* (2020);<br>■ Bivina, Parida (2020);<br>■ Moslem *et al.* (2019);<br>■ Ghorbanzadeh *et al.* (2019);<br>■ Duleba, Moslem (2018);<br>■ Salling, Pryn (2015);<br>■ Pryn *et al.* (2015) | ■ Tadić *et al.* (2020);<br>■ Kumar, Anbanandam (2021);<br>■ Aljohani, Thompson (2019);<br>■ Semanjski, Gautama (2019);<br>■ Kijewska *et al.* (2018);<br>■ Awasthi *et al.* (2018);<br>■ Wang *et al.* (2017);<br>■ Macharis, Milan (2015) | ■ Cornet *et al.* (2018);<br>■ Barfod (2018);<br>■ Boisjoly, El-Geneidy (2017);<br>■ Macharis *et al.* (2012) |
| PROMETHEE | ■ Neofytou *et al.* (2020);<br>■ Ogrodnik (2020) | ■ Nowakowski and Król (2021);<br>■ Antanasijević *et al.* (2017);<br>■ Oltean-Dumbrava, Miah (2016);<br>■ Oltean-Dumbrava *et al.* (2016) | ■ Broniewicz, Ogrodnik (2020) | ■ Palevičius *et al.* (2016);<br>■ Bulckaen *et al.* (2016) | ■ Aljohani, Thompson (2019);<br>■ Wątróbski *et al.* (2017);<br>■ Macharis, Milan (2015);<br>■ Simongáti (2010) | ■ Huang *et al.* (2021);<br>■ Macharis *et al.* (2012) |
| TOPSIS | ■ Jakimavicius, Burinskiene (2009) | ■ Zapolskytė *et al.* (2020) | ■ Broniewicz, Ogrodnik (2020);<br>■ Erdogan, Kaya (2019) | ■ Al-Kaabi *et al.* (2020);<br>■ Shishegaran *et al.* (2020);<br>■ Palevičius *et al.* (2016) | ■ Yazdani *et al.* (2020);<br>■ Chen *et al.* (2019);<br>■ Wątróbski *et al.* (2017) | ■ Shekhovtsov *et al.* (2020) |
| SAW | ■ Jakimavicius, Burinskiene (2009) | ■ Zapolskytė *et al.* (2020);<br>■ Oltean-Dumbrava, Miah (2016);<br>■ Oltean-Dumbrava *et al.* (2013, 2016) | | ■ Palevičius *et al.* (2016);<br>■ Rybarczyk, Wu (2010) | ■ Simongáti (2010); | |
| SMART/ SMARTER | | ■ Oltean-Dumbrava *et al.* (2013) | ■ Salling *et al.* (2018);<br>■ Barfod, Salling (2015) | ■ Salling, Pryn (2015);<br>■ Pryn *et al.* (2015) | | ■ Barfod (2018) |
| VIKOR | | ■ Paul *et al.* (2020) | | ■ Ma *et al.* (2019) | ■ Bai *et al.* (2017) | ■ Shekhovtsov *et al.* (2020) |
| BWM | | ■ Paul *et al.* (2020) | ■ Van de Kaa *et al.* (2017) | ■ Ortega *et al.* (2020);<br>■ Moslem *et al.* (2020) | | |
| DEMATEL | | | ■ Yang *et al.* (2016) | ■ Ma *et al.* (2019) | ■ Yazdani *et al.* (2020);<br>■ Kijewska *et al.* (2018) | |
| ANP | ■ Sayyadi, Awasthi (2020) | | ■ Tadić *et al.* (2019);<br>■ Yang *et al.* (2016) | | | |
| MABAC | | | | ■ Blagojević *et al.* (2020);<br>■ Pamucar *et al.* (2020) | ■ Yazdani *et al.* (2020) | |
| ELECTRE III | | ■ Shmelev, Shmeleva (2018);<br>■ Oltean-Dumbrava, Miah (2016);<br>■ Oltean-Dumbrava *et al.* (2016) | | | | |
| COMET | | | | ■ Sałabun *et al.* (2019) | | ■ Shekhovtsov *et al.* (2020) |

*End of Table 5*

| Method | Transport policy | Sustainability assessment | Project selection | Public transport planning | Logistics | Methods selection |
|---|---|---|---|---|---|---|
| EDAS | | | | ■ Zagorskas, Turskis (2020b) | ■ Yazdani *et al.* (2020) | |
| ARAS | | | | ■ Zagorskas, Turskis (2020a, 2020b) | | |
| MOUT | ■ Höfer, Madlener (2020);<br>■ Casanovas-Rubio *et al.* (2020) | | | | | |
| MAVT | ■ Phdungsilp (2010) | ■ Ekener *et al.* (2018) | | | | |
| MAJA | ■ Cieśla *et al.* (2020) | | | | | |
| CODAS | | | | | ■ Yazdani *et al.* (2020) | |
| COPRAS | | ■ Zapolskytė *et al.* (2020) | | | | |
| WSM | | ■ Oltean-Dumbrava *et al.* (2013) | | | | |
| TODIM | | | ■ Mohagheghi *et al.* (2017) | | | |
| MIVES | | ■ Oses *et al.* (2017) | | | | |
| SIMUS | | | | ■ Stoilova *et al.* (2020) | | |
| FUCOM | | | | ■ Pamucar *et al.* (2020) | | |
| MACBETH | | | ■ Marleau Donais *et al.* (2019) | | | |
| MEW | | | | ■ Zagorskas, Turskis (2020a) | | |
| SWARA | | | | ■ Zagorskas, Turskis (2020a) | | |
| COCOSO | | | | ■ Blagojević *et al.* (2020) | | |
| MULTIMOORA | | | ■ Turskis *et al.* (2019) | | | |
| NAIADE | ■ Corral, Hernandez (2017) | | | | | |
| Other | ■ Le Boennec *et al.* (2019);<br>■ Hickman *et al.* (2012);<br>■ Pettit *et al.* (2011) | ■ Ribeiro *et al.* (2020);<br>■ Shmelev, Shmeleva (2018);<br>■ Awad-Núñez *et al.* (2015);<br>■ Azapagic *et al.* (2013) | ■ Krajangsri, Pongpeng (2019);<br>■ Keshkamat *et al.* (2009) | ■ Yang *et al.* (2020);<br>■ Pamucar *et al.* (2020);<br>■ Sharav *et al.* (2018);<br>■ Mukherjee (2017);<br>■ Chen *et al.* (2017);<br>■ Josimović *et al.* (2016);<br>■ Schmale *et al.* (2015) | ■ Lebeau *et al.* (2018);<br>■ Bandeira *et al.* (2018);<br>■ Feitó-Cespón *et al.* (2017);<br>■ Bouhana *et al.* (2015) | ■ Nguyen *et al.* (2020);<br>■ Barradale, Cornet (2018);<br>■ Vo *et al.* (2017);<br>■ Dimitriou *et al.* (2016);<br>■ Ward *et al.* (2016);<br>■ Griškevičiūtė-Gečienė (2010) |

The predominant MCDM techniques in the logistics category are AHP, PROMETHEE and TOPSIS. The articles in methods selection category mostly propose to apply AHP or PROMETHEE techniques. Also, the biggest number of unidentified methods was found in the articles assigned to this category. The percentage distribution of MCDM techniques in each application area is provided in Table 6. Table 7 shows the popularity of methods by application area.

### 3.2.1. MCDM for solving transport policy issues

Although different studies use quite a wide range of methods, almost one 3rd of studies applied AHP approach for the ranking the alternatives. The studies assigned to this category are focused on sustainable decision-making in the transport sector and are mostly dedicated to stakeholders to assist them in planning.

A part of the research in this category is focused on sustainable urban planning issues. Cieśla *et al.* (2020) pre-

**Table 6.** The distribution of MCDM techniques by application areas [%] (source: created by the authors)

| Method | Transport policy | Sustainability assessment | Project selection | Public transport planning | Logistics | Methods selection |
|---|---|---|---|---|---|---|
| AHP | 28 | 28 | 30 | 18 | 32 | 25 |
| PROMETHEE | 11 | 13 | 5 | 5 | 16 | 13 |
| TOPSIS | 6 | 3 | 10 | 8 | 12 | 6 |
| SAW | 6 | 13 | | 5 | 4 | |
| SMART/SMARTER | | 3 | 10 | 5 | | 6 |
| VIKOR | | 3 | | 3 | 4 | 6 |
| BWM | | 3 | 5 | 5 | | |
| DEMATEL | | | 5 | 3 | 4 | |
| ANP | 6 | | 10 | | | |
| MABAC | | | | 5 | 4 | |
| ELECTRE III | | 9 | | | | |
| COMET | | | | 3 | | 6 |
| EDAS | | | | 3 | 4 | |
| ARAS | | | | 5 | | |
| MOUT | 11 | | | | | |
| MAVT | 6 | 3 | | | | |
| MAJA | 6 | | | | | |
| CODAS | | | | | 4 | |
| COPRAS | | 3 | | | | |
| WSM | | 3 | | | | |
| TODIM | | | 5 | | | |
| MIVES | | 3 | | | | |
| SIMUS | | | | 3 | | |
| FUCOM | | | | 3 | | |
| MACBETH | | | 5 | | | |
| MEW | | | | 3 | | |
| SWARA | | | | 3 | | |
| COCOSO | | | | 3 | | |
| MULTIMOORA | | | 5 | | | |
| NAIADE | 6 | | | | | |
| Other | 17 | 13 | 10 | 18 | 16 | 38 |
| Total [%] | 100 | 100 | 100 | 100 | 100 | 100 |

sented a model for the transport planning in metropolitans. The proposed model includes such indicators as: ecological aspects, transport safety, financial and qualitative aspects. Kramar *et al.* (2019) presented a holistic approach for transport planning in urban areas. The approach is based on the AHP method and is oriented towards sustainable policy targets implementation. The methodology is designed for strategic planning. Jakimavičius & Burinskienė (2009) presented a framework for the analysis and ranking of transportation zones in a capital of Lithuania – Vilnius. The ranking is based on and a GIS and MCDM TOPSIS and SAW techniques. Le Boennec *et al.* (2019) evaluated fifty innovative mobility options in low-density French areas. The authors proposed a decision tool for local authorities in order to help implement sustainable transport policy. Vermote *et al.* (2013) combined the multi-actor multi-criteria assessment and AHP technique to prepare a decision-making tool for the regional freight route network planning in the Flanders region (Belgium). The study evaluates 4 alternatives (freight ring ways) according to the preferences of the different stakeholders. According to the results, transport companies seek for improved access, whereas municipalities and the like bodies as well as residents focus on traffic safety and good living conditions. Casanovas-Rubio *et al.* (2020) presented a tool for decision-making, which measures the impact of construction work on mobility. The tool is based on MAUT approach and could serve for the construction planners and for local authorities. The authors presented a decision-making framework for Barcelona (Spain).

The other part of the studies is focused on the implementation of policy goals. Neofytou *et al.* (2020) measured a number of indicators describing gains in energy efficiency for the Greek transport sector. The authors applied PROMETHEE II approach for the ranking of actions towards achieving significant reduction of GHG emissions in country energy system. The study shows that energy efficiency measures in building sector are more effective than in transport. Höfer & Madlener (2020) assessed 4 energy transition scenarios by ranking them by MOUT approach.

**Table 7.** The distribution of application areas by the MCDM techniques [%] (source: created by the authors)

| Method | Transport policy | Sustainability assessment | Project selection | Public transport planning | Logistics | Methods selection |
|---|---|---|---|---|---|---|
| AHP | 13 | 23 | 15 | 18 | 21 | 10 |
| PROMETHEE | 13 | 27 | 7 | 13 | 27 | 13 |
| TOPSIS | 9 | 9 | 18 | 27 | 27 | 9 |
| SAW | 13 | 50 | 0 | 25 | 13 | |
| SMART/SMARTER | | 17 | 33 | 33 | 0 | 17 |
| VIKOR | | 25 | | 25 | 25 | 25 |
| BWM | | 25 | 25 | 50 | 0 | |
| DEMATEL | | | 33 | 33 | 33 | |
| ANP | 33 | | 67 | | | |
| MABAC | | | | 67 | 33 | |
| ELECTRE III | | 100 | | | | |
| COMET | | | | 50 | | 50 |
| EDAS | | | | 50 | 50 | |
| ARAS | | | | 100 | | |
| MOUT | 100 | | | | | |
| MAVT | 50 | 50 | | | | |
| MAJA | 100 | | | | | |
| CODAS | | | | | 100 | |
| COPRAS | | 100 | | | | |
| WSM | | 100 | | | | |
| TODIM | | | 100 | | | |
| MIVES | | 100 | | | | |
| SIMUS | | | | 100 | | |
| FUCOM | | | | 100 | | |
| MACBETH | | | 100 | | | |
| MEW | | | | 100 | | |
| SWARA | | | | 100 | | |
| CoCoSo | | | | 10 | | |
| MULTIMOORA | | | 100 | | | |
| NAIADE | 100 | | | | | |
| Other | 12 | 15 | 8 | 27 | 15 | 23 |

The constructed decision model and methodology was applied in the whole energy sector (including transport), but could be easily applied to solve sustainable transition in one sector also. Sayyadi & Awasthi (2020) evaluated 5 transportation policies scenarios by using system dynamics simulation model and multi-criteria ANP method. According to the results, the trip sharing policy would be the most sustainable option according to the criteria selected. Ullah *et al.* (2018) evaluated gaseous alternatives for the Pakistan road transport sector. The authors applied the AHP method for ranking the alternatives. It was found that compressed natural gas is the most preferable fuel alternative. The created decision framework can be used for the policy planning in seeking the sustainable transport sector development in the country. Corral & Hernandez (2017) used NAIADE approach for the sustainable transport policy planning in Canary Islands (Spain). The main attention in the proposed DSS was paid to citizen participation and transparency. According to the authors, the involvement of various stakeholders to planning process is the main direction of sustainable planning. Phdungsilp (2010) modelled possible energy policy scenarios to implement low-carbon urban development in Bangkok. It has been found that the transport sector is the main contributor to low carbon city development. A shift from private cars to public transport systems has the big potential to significantly reduce carbon emissions and energy demand in the city. Soria-Lara & Banister (2018) proposed a methodological framework for the determination of sustainable transport futures. The transport sector in a region of Spain has been used for a case study and AHP technique was applied for calculations. Ogrodnik (2020) applied PROMETHEE for the analysis of Polish cities and their compliance with the smart city indicators. The analysis takes into account 43 indicators that reflect the concept of smart city.

#### 3.2.2. MCDM for transport sustainability assessment

The issues addressed in this category are from various areas related to infrastructure development, transport services, sustainability assessment of existing infrastructure projects, sustainability of all transport sector of a city or country.

The biggest part of the studies dealt with sustainable infrastructure development. Zapolskytė *et al.* (2020) applied 4 MCDM methods (AHP, TOPSIS, SAW and COPRAS) for the sustainability assessment of infrastructure developed and transport services in Vilnius (Lithuani). According to the results, there is a link between the distance from site to the city centre. Alzouby *et al.* (2019) analysed accessibility issues of disabled people to necessary services in a city of Jordan. The MCDM AHP technique was applied for the calculations. The proposed assessment methodology could serve the local authorities and city planners in the future transport and whole urban system development. Jones *et al.* (2013) introduced a framework for the sustainability measurement of urban transport projects. The framework is designed to monitor transport projects in developing countries and to reflect local issues. The AHP approach is applied for obtaining utility scores. The article provides a case study in the Accra city (Ghana). The framework can be easily adapted to other cities in developing countries. Oltean-Dumbrava & Miah (2016) assessed thirteen roadside noise barriers by applying SAW, PROMETHEE and ELECTRE III methods. The results of the assessment can be of use for the city and road planners. Also, the proposed methodology could be applied for future research to assess new types of barriers and to select the best one. In another study by Oltean-Dumbrava *et al.* (2016) the same 3 methods were used for the sustainability evaluation of devices for transport noise reduction. In the other study by Oltean-Dumbrava *et al.* (2013), authors applied 4 MCDM techniques (SAW, WSM, AHP and SMART) for the creation of tool, which allows to make sustainable decisions in reducing transport noise.

A quite significant proportion of studies focus on sustainability assessment of the city- or country-level transportation systems. Jasti & Ram (2019b) assessed sustainability of public transport system in a city of India. In the latter case, the AHP was utilized and 29 indicators were chosen to reflect the case study of the city. In the other study by Jasti & Ram (2019a) the same MCDM technique was applied for the sustainability assessment of metro rail system in Mumbai (India). Oses *et al.* (2017) created a sustainability index for transport assessment in the San Sebastian (Spain). The MIVES technique was applied for the calculations. The index could be adopted for transport system sustainability assessment in various cities. Shmelev & Shmeleva (2018) evaluated 57 cities in the World in terms of smart city and sustainability dimensions. The set of indicators used consists of 20 indicators, including indicators reflecting public transport, mobility and cycling conditions in the city. Antanasijević *et al.* (2017) applied MCDM analysis for the evaluation of sustainability performance in European countries. The authors ranked Europe countries by using PROMETHEE technique. Although the performance was assessed not only in transport, indicators reflecting the transport sector were involved in the assessment. Castillo & Pitfield (2010) presented a methodological framework for the identification and selection of indicators for sustainable transport development. The AHP technique was applied for the calculations.

Also, there are studies directly related to the use of vehicles. Nowakowski & Król (2021) applied 2 MCDM techniques (AHP and PROMETHEE) for the measurement of influence of end-of-life tires on transportation cost and exhausts emissions of vehicle. Ekener *et al.* (2018) proposed a sustainability assessment methodology, which is based on life cycle assessment and applied the methodology for evaluation of transportation fuels (fossil based and biomass based). According to authors, evaluation results mostly depend upon the view and values held by the decision-maker.

The framework for the sustainability assessment of transportation service providers by Paul *et al.* (2020) integrates BMW and VIKOR methods. The study considers 4 dimensions of transport sustainability such as economic, social, environmental and operational aspects of transport service sustainability.

### 3.2.3. MCDM for transport project selection

The issues addressed in this category are related to various transport questions. A part of the questions is related to selection of the best option for investments. Henke *et al.* (2020) presented and applied a sustainable evaluation system for investments in the transport sector. The proposed system is based on AHP technique and CBA. Mohagheghi *et al.* (2017) presented an approach for the assessment and ranking of investment projects under uncertainty. The approach is based on TODIM technique.

Other studies address issues related to transport infrastructure development. Broniewicz & Ogrodnik (2020) overviewed several MCDM techniques for transport project selection and applied AHP, TOPSIS and PROMETHEE for selection of the alternative of the expressway section in Poland. Tadić *et al.* (2019) applied ANP approach for the sustainable planning of intermodal terminals. The proposed framework takes into account the requirements of various stakeholders and the concept of sustainable development. Turskis *et al.* (2019) proposed a hybrid MCDM model for the most appropriate 2nd runway of the Vilnius airport (Lithuania) selection. The authors solved the question by applying MULTIMOORA method. Marleau Donais *et al.* (2019) prepared a framework for the identification and selection of streets that need to be redesigned in a city of Canada. The presented framework pays attention to the concept of sustainability and sustainable planning. Also, a lot of attention was paid to communication and collaboration between professionals in decision-making. The MCDM method MACBETH is applied for the calculations. In order to present a framework for the sustainable transport infrastructure project selection Yang *et al.* (2016) combined 2 MCDM techniques (DEMATEL and ANP) and goal programing. The proposed tool allows to involve environmental costs into decision-making process and to plan transport infrastructure in more sustainable way. Barfod & Salling (2015) presented a framework for the sustainable evaluation of transport infrastructure projects. The introduced framework is based on the combination of

CBA and MCDA (AHP, SMART, SMARTER). The framework allows addressing the decision questions from a sustainable, an economic and a strategic point of view at the same time. The article presents a case dealing with the most preferable alternative for a new fixed link between Sweden and Denmark. Salling *et al.* (2018) analysed the Danish research project, which proposed a framework for sustainable transport planning. In order to show the universality of the framework the authors applied SMART and AHP methods for 3 different transport infrastructure projects.

Erdogan and Kaya (2019) presented a prioritization model for the failure analysis for public transport systems. The model is based on 2 multi-criteria techniques. AHP was used to determine the criteria weights, TOPSIS was applied for final ranking. Van de Kaa *et al.* (2017) applied BWM method for the analysis of 2 electric vehicles alternatives (hydrogen fuel cell and battery). The authors tried to determine which factors make the biggest influence for the future development of one or another technology. It was found that the main factors for success are technological superiority, compatibility, brand credibility and reputation. According to the results, battery powered electric vehicles have a better possibility to be widely developed. In the study by Cadena & Magro (2015), the proposed model sought to reduce imprecision and subjectivity for the setting sustainability criteria weights in MCDM models. The AHP approach is used for the determination of criteria weights. The study presents a methodology and suggests setting criteria weights based not only on experts' opinion, but also on the importance of the sustainability criteria regarding the social and geographical context of the project.

#### 3.2.4. MCDM for public transport planning

The largest number of articles have been assigned to the public transport planning category, and the range of methods applied is the widest too.

A part of the research addresses issues related to mobility choices. Moslem *et al.* (2020) applied BWM for identification of mobility choice changes in the face of COVID-19 pandemic. The authors performed a case study in Catania and Palermo cities (Italy). The results showed a tendency to walk for short distances and a decrease in the use of public transport services during the pandemic. Bulckaen *et al.* (2016) applied PROMETHEE method and multi-actor multi-criteria analysis for the evaluation of mobility choices. The proposed framework pays main attention to the synergies of stakeholder's preferences and sustainability issues. The authors applied the framework for the 3 case studies. The results show that stakeholders have preferences closely related to sustainable choices. For the transport planning issues, Ortega *et al.* (2020) combined the BMW and AHP technique. The authors applied the system developed to plan Park and Ride locations in the city. Also, it is worth mentioning, that "accessibility of public transportation" is the most significant aspect in selecting park and ride locations. Bivina & Parida (2020) applied AHP for the identification of the main priorities of pedestrians in city of India. It was found that safety of walking environment is the most important factor for the pedestrians.

The other part of the studies solves problems related to different alternatives of public transport (railways, bicycles, roads). Al-Kaabi *et al.* (2020) introduced a framework for the assessment of the sustainability of roadway intersections. The presented framework is oriented towards road-users, the sustainability indicators selected presented the traditional concept of sustainability. The framework was applied for assessment of sustainability of 4 intersections in UAE. The results indicated that traffic volume had a significant impact on intersection sustainability ranking, while the effect of operational speed was insignificant. The assessment is based on TOPSIS method. Shishegaran *et al.* (2020) applied the TOPSIS method for the sustainability assessment and ranking of 6 scenarios for the improvement of traffic condition in one of the interchanges in Tehran.

Blagojević *et al.* (2020) proposed a new model for the safety assessment of railway traffic based on MABAC. The authors selected eleven criteria to reflect sustainability issues of railway traffic. The model was applied for evaluation of safety level in railways of Bosnia and Herzegovina. Stoilova *et al.* (2020) presented a methodology, which allowed to evaluate and classify the railway network performance. The study provided an assessment of the Trans-European Transport Network corridor and ranked countries by applying SIMUS method.

Zagorskas & Turskis (2020b) presented a tool to set the development and renewal priorities of bicycle pathways. The model is based on ARAS approach and is integrated in GIS. Rybarczyk & Wu (2010) applied SAW and a GIS for the bicycle facility planning in the Milwaukee city (US). Ma *et al.* (2019) assessed a quality of bike sharing service in a city of China. The biggest attention was paid for the criteria selection in the assessment. The study paid attention to different groups of stakeholders (local authority, platform operators, users and bike association). The authors applied a hybrid model in combining DEMATEL and VIKOR for the calculations. In order to implement sustainable city planning Sałabun *et al.* (2019) applied COMET for the selection of the most acceptable bicycle option. The proposed evaluation system allows to assess options under conditions of incomplete knowledge.

Pamucar *et al.* (2020) proposed a new decision-making model based on FUCOM-D'Bonferroni for the demand management of transportation. The model is designed to help transport planners and local authorities to manage urban mobility systems. The validity of the model is proved in comparison with others MCDM methods. The study presented an application of the method for the planning transportation system in the Istanbul (Turkey). Pryn *et al.* (2015) presented the SUSTAIN DSS model, which seeks to help decision-makers to evaluate transport projects in a sustainable way. AHP and SMARTER techniques are applied for calculations. The proposed framework was tested in making decision for planning connection crossing construction in the Frederikssund (Denmark). The same framework was applied to solve congestion problem of a bridge in a city of Frederikssund by Salling & Pryn (2015). Zagorskas & Turskis (2020a) applied several different MCDM techniques in order to create a hybrid model for the determine the best pedestrian bridge locations. The novel model combines MEW, EDAS, ARAS, SWARA MCDM techniques and is based on GIS. The proposed model could serve for the local authorities and city planners as a decision support tool. Palevičius *et al.* (2016) analysed 49 shopping centres' parking lots in the Vilnius (Lithuania) and tried to evaluate how this could contribute to reducing the problem of car parking for the population in the city. The authors introduced a framework and applied 3 MCDM methods (SAW, PROMETHEE and TOPSIS).

It is also necessary to highlight that many studies pay a big attention to integrating stakeholders into the evaluation process. In order to find consensus among various stakeholders for sustainable transport development Moslem *et al.* (2019) applied the AHP. The authors proposed an evaluation procedure and applied it for addressing the sustainable planning issues in a city of Turkey. It was argued that following such a procedure may make the decision-makers more aware of the different interests among the stakeholders and can pay more attention to meeting the different requirements. Ghorbanzadeh *et al.* (2019) created a decision support model sustainable public transport planning by applying AHP method. The model is oriented to find consensus among different groups of stakeholders. The authors applied the model for a case study in a city of Turkey. Duleba & Moslem (2018) present a decision-making support model for the development of public transport, which considers preferences of stakeholder groups. The model uses AHP technique. The proposed model was applied to find sustainable transport development solution in the Mersin city (Turkey).

### 3.2.5. MCDM for solving problems in logistics

Studies on freight planning are common for this category. The principles of sustainability are incorporated in the analysis. Mostly, the questions in this category are related to sustainable freight planning. Tadić *et al.* (2020) proposed a hybrid evaluation model, which combines AHP and CODAS techniques for location selection of dry port terminals. The model takes into account various requirements of stakeholders, which reflect economic, ecologic and social related aspects. The proposed methodology was applied in the Balkans region. According to the results the best option according to the criteria selected is to open 3 terminals in the capitals of Croatia, Slovenia and Serbia. By applying extended TOPSIS technique Chen *et al.* (2019) presented a framework for hazardous materials transportation alternatives selection. The framework is actual for manufacturing enterprises and gives possibility to rank transportation companies and choose the most suitable. Aljohani & Thompson (2019) applied AHP and PROMETHEE techniques for the selection of the most sustainable and suitable delivery fleet alternative. The study highlights the importance of involvement of stakeholders in the planning and selection of urban freight policies. Semanjski & Gautama (2019) presented a stakeholders' decision-making model for sustainable logistics in urban areas. The decision-making model is based on AHP technique and could be flexible applied to different local contexts. Kijewska *et al.* (2018) applied DEMATEL and AHP approaches for solving delivery problems and rationalize freight flow of goods in one region of Poland. Awasthi *et al.* (2018) created a framework based on AHP and VIKOR techniques for the sustainable selection of global supplier. The criteria for the assessment were classified into 5 groups as follows: economic, social, environmental, global risk and quality. The results confirmed the highest importance of the economic criteria alongside the lowest importance of the global risk. Wątróbski *et al.* (2017) evaluated several electric freight vehicles for the city logistics by application of 2 MCDM techniques. The presented framework can be easily adapted to solve selection of vehicles for logistics in other cases. In order to ensure distribution services in a sustainable way Macharis & Milan (2015) presented a methodology to support the decision process. The main attention is paid to the stakeholders' involvement in the planning. The methodology is based on Multi-Actor Multi-Criteria Analysis and 2 MCDM methods (AHP and PROMETHEE) for ranking the alternatives. Simongáti (2010) applied SAW and PROMETHEE for the creation of a decision support tool for the assessment of freight alternatives and the selection of the most sustainable.

Also, there are studies dealing with sustainability assessment of the transport system. Yazdani *et al.* (2020) proposed a framework for performance measurement of a freight transport system with incorporation of economic, social and environmental aspects of sustainability. The tool is based on DEMATEL and MABAC methods. The study measured the sustainability of 7 companies and compared the results with other MCDM methods (TOPSIS, EDAS and CODAS). According to the authors, methodologies based on rough number have advantages versus interval or fuzzy based techniques. Kumar & Anbanandam (2021) assessed environmental responsibility of freight transport service providers' by applying AHP and VIKOR methods. The introduced methodology was applied for evaluation of freight transport industry in India. Bai *et al.* (2017) presented a framework for sustainable transport fleet assessment, where economic, environmental and vehicle performance criteria are involved. The developed framework was used for a case study and VIKOR method rendered the ranking of the alternatives.

In order to investigate expectations of customers' port services Wang *et al.* (2017) created a model for sustainable services decision. The authors provide a case study of the port of Ningbo (China), the model created is based on AHP approach. It was found that improvements in port infrastructure, cargo safety, and charges reduction are the main conditions to attract businesses.

### *3.2.6. Methods selection studies*

Several studies have been found proposing various MCDM approaches for sustainable transport decision-making and were singled out into methods selection category. Mainly these studies introduced frameworks and methodologies from the holistic point of view and paid significant attention to the involvement of stakeholders in decision-making processes.

The authors emphasize the inclusion of sustainability criteria in transport assessments. Shekhovtsov *et al.* (2020) presented several techniques for the determination of decision criteria for solving sustainable transport issues. Cornet *et al.* (2018) drew attention to sustainability in transport appraisal and proposed a methodology for the construction of sustainability point of view. Nguyen *et al.* (2020) presented a framework for the sustainability assessment of transport alternatives. The framework follows the holistic point of view and is constructed in 6 steps. As one of the main instruments for the evaluation, the MCDA is proposed.

Also, there is a strong highlight on stakeholders' involvement in evaluations. By using the PROMETHEE method Huang *et al.* (2021) proposed a methodology, which helps to find consensuses in seeking sustainable mobility. According to the study, the proposed approach allows to find the minimum weight modification for each stakeholder. Barfod (2018) proposed a methodology for the sustainable transport assessment by involving stakeholders, which can serve as an effective support tool in the search for more sustainable options to solve transport problems. Macharis *et al.* (2012) presented the multi actor multi-criteria analysis in combination of AHP and PROMETHEE as a tool to assess transport projects. As is common for such an analysis, the methodology focuses on the opinion and preferences of various stakeholders.

## 4. Discussion on selection of instruments and criteria for sustainable transport decision-making

Decision-making in the transportation sector is a complex process influenced not only by the distinct characteristics of alternatives and potential solutions but also by the multifaceted requirements of transport service providers, passengers, freight companies, and decision-makers themselves. The intricacies of transport development issues are interconnected, impacting diverse stakeholder groups. Consequently, involving a range of stakeholders in decision-making concerning transport development is essential. This inclusive approach is crucial to identifying optimal solutions that can best meet the needs of all stakeholder groups.

Various studies underscore the importance of stakeholder participation in sustainable transport decision-making, as evidenced by studies such as Barfod (2018), Huang *et al.* (2021), Rześny-Cieplińska *et al.* (2021), Lee *et al.* (2021), and Karolemeas *et al.* (2021). Involving various stakeholders yields numerous advantages, including the democratization of decision-making processes, increased awareness, knowledge and information sharing, and the encouragement of meaningful discussions. Importantly, stakeholder engagement enables a comprehensive examination of the problem from diverse perspectives. This engagement serves as a primary tool in the process of selecting indicators and determining their weights. It also plays a role in influencing the responsibility to accept and implement the final project outcome. Given the varied priorities and preferences of stakeholder groups in the transport sector, employing multi-criteria analysis becomes a suitable method for considering and evaluating potentially conflicting solutions and ultimately selecting the most preferable one.

One can identify the main requirements for the development of a comprehensive and reliable set of criteria for the assessment of transport development alternatives. One of the essentials is to ensure that the set of criteria will reflect the concept of sustainability, i.e., criteria selected should cover economic, environmental and social dimensions of sustainability. Also, it is very important that criteria will be selected taking into account the specific characteristics of the location, project and groups of stakeholders. In this stage, it is very reasonable to involve experts and various stakeholders for the selection and weighting of criteria. Besides all that, reliable and reasonable methods should be applied for the measurement and ranking of the sustainable transport development alternatives.

The development a comprehensive and reliable set of criteria for sustainable transport development, especially when it is related to transport policy or public planning issues should follow holistic approach, taking into account the diverse dimensions and complexities associated with the problem. In such cases the engagement of stakeholders in decision-making process is extremely important. It allows to:

- ***to democratize decision-making***. The involvement of a diverse range of stakeholders in the decision-making process allows to ensure that decisions are made with input from various perspectives and interests. This helps to avoid bias and promotes a democratic approach, where decisions reflect the collective needs and preferences of the different groups of stakeholders;
- ***to raise awareness and share knowledge and information***. Sustainable transport initiatives often require public support and awareness. The engagement of stakeholders contributes as informing and educating measure regarding the benefits and implications, fosters a culture of understanding and support;
- ***to encourage discussions and overthink multiple perspectives***. Considering diverse perspectives is crucial for identifying comprehensive and inclusive solutions. Looking at the problem from different perspectives allows a well-rounded analysis of the problem, leading to decisions that account for the various needs and concerns of different stakeholder groups. Also, innovative ideas and solutions can emerge through dialogue;

- ***to select indicators and determine their weights***. The selection of indicators and their weights is fundamental in assessing the most preferable alternative. The engagement of stakeholders allows to ensure, that the criteria will be selected carefully, and weights will be assigned in an appropriate way;
- ***to enlarge responsibility of the decisions made***. Sustainable transport decisions often require commitment and accountability for successful implementation. Therefore, the engagement of various stakeholders allows to ensure that decision-makers not only make informed choices but also take ownership of the outcomes, fostering a commitment to seeing the proposed solutions through to completion.

The creation of a representative set of criteria is necessary not only to assess transport development alternatives in scientific articles or theory, but also to use it in practice for the decision-making in the transport sector. Decision support instruments are essential for policy makers and local authorities in seeking to make decisions in sustainable way. However, often the essence of sustainability concept is ignored. Due attention to the environmental and social dimension is often overlooked. To fill this gap, the thematic areas of criteria for the sustainable transport decision-making that reflect the concept of sustainable development are provided (Table 8).

Relying on an integrated approach, which considers economic, social and environmental perspectives, ensures that sustainable transport initiatives will be environmentally friendly, economically viable and socially beneficial. The economic criteria contribute to a comprehensive evaluation of the financial and economic implications of different decision-making alternatives. By considering these factors, decision-makers can prioritize solutions that not only align with sustainability goals but also make economic sense in the long run. The main thematic areas of economic criteria that should be considered when making decisions in transport sector can be singled out:

- ***cost of infrastructure / project development***. The initial cost of developing transportation infrastructure is a crucial economic criterion. It directly impacts the feasibility and financial viability of sustainable transport projects. Considering this cost helps decision-makers assess the economic sustainability of the project and allocate resources efficiently;
- ***operating cost***. The ongoing operating cost of a sustainable transport system is a key economic factor. This includes expenses related to fuel, energy, personnel, and other operational aspects. Evaluating operating costs is essential for determining the long-term financial viability and efficiency of the chosen sustainable transport solution;
- ***maintenance cost***. The cost associated with maintaining transportation infrastructure and vehicles over time is vital for sustainable transport decision-making. Sustainable options with lower maintenance costs contribute to long-term economic viability and reduce the financial burden on the system's operators and stakeholders;
- ***time cost***. Time is a valuable economic resource for both individuals and businesses. Considering time costs in sustainable transport decision-making accounts for factors such as travel time, congestion, and delays. Efficient and sustainable transport solutions help minimize time costs, improving overall economic productivity and user satisfaction;
- ***accident cost***. Accidents and their associated costs have significant economic implications. Sustainable transport options often come with safety features that can reduce accident rates and their related costs, including medical expenses, property damage, and productivity losses. Considering accident costs emphasizes the importance of safety in the economic sustainability of transportation systems.

The consideration of various environmental criteria ensures a comprehensive assessment of the ecological implications of different transport options. By considering these factors, decision-makers can prioritize sustainable transport solutions that not only meet transportation needs but also takes into account the environmental perspective. After careful content analysis of studies dealing with sustainable transport issues the main thematic areas of environmental criteria can be categorized into several categories:

- ***energy consumption***. Evaluating energy consumption is crucial for assessing the sustainability of alternatives. Sustainable options typically aim to minimize energy consumption, promoting the use of efficient and eco-friendly technologies that reduce reliance on non-renewable energy sources;

**Table 8.** Thematic areas of criteria for the sustainable transport decision-making (source: created by the authors)

| Economic criteria | Environmental criteria | Social criteria |
|---|---|---|
| ▪ cost of infrastructure / project development;<br>▪ operating cost;<br>▪ maintenance cost;<br>▪ time cost;<br>▪ accident cost | ▪ energy consumption;<br>▪ resource use;<br>▪ renewable fraction;<br>▪ GHG emissions;<br>▪ air pollution;<br>▪ noise;<br>▪ effects on species;<br>▪ landscape degradation;<br>▪ negative visual impact | ▪ safety;<br>▪ health;<br>▪ quality of life criteria (noise, visual impact, disruption);<br>▪ impact on businesses services;<br>▪ impact on community services;<br>▪ impact on employment |

- ***resource use***. Sustainable transport decisions should consider the impact on natural resources. Efficient use of resources, such as materials for infrastructure or vehicle production, is essential to minimize environmental degradation and depletion of finite resources;
- ***renewable fraction***. The proportion of renewable energy used in transport operations is the other important criterion. A higher renewable fraction indicates a reduced reliance on fossil fuels, contributing to lower GHG emissions and a more sustainable transport system;
- ***GHG emissions***. GHG emissions directly contribute to climate change. Therefore, evaluating and minimizing GHG emissions is a fundamental environmental criterion for sustainable transport decision-making, promoting options with lower carbon footprints;
- ***air pollution***. The environmental impact of air pollution is a significant concern. Sustainable transport options aim to minimize emissions of pollutants harmful to air quality, promoting public health and reducing the ecological impact on ecosystems;
- ***noise***. Noise pollution is a critical environmental factor associated with transport. Sustainable options focus on minimizing noise levels, contributing to improved quality of life for communities near transportation routes and protecting wildlife habitats;
- ***effects on species***. Transportation systems can have adverse effects on local flora and fauna. Considering the impact on species helps identify sustainable options that minimize disruptions to ecosystems and protect biodiversity;
- ***landscape degradation***. Sustainable transport decisions should account for the potential degradation of landscapes and natural environments. Minimizing the impact on scenic beauty and preserving natural habitats is essential for long-term environmental sustainability;
- ***negative visual impact***. Visual aesthetics play a role in the environmental impact of transport infrastructure. Sustainable options strive to minimize negative visual impacts, preserving the visual harmony of landscapes and urban areas.

Incorporating social criteria into sustainable transport decision-making allows to ensure a holistic approach that goes beyond infrastructure and efficiency. By addressing safety, health, quality of life, impacts on businesses and community services, and employment considerations, decision-makers can prioritize options that not only meet transportation needs but also enhance the well-being of society and local communities:

- ***safety***. Safety is a paramount social criterion in sustainable transport decision-making. Prioritizing safety helps protect the well-being of individuals and communities. Sustainable transport options aim to minimize accidents and enhance overall safety for users and pedestrians;
- ***health***. The impact of transport on public health is a critical social consideration. Sustainable transport options contribute to better air quality, reduced exposure to pollutants, and increased physical activity, positively influencing public health and well-being;
- ***quality of life criteria (noise, visual impact, disruption)***. Quality of life criteria encompass various factors that directly affect residents' well-being. Minimizing noise and visual impact, as well as reducing disruptions from transport activities, helps create more liveable and pleasant communities, enhancing the overall quality of life for residents;
- ***impact on business services***. Sustainable transport decisions should consider their impact on local businesses. Efficient and accessible transportation can positively influence business activities by facilitating the movement of goods and people, contributing to economic vitality and community development;
- ***impact on community services***. Sustainable transport decisions can impact the accessibility of community services such as schools, healthcare facilities, and recreational areas. Ensuring that transportation options support easy access to essential services contributes to the social well-being of communities;
- ***impact on employment***. Transportation projects and services have the potential to generate employment opportunities. Sustainable transport decision-making considers the impact on employment, aiming to create jobs and support local economies while minimizing negative social consequences such as displacement.

Based on the literature review, the 4 most typical MCDM techniques have been identified that were used to solve different transport sustainability issues (Figure 6).

Indeed, these 4 techniques cover different schools of the MCDM and can provide a rather comprehensive overview of the possible options for methodological approaches regarding the data aggregation. Obviously, there have been numerous MCDM techniques developed, and a single article cannot take all of them into consideration. Thus, we use the 4 options identified through the review as representatives for the related techniques that are applied less frequently. Also note that here we mainly focus on discrete optimization and ignore approaches for the infinite sets of alternatives (mathematical programming).

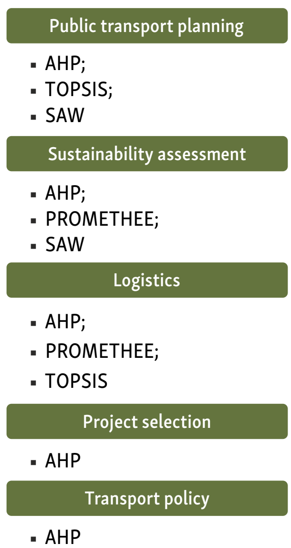



**Figure 6.** The most popular MCMD approaches used by the application areas (source: created by the authors)

The AHP approach represents the value-function approach and is based on pair-wise comparisons. These comparisons are usually done by the experts assigning the values of dominance for each pair (of criteria or alternatives). Often times the AHP is used to generate the weights of criteria. Sometimes it can also be used to gauge the utility of alternatives themselves. The technique may become cumbersome if the experts are not experienced enough. The calculations need to be carried out following special algorithms. For fully automated processes, dedicated software may be used.

The PROMETHEE approach relies on pair-wise comparisons, yet these are carried out on a basis of the predefined dominance functions. Therefore, expert input is needed when determining the shape of the dominance functions (which can be cumbersome for novice users). The PROMETHEE approach represents the outranking school, which has also developed an array of the like methods. These methods are often implemented by utilizing dedicated software. The appealing property of the outranking methods is that they can ignore extreme deviations via the special assumptions regarding the distance functions. Some of the approaches render partial ranking (i.e., some alternatives are assigned the same ranks).

The TOPSIS approach belongs to the group of reference-based methods. These methods consider the reference points and measure the distances to these points for each of the alternatives. The resulting measures then show the relative performance in a non-compensatory manner. The ideal solutions are established by using theoretically possible values rather than the observed ones. The method is easy to implement in simple spreadsheets.

The SAW method represents the value-function methods that are fully compensatory. In this case, the weight directly represents the marginal utility of the normalized decision values and can be used to understand the trade-offs in a straightforward manner. The method is extremely simple and can be implemented by inexperienced users as well. The SAW relies on the additive utility function and other methods (e.g., weighted product) can be used to derive the utility functions of different forms.

The applications of MCDM techniques provide a structured and flexible approach for decision-makers to navigate the complexities of sustainable transport decision-making. They are highly useful due to their ability to handle complex and conflicting criteria. Such features as possibility to consider of multiple criteria simultaneously; incorporate both quantitative and qualitative criteria; perform trade-off analysis; involve stakeholders in decision-making; perform sensitivity analysis; follow a systematic and transparent framework for decision-making and adapt decision-making process to different approaches are very useful in order to make decisions in sustainable way. By facilitating the consideration of diverse criteria, accommodating stakeholder preferences, and offering systematic decision support, MCDM methods contribute significantly to identifying and selecting sustainable transport solutions.

## 5. Conclusions

The article overviews of the applications of MCDM for addressing transport sustainability issues and provides the main insights of methods selection for future research. The SALSA framework and the PRISMA statement were the basis for the research. The search was made on the 2 combinations of topics "sustainable transport" + "multi-criteria decision-making" and "sustainable transport" + "multi-criteria decision analysis" in all WoS categories.

All the publications identified (172) were overviewed according to the main characteristics (publication year, WoS subject area, research institution, countries, journals). The detailed analysis of publications was made only for those publications (130), which met inclusion criteria selected. In the detailed analysis, all selected publications were categorized into 6 categories by application area: transport policy studies, sustainability assessment studies, project selection studies, public transport planning studies, logistics studies and methods selection studies. Also, all the selected articles were categorized by the method applied.

Various methods were applied for solving various transport sustainability issues. The detailed content analysis of publications and the categorization by the application areas revealed that most of the cases of the multi-criteria analysis were focused on sustainable transport planning and sustainability assessment issues. The most popular MCDM technique is AHP, which was applied in 39 studies. Also, popular choices include PROMETHEE (15), TOPSIS (11) and SAW (8) techniques. The AHP, PROMETHEE and MOUT techniques are commonly used to solve sustainable transport policy issues. The most popular MCDM techniques in transport sustainability assessment category were AHP, PROMETHEE and SAW. The predominant MCDM methods in the transport project selection category are AHP, TOPSIS, SMART/SMARTER and ANP. The widest range of methods applied was found in the public transport planning category. AHP and TOPSIS can be distinguished as the dominant methods in this category. The predominant MCDM techniques in the logistics category are AHP, PROMETHEE and TOPSIS. The articles in methods selection category mostly propose to apply AHP or PROMETHEE techniques.

The main criteria for sustainability assessment studies in transport include: environmental (energy consumption, resource use and GHG emissions; habitat fragmentation and negative effects on species; air pollution; noise pollution; landscape degradation and negative visual impact etc.); economic (infrastructure costs – construction/ maintenance/operating; travel time cost/saving; vehicle operating cost; accident cost/saving etc.), social (community disruption; impacts on businesses and community services; employment and labour standards, distributive effects of the transport project; occupational and community health and safety).

Based on the conducted overview, the future research guidelines can be formulated. Though, the multi-criteria analysis provides a proper structure for addressing the main sustainability issues of transport sector on various levels, however, the assessment process is highly subjective in terms of criteria and indicators selection. The big problem is the lack of procedures for aggregating the evaluations of the individual criteria and weights of criteria. The future research is necessary to provide valid frameworks for integration of all stakeholders' opinions in MCDA analysis of sustainability in transport. Mix of semi-structured interviews, focus groups and Delphi research methods can be applied for identifying opportunities and immediate challenges for sustainable transport development in a specific stakeholder environment, assessing their views and priorities. Based on these studies, criteria and their weights can be selected for MCDM and the best acclaimed MCDM techniques like AHP or PROMETHEE can be successfully applied.

## References

Al-Kaabi, M. J.; Maraqa, M. A.; Hawas, Y. S. 2020. Development of a composite sustainability index for roadway intersection design alternatives in the UAE, *Sustainability* 12(20): 8696. https://doi.org/10.3390/su12208696

Aljohani, K.; Thompson, R. G. 2019. A stakeholder-based evaluation of the most suitable and sustainable delivery fleet for freight consolidation policies in the inner-city area, *Sustainability* 11(1): 124. https://doi.org/10.3390/su11010124

Alzouby, A. M.; Nusair, A. A.; Taha, L. M. 2019. GIS based multi criteria decision analysis for analyzing accessibility of the disabled in the Greater Irbid municipality area, Irbid, Jordan, *Alexandria Engineering Journal* 58(2): 689–698. https://doi.org/10.1016/j.aej.2019.05.015

Antanasijević, D.; Pocajt, V.; Ristić, M.; Perić-Grujić, A. 2017. A differential multi-criteria analysis for the assessment of sustainability performance of European countries: beyond country ranking, *Journal of Cleaner Production* 165: 213–220. https://doi.org/10.1016/j.jclepro.2017.07.131

Awad-Núñez, S.; González-Cancelas, N.; Soler-Flores, F.; Camarero-Orive, A. 2015. How should the sustainability of the location of dry ports be measured? A proposed methodology using Bayesian networks and multi-criteria decision analysis, *Transport* 30(3): 312–319. https://doi.org/10.3846/16484142.2015.1081618

Awasthi, A.; Govindan, K.; Gold, S. 2018. Multi-tier sustainable global supplier selection using a fuzzy AHP-VIKOR based approach, *International Journal of Production Economics* 195: 106–117. https://doi.org/10.1016/j.ijpe.2017.10.013

Azapagic, A.; Chalabi, Z.; Fletcher, T.; Grundy, C.; Jones, M.; Leonardi, G.; Osammor, O.; Sharifi, V.; Swithenbank, J.; Tiwary, A.; Vardoulakis, S. 2013. An integrated approach to assessing the environmental and health impacts of pollution in the urban environment: methodology and a case study, *Process Safety and Environmental Protection* 91(6): 508–520. https://doi.org/10.1016/j.psep.2012.11.004

Bai, C.; Fahimnia, B.; Sarkis, J. 2017. Sustainable transport fleet appraisal using a hybrid multi-objective decision making approach, *Annals of Operations Research* 250(2): 309–340. https://doi.org/10.1007/s10479-015-2009-z

Bana e Costa, C. A.; De Corte J.-M.; Vansnick, J.-C. 2012. MACBETH, *International Journal of Information Technology & Decision Making* 11(2): 359–387. https://doi.org/10.1142/S0219622012400068

Bandeira, R. A. M.; D'Agosto, M. A.; Ribeiro, S. K.; Bandeira, A. P. F.; Goes, G. V. 2018. A fuzzy multi-criteria model for evaluating sustainable urban freight transportation operations, *Journal of Cleaner Production* 184: 727–739. https://doi.org/10.1016/j.jclepro.2018.02.234

Barfod, M. B. 2018. Supporting sustainable transport appraisals using stakeholder involvement and MCDA, *Transport* 33(4): 1052–1066. https://doi.org/10.3846/transport.2018.6596

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. https://doi.org/10.1016/j.tra.2014.12.001

Barradale, M. J.; Cornet, Y. 2018. Developing assessment criteria for sustainable transport appraisal, *Transportation Research Record: Journal of the Transportation Research Board* 2672(3): 104–117. https://doi.org/10.1177/0361198118799033

Bivina, G. R.; Parida, M. 2020. Prioritizing pedestrian needs using a multi-criteria decision approach for a sustainable built environment in the Indian context, *Environment, Development and Sustainability* 22(5): 4929–4950. https://doi.org/10.1007/s10668-019-00381-w

Blagojević, A.; Stević, Ž.; Marinković, D.; Kasalica, S.; Rajilić, S. 2020. A novel entropy-fuzzy PIPRECIA-DEA model for safety evaluation of railway traffic, *Symmetry* 12(9): 1479. https://doi.org/10.3390/sym12091479

Boisjoly, G.; El-Geneidy, A. M. 2017. How to get there? A critical assessment of accessibility objectives and indicators in metropolitan transportation plans, *Transport Policy* 55: 38–50. https://doi.org/10.1016/j.tranpol.2016.12.011

Bouhana, A.; Zidi, A.; Fekih, A.; Chabchoub, H.; Abed, M. 2015. An ontology-based CBR approach for personalized itinerary search systems for sustainable urban freight transport, *Expert Systems with Applications* 42(7): 3724–3741. https://doi.org/10.1016/j.eswa.2014.12.012

Brans, J. P.; Mareschal, B. 1992. PROMETHEE V: MCDM problems with segmentation constraints, *INFOR: Information Systems and Operational Research* 30(2): 85–96. https://doi.org/10.1080/03155986.1992.11732186

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. https://doi.org/10.3846/tede.2010.01

Broniewicz, E; Ogrodnik, K. 2020. Multi-criteria analysis of transport infrastructure projects, *Transportation Research Part D: Transport and Environment* 83: 102351. https://doi.org/10.1016/j.trd.2020.102351

Brůhová Foltýnová, H.; Vejchodská, E.; Rybová, K.; Květoň, V. 2020. Sustainable urban mobility: one definition, different stakeholders' opinions, *Transportation Research Part D: Transport and Environment* 87: 102465. https://doi.org/10.1016/j.trd.2020.102465

Bulckaen, J; Keseru, I; Macharis, C. 2016. Sustainability versus stakeholder preferences: Searching for synergies in urban and regional mobility measures, *Research in Transportation Economics* 55: 40–49. https://doi.org/10.1016/j.retrec.2016.04.009

Cadena, P. C. B.; Magro, J. M. V. 2015. Setting the weights of sustainability criteria for the appraisal of transport projects, *Transport* 30(3): 298–306. https://doi.org/10.3846/16484142.2015.1086890

Casanovas-Rubio, M. M.; Ramos, G.; Armengou, J. 2020. Minimizing the social impact of construction work on mobility: a decision-making method, *Sustainability* 12(3): 1183. https://doi.org/10.3390/su12031183

Castillo, H.; Pitfield, D. E. 2010. ELASTIC – a methodological framework for identifying and selecting sustainable transport indicators, *Transportation Research Part D*: *Transport and Environment* 15(4): 179–188. https://doi.org/10.1016/j.trd.2009.09.002

Chen, C.; Achtari, G.; Majkut, K.; Sheu, J.-B. 2017. Balancing equity and cost in rural transportation management with multi-objective utility analysis and data envelopment analysis: a case of Quinte West, *Transportation Research Part A*: *Policy and Practice* 95: 148–165. https://doi.org/10.1016/j.tra.2016.10.015

Chen, Z.-S.; Li, M.; Kong, W.-T.; Chin, K.-S. 2019. Evaluation and selection of HazMat transportation alternatives: a PHFLTS- and TOPSIS-integrated multi-perspective approach, *International Journal of Environmental Research and Public Health* 16(21): 4116. https://doi.org/10.3390/ijerph16214116

Cieśla, M.; Sobota, A.; Jacyna, M. 2020. Multi-criteria decision making process in metropolitan transport means selection based on the sharing mobility idea, *Sustainability* 12(17): 7231. https://doi.org/10.3390/su12177231

Cornet, Y.; Barradale, M. J.; Barfod, M. B.; Hickman, R. 2018. Giving current and future generations a real voice: a practical method for constructing sustainability viewpoints in transport appraisal, *European Journal of Transport and Infrastructure Research* 18(3): 316–339. https://doi.org/10.18757/EJTIR.2018.18.3.3244

Corral, S; Hernandez, Y. 2017. Social sensitivity analyses applied to environmental assessment processes, *Ecological Economics* 141: 1–10. https://doi.org/10.1016/j.ecolecon.2017.05.022

Del Amo, I. F.; Erkoyuncu, J. A.; Roy, R.; Palmarini, R.; Onoufriou, D. 2018. A systematic review of augmented reality content-related techniques for knowledge transfer in maintenance applications, *Computers in Industry* 103: 47–71. https://doi.org/10.1016/j.compind.2018.08.007

Delibasic, M. 2022. Institutional imbalance of interests in maritime transport and sustainable development, *Transformations in Business & Economics* 21(1): 263–273.

Dimitriou, H. T; Ward, E. J; Dean, M. 2016. Presenting the case for the application of multi-criteria analysis to mega transport infrastructure project appraisal, *Research in Transportation Economics* 58: 7–20. https://doi.org/10.1016/j.retrec.2016.08.002

Duleba, S.; Moslem, S. 2018. Sustainable urban transport development with stakeholder participation, an AHP-Kendall model: a case study for Mersin, *Sustainability* 10(10): 3647. https://doi.org/10.3390/su10103647

EC. 2019. *The European Green Deal*. European Commission (EC). Available from Internet: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

Edwards, W. 1977. How to use multiattribute utility measurement for social decisionmaking, *IEEE Transactions on Systems*, *Man*, *and Cybernetics* 7(5): 326–340. https://doi.org/10.1109/TSMC.1977.4309720

Edwards, W.; Barron, F. H. 1994. SMARTS and SMARTER: improved simple methods for multiattribute utility measurement, *Organizational Behavior and Human Decision Processes* 60(3): 306–325. https://doi.org/10.1006/obhd.1994.1087

Ekener, E.; Hansson, J.; Larsson, A.; Peck, P. 2018. Developing life cycle sustainability assessment methodology by applying values-based sustainability weighting – tested on biomass based and fossil transportation fuels, *Journal of Cleaner Production* 181: 337–351. https://doi.org/10.1016/j.jclepro.2018.01.211

Erdogan, M.; Kaya, I. 2019. Prioritizing failures by using hybrid multi criteria decision making methodology with a real case application, *Sustainable Cities and Society* 45: 117–130. https://doi.org/10.1016/j.scs.2018.10.027

Eurostat. 2024. *Database*. Available from Internet: https://ec.europa.eu/eurostat/data/database

Feitó-Cespón, M.; Sarache, W.; Piedra-Jimenez, F.; Cespón-Castro, R. 2017. Redesign of a sustainable reverse supply chain under uncertainty: a case study, *Journal of Cleaner Production* 151: 206–217. https://doi.org/10.1016/j.jclepro.2017.03.057

Fishburn, P. C. 1967. Methods of estimating additive utilities, *Management Science* 13(7): 435–453. https://doi.org/10.1287/mnsc.13.7.435

Gabus, A.; Fontela, E. 1972. *World Problems*, *An Invitation to Further Thought Within the Framework of DEMATEL*. Battelle Geneva Research Center, Geneva, Switzerland.

Ghorbanzadeh, O.; Moslem, S.; Blaschke, T.; Duleba, S. 2019. Sustainable urban transport planning considering different stakeholder groups by an interval-AHP decision support model, *Sustainability* 11(1): 9. https://doi.org/10.3390/su11010009

Gomes, L.; Lima, M. 1991. TODIM: basics and application to multicriteria ranking of projects with environmental impacts, *Foundations of Computing and Decision Sciences* 16(3–4): 113–127.

Grant M. J.; Booth A. 2009. A typology of reviews: an analysis of 14 review types and associated methodologies, *Health Information & Libraries Journal* 26(2): 91–108. https://doi.org/10.1111/j.1471-1842.2009.00848.x

Griškevičiūtė-Gečienė, A. 2010. The evaluation of investment projects within the territory of development, *Transport* 25(2): 203–214. https://doi.org/10.3846/transport.2010.25

Henke, I.; Cartenì, A.; Di Francesco, L. 2020. A Sustainable evaluation processes for investments in the transport sector: a combined multi-criteria and cost–benefit analysis for a new highway in Italy, *Sustainability* 12(23): 9854. https://doi.org/10.3390/su12239854

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. https://doi.org/10.1016/j.tra.2011.11.006

Höfer, T.; Madlener, R. 2020. A participatory stakeholder process for evaluating sustainable energy transition scenarios, *Energy Policy* 139: 111277. https://doi.org/10.1016/j.enpol.2020.111277

Huang, H.; De Smet, Y.; Macharis, C.; Doan, N. A. V. 2021. Collaborative decision-making in sustainable mobility: identifying possible consensuses in the multi-actor multi-criteria analysis based on inverse mixed-integer linear optimization, *International Journal of Sustainable Development & World Ecology* 28(1): 64–74. https://doi.org/10.1080/13504509.2020.1795005

Hwang, C.-L.; Yoon, K. 1981. Methods for multiple attribute decision making, *Lecture Notes in Economics and Mathematical Systems* 186: 58–191. https://doi.org/10.1007/978-3-642-48318-9_3

Jacyna, M. 2006. The multiobjective optimisation to evaluation of the infrastructure adjustment to transport needs, in K. G. Goulias (Ed.). *Transport Science and Technology*, 395–405. https://doi.org/10.1108/9780080467542-031

Jakimavičius, M.; Burinskienė, M. 2009. A GIS and multi-criteria-based analysis and ranking of transportation zones of Vilnius city, *Technological and Economic Development of Economy* 15(1): 39–48. https://doi.org/10.3846/1392-8619.2009.15.39-48

Jasti, P. C.; Ram, V. V. 2019a. Integrated and sustainable benchmarking of metro rail system using analytic hierarchy process and fuzzy logic: a case study of Mumbai, *Urban Rail Transit* 5(3): 155–171. https://doi.org/10.1007/s40864-019-00107-1

Jasti, P. C.; Ram, V. V. 2019b. Sustainable benchmarking of a public transport system using analytic hierarchy process and fuzzy logic: a case study of Hyderabad, India, *Public Transport* 11(3): 457–485. https://doi.org/10.1007/s12469-019-00219-8

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. https://doi.org/10.1016/j.tra.2013.01.003

Josimović, B.; Krunić, N.; Nenković-Riznić, M. 2016. The impact of airport noise as part of a strategic environmental assessment, case study: the Tivat (Montenegro) airport expansion plan, *Transportation Research Part D*: *Transport and Environment* 49: 271–279. https://doi.org/10.1016/j.trd.2016.10.005

Karolemeas, C.; Tsigdinos, S.; Tzouras, P. G.; Nikitas, A.; Bakogiannis, E. 2021. Determining electric vehicle charging station location suitability: a qualitative study of Greek stakeholders employing thematic analysis and analytical hierarchy process, *Sustainability* 13(4): 2298. https://doi.org/10.3390/su13042298

Keeney, R. L. 1982. Decision analysis: an overview, *Operations Research* 30(5): 803–838. https://doi.org/10.1287/opre.30.5.803

Keeney, R. L., Raiffa, H. 1993. *Decisions with Multiple Objectives*: *Preferences and Value Tradeoffs*. Cambridge University Press. 592 p.

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

Keshavarz Ghorabaee, M., Zavadskas, E. K., Olfat, L., Turskis, Z. 2015. Multi-criteria inventory classification using a new method of evaluation based on distance from average solution (EDAS), *Informatica* 26(3): 435–451. https://doi.org/10.15388/Informatica.2015.57

Keshavarz Ghorabaee, M.; Zavadskas, E. K.; Turskis, Z.; Antuchevičienė, J. 2016. A new combinative distance-based assessment (CODAS) method for multi-criteria decision-making, *Economic Computation and Economic Cybernetics Studies and Research* 50(3): 25–44. Available from Internet: https://ecocyb.ase.ro/nr20163/02%20-%20Mehdi%20K.%20GHORABAEE,%20Ed.%20Zavadskas(T).pdf

Keshkamat, S. S.; Looijen, J. M.; Zuidgeest, M. H. P. 2009. The formulation and evaluation of transport route planning alternatives: a spatial decision support system for the Via Baltica project, Poland, *Journal of Transport Geography* 17(1): 54–64. https://doi.org/10.1016/j.jtrangeo.2008.04.010

Kijewska, K.; Torbacki, W.; Iwan, S. 2018. Application of AHP and DEMATEL methods in choosing and analysing the measures for the distribution of goods in Szczecin region, *Sustainability* 10(7): 2365. https://doi.org/10.3390/su10072365

Krajangsri, T.; Pongpeng, J. 2019. Sustainable infrastructure assessment model: an application to road projects, *KSCE Journal of Civil Engineering* 23(3): 973–984. https://doi.org/10.1007/s12205-019-1007-0

Kramar, U.; Dragan, D.; Topolšek, D. 2019. The holistic approach to urban mobility planning with a modified focus group, swot, and fuzzy analytical hierarchical process, *Sustainability* 11(23): 6599. https://doi.org/10.3390/su11236599

Kumar, A.; Anbanandam, R. 2021. Environmentally responsible freight transport service providers' assessment under data-driven information uncertainty, *Journal of Enterprise Information Management* 34(1): 506–542. https://doi.org/10.1108/JEIM-12-2019-0403

Le Boennec, R.; Nicolaï, I.; Da Costa, P. 2019. Assessing 50 innovative mobility offers in low-density areas: a French application using a two-step decision-aid method, *Transport Policy* 83: 13–25. https://doi.org/10.1016/j.tranpol.2019.08.003

Lebeau, P.; Macharis, C.; Van Mierlo, J.; Janjevic, M. 2018. Improving policy support in city logistics: the contributions of a multi-actor multi-criteria analysis, *Case Studies on Transport Policy* 6(4): 554–563. https://doi.org/10.1016/j.cstp.2018.07.003

Lee, J.; Arts, J.; Vanclay, F. 2021. Stakeholder views about land use and transport integration in a rapidly-growing megacity: social outcomes and integrated planning issues in Seoul, *Sustainable Cities and Society* 67: 102759. https://doi.org/10.1016/j.scs.2021.102759

Ma, F.; Shi, W.; Yuen, K. F.; Sun, Q.; Guo, Y. R. 2019. Multi-stakeholders' assessment of bike sharing service quality based on DEMATEL–VIKOR method, *International Journal of Logistics Research and Applications*: *a Leading Journal of Supply Chain Management* 22(5): 449–472. https://doi.org/10.1080/13675567.2019.1568401

MacCrimmon, K. R. 1968. Decision making Among Multiple-Attribute Alternatives: A Survey and Consolidated Approach. RAND Corporation, Santa Monica, CA, US. 78 p. Available from Internet: https://www.rand.org/pubs/research_memoranda/RM4823.html

Macharis, C.; Milan, L. 2015. Transition through dialogue: a stakeholder based decision process for cities: the case of city distribution, *Habitat International* 45: 82–91. https://doi.org/10.1016/j.habitatint.2014.06.026

Macharis, C.; Turcksin, L.; Lebeau, K. 2012. Multi actor multi criteria analysis (MAMCA) as a tool to support sustainable decisions: state of use, *Decision Support Systems* 54(1): 610–620. https://doi.org/10.1016/j.dss.2012.08.008

Marleau Donais, F.; Abi-Zeid, I.; Waygood, E. O. D.; Lavoie, R. 2019. Assessing and ranking the potential of a street to be redesigned as a complete street: a multi-criteria decision aiding approach, *Transportation Research Part A*: *Policy and Practice* 124: 1–19. https://doi.org/10.1016/j.tra.2019.02.006

Mohagheghi, V.; Mousavi, S. M.; Aghamohagheghi, M.; Vahdani, B. 2017. A new approach of multi-criteria analysis for the evaluation and selection of sustainable transport investment projects under uncertainty: a case study, *International Journal of Computational Intelligence Systems* 10(1): 605–626. https://doi.org/10.2991/ijcis.2017.10.1.41

Moher, D.; Liberati, A.; Tetzlaff, J.; Altman, D. G. 2010. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement, *International Journal of Surgery* 8(5): 336–341. https://doi.org/10.1016/j.ijsu.2010.02.007

Moslem, S.; Campisi, T.; Szmelter-Jarosz, A.; Duleba, S.; Nahiduzzaman, K. M.; Tesoriere, G. 2020. Best–worst method for modelling mobility choice after COVID-19: Evidence from Italy, *Sustainability* 12(17): 6824. https://doi.org/10.3390/su12176824

Moslem, S.; Ghorbanzadeh, O.; Blaschke, T.; Duleba, S. 2019. Analysing stakeholder consensus for a sustainable transport development decision by the fuzzy AHP and interval AHP, *Sustainability* 11(12): 3271. https://doi.org/10.3390/su11123271

Mukherjee, S. 2017. Selection of alternative fuels for sustainable urban transportation under multi-criteria intuitionistic fuzzy environment, *Fuzzy Information and Engineering* 9(1): 117–135. https://doi.org/10.1016/j.fiae.2017.03.006

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

Munier, N. 2016. A new approach to the rank reversal phenomenon in MCDM with the SIMUS method, *Multiple Criteria Decision Making* 11: 137–152. https://doi.org/10.22367/mcdm.2016.11.09

Neofytou, H.; Sarafidis, Y.; Gkonis, N.; Mirasgedis, S.; Askounis, D. 2020. Energy efficiency contribution to sustainable development: a multi-criteria approach in Greece, *Energy Sources*, *Part B*: *Economics*, *Planning*, *and Policy* 15(10–12): 572–604. https://doi.org/10.1080/15567249.2020.1849449

Nguyen, T. T.; Brunner, H.; Hirz, M. 2020. Towards a holistic sustainability evaluation for transport alternatives, *European Journal of Sustainable Development* 9(4): 1–12. https://doi.org/10.14207/ejsd.2020.v9n4p1

Nowakowski, P.; Król, A. 2021. The influence of preliminary processing of end-of-life tires on transportation cost and vehicle exhausts emissions, *Environmental Science and Pollution Research* 28(19): 24256–24269. https://doi.org/10.1007/s11356-019-07421-y

Ogrodnik, K. 2020. Multi-criteria analysis of smart cities in Poland, *Geographia Polonica* 93(2): 163–181. https://doi.org/10.7163/GPol.0168

Oltean-Dumbrava, C.; Miah, A. 2016. Assessment and relative sustainability of common types of roadside noise barriers, *Journal of Cleaner Production* 135: 919–931. https://doi.org/10.1016/j.jclepro.2016.06.107

Oltean-Dumbrava, C.; Watts, G.; Miah, A. 2016. Towards a more sustainable surface transport infrastructure: a case study of applying multi criteria analysis techniques to assess the sustainability of transport noise reducing devices, *Journal of Cleaner Production* 112: 2922–2934. https://doi.org/10.1016/j.jclepro.2015.09.096

Oltean-Dumbrava, C.; Watts, G.; Miah, A. 2013. Transport infrastructure: making more sustainable decisions for noise reduction, *Journal of Cleaner Production* 42: 58–68. https://doi.org/10.1016/j.jclepro.2012.10.008

Opricović, S. 1998. *Višekriterijumska optimizacija sistema u građevinarstvu*. Doktorska disertacija. Građevinski fakultet, Univerzitet u Beogradu, Srbija. 302 s. (in Serbian).

Ortega, J.; Moslem, S.; Tóth, J.; Péter, T.; Palaguachi, J.; Paguay, M. 2020. Using best worst method for sustainable park and ride facility location, *Sustainability* 12(23): 10083. https://doi.org/10.3390/su122310083

Oses, U.; Rojí, E.; Gurrutxaga, I.; Larrauri, M. 2017. A multidisciplinary sustainability index to assess transport in urban areas: a case study of Donostia-San Sebastian, Spain, *Journal of Environmental Planning and Management* 60(11): 1891–1922. https://doi.org/10.1080/09640568.2016.1264374

Palevičius, V.; Burinskienė, M.; Podvezko, V.; Paliulis, G. M.; Šarkienė, E.; Šaparauskas, J. 2016. Research on the demand for parking lots of shopping centres, *E&M Economics and Management* 19(3): 173–194. https://doi.org/10.15240/tul/001/2016-3-012

Pamucar, D.; Deveci, M.; Canıtez, F.; Bozanic, D. 2020. A fuzzy full consistency method-Dombi-Bonferroni model for prioritizing transportation demand management measures, *Applied Soft Computing* 87: 105952. https://doi.org/10.1016/j.asoc.2019.105952

Pamučar, D.; Ćirović, G. 2015. The selection of transport and handling resources in logistics centers using multi-attributive border approximation area comparison (MABAC), *Expert Systems with Applications* 42(6): 3016–3028. https://doi.org/10.1016/j.eswa.2014.11.057

Pamučar, D.; Stević, Ž.; Sremac, S. 2018. A new model for determining weight coefficients of criteria in MCDM models: full consistency method (FUCOM), *Symmetry* 10(9): 393. https://doi.org/10.3390/sym10090393

Paul, A.; Moktadir, M. A.; Paul, S. K. 2020. An innovative decision-making framework for evaluating transportation service providers based on sustainable criteria, *International Journal of Production Research* 58(24): 7334–7352. https://doi.org/10.1080/00207543.2019.1652779

Pettit, C.; Chung, W.; Sharifi, V.; Chalabi, Z.; Fletcher, T.; Cleall, P.; Thomas, H.; De Munck, C.; Sinnett, D.; Jefferies, S.; Jones, M.; Azapagic, A. 2011. Sustainable management of urban pollution: an integrated approach, *Building Services Engineering Research and Technology* 32(1): 21–34. https://doi.org/10.1177/0143624410394528

Phdungsilp, A. 2010. Integrated energy and carbon modeling with a decision support system: Policy scenarios for low-carbon city development in Bangkok, *Energy Policy* 38(9): 4808–4817. https://doi.org/10.1016/j.enpol.2009.10.026

Pryn, M. R.; Cornet, Y.; Salling, K. B. 2015. Applying sustainability theory to transport infrastructure assessment using a multiplicative AHP decision support model, *Transport* 30(3): 330–341. https://doi.org/10.3846/16484142.2015.1081281

Raiffa, H. 1997. *Decision Analysis*: *Introductory Lectures on Choices under Uncertainty*. McGraw-Hill. 309 p.

Rezaei, J. 2015. Best-worst multi-criteria decision-making method, *Omega* 53: 49–57. https://doi.org/10.1016/j.omega.2014.11.009

Ribeiro, P.; Fonseca, F.; Santos, P. 2020. Sustainability assessment of a bus system in a mid-sized municipality, *Journal of Environmental Planning and Management* 63(2): 236–256. https://doi.org/10.1080/09640568.2019.1577224

Roy, B. 1968. Classement et choix en présence de points de vue multiples (la méthode ELECTRE), *R.I.R.O* 2(8): 57–75. https://doi.org/10.1051/ro/196802V100571 (in French).

Rybarczyk, G.; Wu, C. 2010. Bicycle facility planning using GIS and multi-criteria decision analysis, *Applied Geography* 30(2): 282–293. https://doi.org/10.1016/j.apgeog.2009.08.005

Rześny-Cieplińska, J.; Szmelter-Jarosz, A.; Moslem, S. 2021. Priority-based stakeholders analysis in the view of sustainable city logistics: evidence for Tricity, Poland, *Sustainable Cities and Society* 67: 102751. https://doi.org/10.1016/j.scs.2021.102751

Saaty, T. L. 1980. *The Analytic Hierarchy Process*: *Planning*, *Priority Setting*, *Resource Allocation*. McGraw-Hill. 287 p.

Saaty, T. L. 2001. *The Analytic Network Process*: *Decision Making with Dependence and Feedback*. 2nd edition. RWS Publications. 370 p.

Sałabun, W. 2015. The characteristic objects method: a new distance-based approach to multicriteria decision-making problems, *Journal of Multi-Criteria Decision Analysis*: *Optimization*, *Learning*, *and Decision Support* 22(1–2): 37–50. https://doi.org/10.1002/mcda.1525

Sałabun, W.; Palczewski, K.; Wątróbski, J. 2019. Multicriteria approach to sustainable transport evaluation under incomplete knowledge: electric bikes case study, *Sustainability* 11(12): 3314. https://doi.org/10.3390/su11123314

Salling, K. B.; Barfod, M. B.; Pryn, M. R.; Leleur, S. 2018. Flexible decision support for sustainable development: the SUSTAIN framework model, *European Journal of Transport and Infrastructure Research* 18(3): 295–315. https://doi.org/10.18757/ejtir.2018.18.3.3242

Salling, K. B.; Pryn, M. R. 2015. Sustainable transport project evaluation and decision support: indicators and planning criteria for sustainable development, *International Journal of Sustainable Development & World Ecology* 22(4): 346–357. https://doi.org/10.1080/13504509.2015.1051497

San-José Lombera, J. T.; Cuadrado, J. 2010. Industrial building design stage based on a system approach to their environmental sustainability, *Construction and Building Materials* 24(4): 438–447. https://doi.org/10.1016/j.conbuildmat.2009.10.019

Sayyadi, R.; Awasthi, A. 2020. An integrated approach based on system dynamics and ANP for evaluating sustainable transportation policies, *International Journal of Systems Science*: *Operations* & *Logistics* 7(2): 182–191. https://doi.org/10.1080/23302674.2018.1554168

Schmale, J.; Von Schneidemesser, E.; Dörrie, A. 2015. An integrated assessment method for sustainable transport system planning in a middle sized German city, *Sustainability* 7(2): 1329–1354. https://doi.org/10.3390/su7021329

Semanjski, I.; Gautama, S. 2019. A collaborative stakeholder decision-making approach for sustainable urban logistics, *Sustainability* 11(1): 234. https://doi.org/10.3390/su11010234

Sharav, N.; Szeinuk, M.; Shiftan, Y. 2018. Does your city need a metro? – A Tel Aviv case study, *Case Studies on Transport Policy* 6(4): 537–553. https://doi.org/10.1016/j.cstp.2018.07.002

Shekhovtsov, A.; Kozlov, V.; Nosov, V.; Sałabun, W. 2020. Efficiency of methods for determining the relevance of criteria in sustainable transport problems: a comparative case study, *Sustainability* 12(19): 7915. https://doi.org/10.3390/su12197915

Shishegaran, A.; Shishegaran, A.; Mazzulla, G.; Forciniti, C. 2020. A novel approach for a sustainability evaluation of developing system interchange: the case study of the Sheikhfazolah-Yadegar interchange, Tehran, Iran, *International Journal of Environmental Research and Public Health* 17(2): 435. https://doi.org/10.3390/ijerph17020435

Shmelev, S. E.; Shmeleva, I. A. 2018. Global urban sustainability assessment: a multidimensional approach, *Sustainable Development* 26(6): 904–920. https://doi.org/10.1002/sd.1887

Simongáti, G. 2010. Multi-criteria decision making support tool for freight integrators: selecting the most sustainable alternative, *Transport* 25(1): 89–97. https://doi.org/10.3846/transport.2010.12

Soria-Lara, J. A.; Banister, D. 2018. Evaluating the impacts of transport backcasting scenarios with multi-criteria analysis, *Transportation Research Part A*: *Policy and Practice* 110: 26–37. https://doi.org/10.1016/j.tra.2018.02.004

Spadaro, I.; Pirlone, F. 2021. Sustainable urban mobility plan and health security, *Sustainability* 13(8): 4403. https://doi.org/10.3390/su13084403

Stoilova, S.; Munier, N.; Kendra, M.; Skrúcaný, T. 2020. Multi-criteria evaluation of railway network performance in countries of the TEN-T Orient–East Med corridor, *Sustainability* 12(4): 1482. https://doi.org/10.3390/su12041482

Tadić, S.; Krstić, M.; Roso, V.; Brnjac, N. 2020. Dry port terminal location selection by applying the hybrid grey MCDM model, *Sustainability* 12(17): 6983. https://doi.org/10.3390/su12176983

Tadić, S.; Krstić, M.; Roso, V.; Brnjac, N. 2019. Planning an intermodal terminal for the sustainable transport networks, *Sustainability* 11(15): 4102. https://doi.org/10.3390/su11154102

Tang, J.; McNabola, A.; Misstear, B. 2020. The potential impacts of different traffic management strategies on air pollution and public health for a more sustainable city: a modelling case study from Dublin, Ireland, *Sustainable Cities and Society* 60: 102229. https://doi.org/10.1016/j.scs.2020.102229

Turskis, Z.; Antuchevičienė, J.; Keršulienė, V.; Gaidukas, G. 2019. Hybrid group MCDM model to select the most effective alternative of the second runway of the airport, *Symmetry* 11(6): 792. https://doi.org/10.3390/sym11060792

Ullah, K.; Hamid, S.; Mirza, F. M.; Shakoor, U. 2018. Prioritizing the gaseous alternatives for the road transport sector of Pakistan: a multi criteria decision making analysis, *Energy* 165: 1072–1084. https://doi.org/10.1016/j.energy.2018.10.055

Vallée, D.; Zielniewicz, P. 1994. *ELECTRE III-IV*, *Version 3.x*: *Aspects Méthodologiques*. Laboratoire d'Analyse et Modélisation de Systèmes pour l'Aide à la Décision (LAMSADE), Université de Paris, Paris, France. 52 p. (in French).

Van de Kaa, G.; Scholten, D.; Rezaei, J.; Milchram, C. 2017. The battle between battery and fuel cell powered electric vehicles: a BWM approach, *Energies* 10(11): 1707. https://doi.org/10.3390/en10111707

Vermote, L.; Macharis, C.; Putman, K. 2013. A road network for freight transport in Flanders: multi-actor multi-criteria assessment of alternative ring ways, *Sustainability* 5(10): 4222–4246. https://doi.org/10.3390/su5104222

Vo, T. T. Q.; Xia, A.; Rogan, F.; Wall, D. M.; Murphy, J. D. 2017. Sustainability assessment of large-scale storage technologies for surplus electricity using group multi-criteria decision analysis, *Clean Technologies and Environmental Policy* 19(3): 689–703. https://doi.org/10.1007/s10098-016-1250-8

Wang, Z.; Subramanian, N.; Abdulrahman, M. D.; Hong, C.; Wu, L.; Liu, C. 2017. Port sustainable services innovation: Ningbo port users' expectation, *Sustainable Production and Consumption* 11: 58–67. https://doi.org/10.1016/j.spc.2016.08.002

Ward, E. J.; Dimitriou, H. T.; Dean, M. 2016. Theory and background of multi-criteria analysis: Toward a policy-led approach to mega transport infrastructure project appraisal, *Research in Transportation Economics* 58: 21–45. https://doi.org/10.1016/j.retrec.2016.08.003

Wątróbski, J.; Małecki, K.; Kijewska, K.; Iwan, S.; Karczmarczyk, A.; Thompson, R. G. 2017. Multi-criteria analysis of electric vans for city logistics, *Sustainability* 9(8): 1453. https://doi.org/10.3390/su9081453

Yang, C.-H.; Lee, K.-C; Chen, H.-C. 2016. Incorporating carbon footprint with activity-based costing constraints into sustainable public transport infrastructure project decisions, *Journal of Cleaner Production* 133: 1154–1166. https://doi.org/10.1016/j.jclepro.2016.06.014

Yang, L.; Van Dam, K. H.; Zhang, L. 2020. Developing goals and indicators for the design of sustainable and integrated transport infrastructure and urban spaces, *Sustainability* 12(22): 9677. https://doi.org/10.3390/su12229677

Yazdani, M.; Pamucar, D.; Chatterjee, P.; Chakraborty, S. 2020. Development of a decision support framework for sustainable freight transport system evaluation using rough numbers, *International Journal of Production Research* 58(14): 4325–4351. https://doi.org/10.1080/00207543.2019.1651945

Yazdani, M.; Zarate, P.; Zavadskas, E. K.; Turskis, Z. 2019. A combined compromise solution (CoCoSo) method for multi-criteria decision-making problems, *Management Decision* 57(9): 2501–2519. https://doi.org/10.1108/MD-05-2017-0458

Zadeh, L. 1963. Optimality and non-scalar-valued performance criteria, *IEEE Transactions on Automatic Control* 8(1): 59–60. https://doi.org/10.1109/TAC.1963.1105511

Zagorskas, J; Turskis, Z. 2020a. Location preferences of new pedestrian bridges based on multi-criteria decision-making and GIS-based estimation, *The Baltic Journal of Road and Bridge Engineering* 15(2): 158–181. https://doi.org/10.7250/bjrbe.2020-15.478

Zagorskas, J.; Turskis, Z. 2020b. Setting priority list for construction works of bicycle path segments based on Eckenrode rating and ARAS-F decision support method integrated in GIS, *Transport* 35(2): 179–192. https://doi.org/10.3846/transport.2020.12478

Zanakis, S. H.; Solomon, A.; Wishart, N.; Dublish, S. 1998. Multi-attribute decision making: a simulation comparison of select methods, *European Journal of Operational Research* 107(3): 507–529. https://doi.org/10.1016/S0377-2217(97)00147-1

Zapolskytė, S.; Vabuolytė, V.; Burinskienė, M.; Antuchevičienė, J. 2020. Assessment of sustainable mobility by MCDM methods in the science and technology parks of Vilnius, Lithuania, *Sustainability* 12(23): 9947. https://doi.org/10.3390/su12239947

Zavadskas, E. K.; Kaklauskas, A.; Šarka, V. 1994. The new method of multicriteria complex proportional assessment of projects, *Ūkio technologinis ir ekonominis vystymas* 3: 131–139.

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. https://doi.org/10.3846/tede.2010.10

Zhang, B.; Qi, R. 2021. Transportation infrastructure, innovation capability, and urban economic development, *Transformations in Business* & *Economics* 20(3C): 526–545.

Zhao, C.; Xu, S.; Wu, M.; Yao, S.; Luo, X. 2022. Load flow prediction of intelligent logistics transportation network based on LSTM algorithm, *Transformations in Business* & *Economics* 21(2): 305–321.