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MULTI-CRITERIA DECISION-MAKING ON ROAD TRANSPORT VEHICLES BY THE AHP METHOD

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Abstract

Decision-making processes require the selection of appropriate and choice of the optimal solution for implementation. This means that different criteria and their sub-criteria evaluate various alternatives of possible solutions to determine the optimal solution. The research focuses on an Analytic Hierarchy Process (AHP) as one of the multi-criteria decision-making (MCDM) methods and its implementation to evaluate road transport vehicles. The AHP is one of the most used methods for evaluating projects in transport and traffic area. This paper presents a comprehensive review of studies on road transport vehicles evaluated by the AHP method. To gather research articles for the study, several databases such as Web of Science and Scopus were searched. The focus of the research is on road transport vehicles but the performance of the AHP method in the road sector, in general, is briefly reviewed. The results show that most of the studies use AHP for the evaluation of electric and autonomous vehicles. Finally, research results are discussed and recommendations for future research are proposed.

Keywords: transport; vehicles; road; AHP; multi-criteria decision-making

Introduction

Planning plays an essential role in modern society. It is present in many aspects of the lives of individuals, corporations, and nations as well. There are different kinds of planning such as urban, economic, financial, industrial, environmental, etc. Among these, planning for the development and maintenance of the transportation systems is crucial for promoting the different movement of the people and goods and playing a vital supportive role in attaining other community objectives [24]. Numerous methods of multi-criteria decision-making (MCDM) are applied in evaluating transport solutions in their evaluation and investment decision-making [11, 18]. Of the many MCDM methods, the Analytic Hierarchy Process (AHP) is used most; therefore, it is increasingly important in making decisions in transport [8].

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The AHP is a multi-objective, multi-criteria decision-making approach that employs a pairwise comparison procedure to arrive at a scale of preferences among sets of alternatives. From the mathematics point of view, the AHP method is a general theory of measurement. The popularity of the AHP method is primarily because it is very close to the way an individual intuitively solves complex problems by breaking them down into simpler ones. To use this method, it is necessary to break down a complex unstructured problem into its elementary parts; arraying these parts, or variables, into a hierarchic order; assigning numerical values to subjective judgments on the relative importance of each variable and synthesising the judgments to determine which variables have the highest priority and should be acted upon to influence the outcome of the situation [28, 29].

The main goal of this study is to analyse scientific papers and determine the extent to which the AHP method is applied in the field of transport and traffic, specifically for road vehicles. To gather research articles for the study, we used several databases such as Web of Science and Scopus. Our research only includes studies after 2014 as they are focused on the mainly used electric and autonomous vehicles. Our analysis shows that studies concerning vehicles from the previous period don't apply the AHP method significantly. This literature review aims to answer several questions: how often the AHP method is used for evaluation road vehicles, for which purpose and for which road vehicle categories the AHP method is applied.

2. The AHP method – methodology

The AHP method is one of the methods of multi-criteria decision-making based on the need to analyse complex problems into a hierarchical structure of specific elements. The elements in the hierarchical structure are the goal, criteria, sub-criteria and alternatives/variants. The first step in solving the problem using the AHP method is developing a model of hierarchical structure. We should make a decision or the goal that the decision is to achieve and is at the top of the hierarchical model.

The problem structuring process is followed by a second step, which involves comparing attribute pairs at each hierarchical level, depending on each higher-level attribute. In this step, the decision-maker assigns grades to each pair of attributes at each hierarchical level. It is not enough to define only the preference of the alternative, but it is also necessary to determine the weight of the importance.

The AHP method for determining the weights of preferences uses ratio scales, of which the most well-known and most commonly used is the Saaty scale. The relative importance of criteria and subcriteria concerning the research objective are defined and ranked by Saaty scale of pairwise comparison. This scale consists of nine intensities of importance, five primary (1, 3, 5, 7, 9) and four intermediate (2, 4, 6, 8). The meanings of each intensity of importance are 1 – equal importance, 2 – weak or slight, 3 – moderate importance, 4 – moderate plus, 5 – strong importance, 6 – strong plus, 7 – very strong or demonstrated importance, 8 – very, very strong, 9 – extreme importance. This weighting should continue until the final priorities of the alternatives in the bottom level are obtained [8, 28].

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After the hierarchical structure in each node, using the Saaty scale to assess the relative importance of the elements of each level of the hierarchical structure of the problem, the local priorities of criteria, subcriteria and variants are calculated, which will ultimately be synthesised into overall alternative priorities. From the assessments of the relative importance of the elements of the appropriate level of the hierarchical structure of the problem, the local weights of the criteria and sub-criteria are calculated, and at the last level, the priorities of the alternatives.

The best alternative is selected based on the defined total weight priority vector by synthesising all weight vectors, and the following expression describes it:

$$W_i = \sum_{j=1}^{n} c_j w_{ij}, \quad \forall i = 1,\ldots,m \tag{1}$$

where:

W_i – weight, priority of alternative i,
c_j – weight of criterion j (j = 1, 2, ..., n),
w_{ij} – weight of alternative i regarding criterion j,
m – number of alternatives,
n – number of criteria.

The next step is to check the consistency. Saaty proved that for the consistent reciprocal matrix, the largest eigenvalue equals the number of comparisons or $\lambda_{max} = n$. Then he defined a measure of consistency, called the consistency index (CI), which indicates the deviation or degree of consistency using the following formula

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{2}$$

The CI should be compared with the corresponding random index (RI). Saaty randomly generated reciprocal matrices using scale and calculated the RI (Table 1).

Tab. 1. Random index determination table RI

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

The consistency ratio (CR) compares the CI with RI:

$$CR = \frac{CI}{RI} \tag{3}$$

If CR is smaller or equal to 10%, the inconsistency is acceptable. If CR is greater than 10%, the preference needs to be revised.

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3. Research methodology

The research methodology is based on searching and analysing scientific papers in the field of road transport. The AHP method evaluates project alternatives, alone or in combination with another method, depending on the application area. The platforms through which scientific papers were searched are the Web of Science and Scopus databases. The publishers on whose websites the papers were searched are Science Direct, Taylor & Frances and Springer. The search was performed in such a way that the searched keywords, titles of articles and abstracts of scientific papers contained the terms: "AHP", "Analytical Hierarchy Process", "road", "transport", and "traffic". The search results obtained in the title, keyword list, and summary contain some of the search terms given by the search, but this does not place them in the area to be explored by this analysis. Each of the selected works potentially related to the AHP method or road traffic was analysed in more detail, and results that contained the word "vehicle" were additionally singled out. Many papers, including some of the key terms such as road and AHP in keywords, titles or contents, do not belong to the field of road traffic but refer to another area of research. As such, papers are not included in the analysis.

4. Results

4.1. Classification of research by areas of application

To analyse the application of the AHP method in road traffic, 180 scientific papers from 2014 to 2021 were selected and analysed. All these scientific papers relate to road traffic but different areas of application in road traffic. A more detailed analysis identified areas of application within road transport and categorised them into eight areas of application, namely: infrastructure, vehicles, logistics, human factor, safety, transport network, public transport and ecology. Further analysis of the papers revealed that many papers in the field of application fall into several different areas of application simultaneously. For such works, the classification dec was made based on the goal to be achieved by scientific research. The type of scientific papers by fields of application is shown in Figure 1.

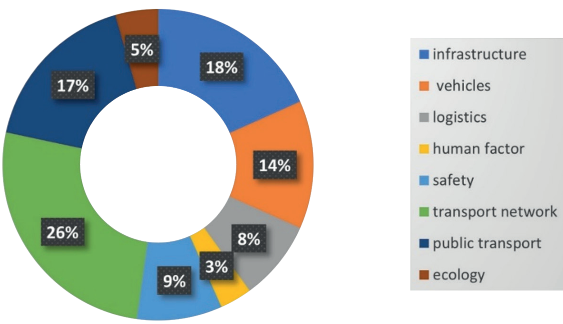

Fig. 1. Classification of research by areas of application

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4.2. Distribution of research about publishers and year of publication

The methodology of this research was conducted so that the databases of Springer, Taylor & Frances and ScienceDirect were searched. In addition to publishers' pages, scientific papers were searched and analysed on the Web of Science and Scopus websites, which are databases containing scientific papers from many publishers. Many papers published by these three publishers also appear on the pages of these databases. Still, they are classified for research purposes as papers published by publishers to gain helpful insight into distributing scientific papers in scientific journals. Figure 2. shows the distribution of analysed scientific papers by publishers in the field of application (road vehicles). The distribution of the researched scientific papers according to the years of publication is shown in Figure 3, which shows an upward trend in applying the AHP method for the evaluation of projects related to road vehicles.

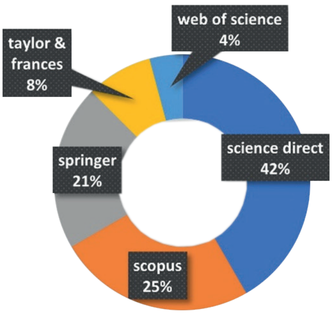

Fig. 2. Distribution of analysed scientific papers by the publisher in the field of application

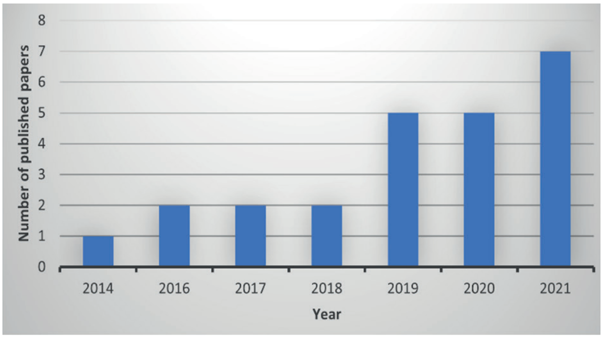

Fig. 3. Distribution of analysed papers in the field of road vehicles applications by years of publication

4.3. Application of the AHP method for the field of road vehicles

Road motor vehicles are used to transport people and goods. The modern development of road transport is oriented towards improving elements that affect traffic safety and reduce emissions. The analysed scientific papers in which the AHP method was applied are mostly related to electric vehicles and vehicles that have autonomous control systems. Analysed scientific papers in road transport in which the AHP method was used are listed in Table 2.

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Tab. 2. Selected ana and scientific papers in the field of road transport vehicles

No.	Authors	Title of the paper	Publisher	Journal	Year
1	James, Ajith Tom Vaidya, Dhruval Sodawala, Mustufa Verma, Sunny	Selection of Bus Chassis for Large Fleet Operators in India: An AHP-TOPSIS Approach	Science Direct	Expert Systems with Applications	2021
2	Sonar, Harshad Chandrakant Kulkarni, Sourabh Devidas	An Integrated AHP-MABAC Approach for Electric Vehicle Selection	Science Direct	Research in Transportation Business & Management	2021
3	Bakioglu, Gozde Atahan, Ali Osman	AHP Integrated TOPSIS and VIKOR Methods with Pythagorean Fuzzy Sets to Prioritize Risks in Self-Driving Vehicles	Science Direct	Applied Soft Computing	2021
4	Patil, Mallikarjun Majumdar, Bandhan Bandhu	An Investigation on the Key Determinants Influencing Electric Two-Wheeler Usage in Urban Indian Context	Science Direct	Research in Transportation Business & Management	2021
5	Lei, Fei Lv, Xiaojiang Fang, Jianguang Li, Qing Sun, Guangyong	Nondeterministic Multi-Objective and Multi-Case Discrete Optimization of Functionally-Graded Front-Bumper Structures for Pedestrian Protection	Science Direct	Thin-Walled Structures	2021
6	Abdel-Basset, Mohamed Gamal, Abduallah Moustafa, Nour Abdel-Monem, Ahmed El-Saber, Nissreen	A Security-By-Design Decision-Making Model for Risk Management in Autonomous Vehicles	Scopus	IEEE Access	2021
7	Gilbert, Alex Petrovic, Dobrila Pickering, James E. Warwick, Kevin	Multi-Attribute Decision Making on Mitigating a Collision of an Autonomous Vehicle on Motorways	Science Direct	Expert Systems with Applications	2021
8	Fabianek, Paul Will, Christian Wolff, Stefanie Madlener, Reinhard	Green and Regional? A Multi-Criteria Assessment Framework for the Provision of Green Electricity for Electric Vehicles in Germany	Science Direct	Transportation Research Part D: Transport and Environment	2020
9	Karasan, Ali Kaya, İhsan Erdoğan, Melike Budak, Ayşenur	Risk Analysis of the Autonomous Vehicle Driving Systems by Using Pythagorean Fuzzy AHP	Springer	Intelligent and Fuzzy Techniques in Big Data Analytics and Decision Making	2020
10	Dogan, Onur Deveci, Muhammet Canıtez, Fatih Kahraman, Cengiz	A Corridor Selection for Locating Autonomous Vehicles Using an Interval-Valued Intuitionistic Fuzzy AHP and TOPSIS Method	Springer	Soft Computing	2020
11	Obeidat, Mohammed Said Altheeb, Nadah Faris Momani, Amer Al Theeb, Nader	Analyzing the Invisibility Angles Formed by Vehicle Blind Spots to Increase Driver's Field of View and Traffic Safety	Taylor & Frances	International Journal of Occupational Safety and Ergonomics	2020
12	Dieguez, Teresa Corcetti, L. Silva, F. J.G. Campilho, R. D.S.G. Ferreira, L. P.	How Can Technology on the Automotive Industry Save the Future?	Science Direct	Procedia Manufacturing	2020
13	Biswas, Tapas Kumar Das, Manik Chandra	Selection Of Commercially Available Electric Vehicle Using Fuzzy AHP-MABAC	Springer	Journal of The Institution of Engineers (India): Series C	2019
14	Anis, Summair Csiszar, Csaba	Management of Potential Conflicts Between Pedestrians and Autonomous Vehicles	Scopus	Smart Cities Symposium Prague, SCSP	2019
15	Askary, Zareef Singh, Abhishek Gupta, Sumit Shukla, R. K. Jaiswal, Piyush	Development of AHP Framework of Sustainable Product Design and Manufacturing of Electric Vehicle	Springer	Advances in Engineering Design	2019
16	Akti, Sercan Celikoglu, Hilmi Berk	An Integrated Decision Making Framework for Vehicle Selection in Shuttle Services: Case of a University Campus	Scopus	6th International Conference on Models and Technologies for Intelligent Transportation Systems	2019
17	Hu, Zongmei	Construction and Experimental Study on Subjective Evaluation System of Braking Performance of New Energy Vehicle ABS System	Scopus	IOP Conference Series: Materials Science and Engineering	2019
18	Erbaş, Mehmet Kabak, Mehmet Özceylan, Eren Çetinkaya, Cihan	Optimal Siting of Electric Vehicle Charging Stations: A GIS-Based Fuzzy Multi-Criteria Decision Analysis	Science Direct	Energy	2018
19	Gupta, Siddharth Ahuja, Gunjar Kumar, Girish	Identification of Optimum Locations for Charging of Electric Vehicles	Scopus	7th International Conference on Reliability, Infocom Technologies and Optimization: Trends and Future Directions, ICRITO	2018
20	Osorio-Tejada, Jose Luis Llera-Sastresa, Eva Scarpellini, Sabina	A Multi-Criteria Sustainability Assessment for Biodiesel and Liquefied Natural Gas as Alternative Fuels in Transport Systems	Science Direct	Journal of Natural Gas Science and Engineering	2017
21	Almeida, Fernando Silva, Pedro Leite, João	Proposal of a Carsharing System to Improve Urban Mobility	Scopus	Theoretical and Empirical Researches in Urban Management	2017
22	Kristina, Jakimovska Čedomir, Duboka Dimitar, Karastoyanov	Application of Fuzzy Topsis and Ahp Method in Evaluating Vehicle Roadworthiness Performance	Springer	Proceedings of the European Automotive Congress EAEC-ESFA	2016
23	Ahmed, Shameem Ahmed, Shamsuddin Shumon, Md Rezaul Hasan Falatoonitoosi, Elham Quader, M. Abdul	A Comparative Decision-Making Model for Sustainable End-Of-Life Vehicle Management Alternative Selection Using AHP and Extent Analysis Method on Fuzzy AHP	Taylor & Frances	International Journal of Sustainable Development & World Ecology	2016
24	Chen, Jiajia Zhao, Pan Liang, Huawei Mei, Tao	A Multiple Attribute-Based Decision Making Model for Autonomous Vehicle in Urban Environment	Web of Science	IEEE Intelligent Vehicle Symposium Proceedings	2014

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5. Discussion and conclusion

The AHP method is one of the most frequently used multi-criteria decision-making methods to solve transport and traffic problems. This paper aimed to analyse the application of the AHP method in evaluating projects in road transport, especially in the field of application related to road motor vehicles. The number of 180 scientific papers in road transport from 2014 to 2021, which apply the AHP method as a method for decision making, were analysed. Out of all 180 analysed studies in the area of traffic and transport, 24 are specifically related to road motor vehicles. An in-depth analysis of the above papers showed that the AHP method is used mainly in electric and autonomous vehicles.

The large number of road vehicles that have started to appear on the market of new vehicles represent an excellent opportunity to apply the method of multi-criteria decision-making to select an adequate model for purchase [9, 30]. The promotion of electric vehicles is considered a critical aspect of government policy to move to a green mobility system to reduce vehicle emissions and meet the challenges of sustainable energy development in the transport sector. The AHP framework is developed for the sustainable product design and manufacturing of electric vehicles [6]. The analysis of the transition to two-wheel electric vehicles in areas where motorcycles and motor-powered mopeds are used in large numbers for vehicles is presented in [27]. The AHP method was used to identify critical criteria for policy interventions to prove electric motorcycles and mopeds as an attractive alternative. The AHP method is used to point out the best model of vehicle to help reduce the amount of pollutant gas emission and contribute to public policy decision making [12]. A significant and unavoidable problem associated with electric vehicles is the charging network for electric vehicles. Developing a charging station network for electric vehicles is extremely work demanding and requires detailed analysis and research to determine the adequate number of charging stations and their position on the transport network. Positioning filling stations on the transport network is in itself a demanding task. In addition, decisions on the number of filling stations and whether they will meet the capacity require detailed analysis and good planning. In papers [14, 15, 17], the AHP method is used to adequately develop the charging station network for electric vehicles and their number, acc and safety.

Vehicles with a self-driving system are critical to a future sustainable transport system, which is expected to become widespread worldwide. A significant amount of risk is associated with vehicles with a self-driving system and need to be effectively considered by decision-makers. Given that automated driving technology and how they interact with the transport system are hazardous, it is necessary to adequately address the risks associated with self-driving vehicles. There is no identification review that fully takes into account all types of risks related to vehicles that have a self-driving system. In response to this lack of knowledge, many scientific papers aim to prioritise analyzing all the risks associated with self-driving vehicles. Risk prioritisation is a complex problem of multi-criteria decision-making that requires the application of a multi-criteria method, i.e. the AHP method, to consider several possible variants and conflicting criteria [1, 7]. In addition, paper [21] deals with the risk analysis of autonomous vehicle driving systems. The collisions of an autonomous vehicle on motorways are analysed in [16] and

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in urban areas in [10]. To prevent the risk or at least reduce it to the lowest possible level, it is necessary to determine its causes. Pedestrians are the most vulnerable road users. Identification, prioritization, and management of conflict situation types between autonomous vehicles and pedestrians by using the AHP method are researched in [5].

The construction of means of transport is highly complex and consists of many systems of components that work in harmony so that the means of transport can function adequately. Scientific works related to the optimisation and reconstruction of some of the construction systems of vehicles are highly complex and require detailed analyses. The application of the AHP method in scientific papers that seek to successfully analyse some of the structural elements of vehicles has proven to be a suitable method [19, 20, 23]. Analysis of alternative fuels for vehicles is described in [26]. The AHP method is applied for the evaluation of vehicle performance such as roadworthiness performance, vehicle performance [22], end-of-life vehicle management [2] and traffic safety such as invisibility angles formed by vehicle blind spots [25]. The AHP method proved to be helpful for the decision making of the car-sharing system [4] and the shuttle service [3]. This analysis showed that the AHP method has a wide range of applications not only in transport but in the specific field of road vehicles.

In some studies, the AHP method has been applied in combination with other multicriteria decision-making methods, such as TOPSIS and VIKOR [7, 13].

The analysis of scientific papers established that the AHP method is used in different areas and for evaluating different types of data. Transport and road traffic project planning cover various scientific fields. Among the analysed projects, it is evident that the AHP method is used in projects related to infrastructure, road motor vehicles, safety, ecology, public transport. For these projects to be evaluated appropriately, there are criteria and sub-criteria that need to be weighed. For such projects, the AHP method has proven to be suitable, and for this reason, it is increasingly used for the evaluation of projects in road transport. Transport as a scientific discipline is closely related to other scientific fields such as construction, architecture, mechanical engineering, economics, geodesy, law, informatics, etc. Thus, it is evident that large road transport projects in the process of planning or analysing relate to the areas of expertise of some other scientific disciplines; for this reason, to make crucial decisions, it is necessary to apply adequate methods that allow the application of many criteria for decision making. More frequent application of the AHP method to evaluate projects in road transport seeks to solve the problem of choosing the optimal variant based on the evaluation of a large number of criteria related to decision-making in projects related to road transport.

The limitation in this research primarily relates to the fact that the papers were searched only by the terms "vehicle" and "AHP" in the title and keywords. It is possible to assume that there are several papers in which the AHP method was applied in road motor vehicles. Still, they did not contain "vehicle" and "AHP" in the title and keywords and thus were not included in the analysis. Future research should aim to expand our in-depth analysis of all possible research not only by keywords and title but also by content. This would provide a more detailed basis for applying the AHP method in the field of road motor vehicles. In addition, it should be noted that some papers may have used

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the full name of the "Analytic Hierarchy Process" method instead of the abbreviation "AHP". Therefore, future research should aim to expand our research to a broader range of research papers.

6. References

[1] Abdel-Basset M., Gamal A., Moustafa N., Abdel-Monem A., El-Saber N.: A Security-by-Design Decision-Making Model for Risk Management in Autonomous Vehicles. IEEE Access. 2021, 9, 107657–107679, DOI: 10.1109/ACCESS.2021.3098675.

[2] Ahmed S., Ahmed S., Shumon M.R.H., Falatoonitoosi E., Quader M.A.: A comparative decision-making model for sustainable end-of-life vehicle management alternative selection using AHP and extent analysis method on fuzzy AHP. International Journal of Sustainable Development & World Ecology. 2016, 23(1), 83–97, DOI: 10.1080/13504509.2015.1062814.

[3] Akti S., Celikoglu H.B.: An Integrated Decision-Making Framework for Vehicle Selection in Shuttle Services: Case of A University Campus. 6th International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS). Cracow, Poland, 2019, DOI: 10.1109/MTITS.2019.8883389.

[4] Almeida F., Silva P., Leite J.: Proposal of a carsharing system to improve urban mobility. Theoretical and Empirical Researches in Urban Management. 2017, 12(3), 32–44.

[5] Anis S., Csiszar C.: Management of Potential Conflicts between Pedestrians and Autonomous Vehicles. Smart City Symposium Prague (SCSP). Czech Republic, 2019, DOI: 10.1109/SCSP.2019.8805678.

[6] Askary Z., Singh A., Gupta S., Shukla R.K., Jaiswal P.: Development of AHP framework of sustainable product design and manufacturing of the electric vehicle. Lecture Notes in Mechanical Engineering. 2019, 415–422, DOI: 10.1007/978-981-13-6469-3_37.

[7] Bakioglu G., Atahan A.O.: AHP integrated TOPSIS and VIKOR methods with Pythagorean fuzzy sets to prioritise risks in self-driving vehicles. Applied Soft Computing. 2021, 99, 106948, DOI: 10.1016/J.ASOC.2020.106948.

[8] Barić D., Pilko H., Strujić J.: An analytic hierarchy process model to evaluate road section design. Transport. 2016, 31(3), 312–321, DOI: 10.3846/16484142.2016.1157830.

[9] Biswas T.K., Das M.C.: Selection of Commercially Available Electric Vehicle using Fuzzy AHP-MABAC. Journal of The Institution of Engineers (India): Series C. 2019, 100(3), 531–537, DOI: 10.1007/S40032-018-0481-3.

[10] Chen J., Zhao P., Liang H., Mei T.: A Multiple Attribute-Based Decision Making Model for Autonomous Vehicle in Urban Environment. IEEE Intelligent Vehicles Symposium Proceedings. USA, 2014, 480–485, DOI: 10.1109/IVS.2014.6856470.

[11] Dzemydiene D., Burinskiene A., Miliauskas A.: Integration of Multi-Criteria Decision Support with Infrastructure of Smart Services for Sustainable Multi-Modal Transportation of Freights. Sustainability. 2021, 13(9), 4675, DOI: 10.3390/su13094675.

[12] Dieguez T., Corcetti L., Silva F.J.G., Campilho R.D.S.G., Ferreira L.P.: How can technology on the automotive industry save the future? Procedia Manufacturing. 2020, 51, 1763–1772, DOI: 10.1016/J.PROMFG.2020.10.245.

[13] Dogan O., Deveci M., Canıtez F., Kahraman C.: A corridor selection for locating autonomous vehicles using an interval-valued intuitionistic fuzzy AHP and TOPSIS method. Soft Computing. 2020, 24(12), 8937–8953, DOI: 10.1007/S00500-019-04421-5.

[14] Erbaş M., Kabak M., Özceylan E., Çetinkaya C.: Optimal siting of electric vehicle charging stations: A GIS-based fuzzy Multi-Criteria Decision Analysis. Energy. 2018, 163, 1017–1031, DOI: 10.1016/J.ENERGY.2018.08.140.

[15] Fabianek P., Will C., Wolff S., Madlener R.: Green and regional? A multi-criteria assessment framework for the provision of green electricity for electric vehicles in Germany. Transportation Research Part D: Transport and Environment. 2020, 87, 102504, DOI: 10.1016/J.TRD.2020.102504.

[16] Gilbert A., Petrovic D., Pickering J.E., Warwick K.: Multi-attribute decision making on mitigating a collision of an autonomous vehicle on motorways. Expert Systems with Applications. 2021, 171, 114581, DOI: 10.1016/J.ESWA.2021.114581.

[17] Gupta S., Ahuja G., Kumar G.: Identification of Optimum Locations for Charging of Electric Vehicles. 7th Int Conf Reliab Infocom Technol Optim Trends Futur Dir ICRITO. 2018, 867–72, DOI: 10.1109/ICRITO.2018.8748280.

DOI: https://doi.org/10.14669/AM.VOL94.ART2

[18] Henke I., Carteni A., Molitierno C., Errico A.: Decision-Making in the Transport Sector: A Sustainable Evaluation Method for Road Infrastructure. Sustainability. 2020, 12(3), 764, DOI: 10.3390/su12030764.

[19] Hu Z.: Construction and Experimental Study on Subjective Evaluation System of Braking Performance of New Energy Vehicle ABS System. IOP Conference Series: Materials Science and Engineering. 2019, 677(5), 052102, DOI: 10.1088/1757-899X/677/5/052102.

[20] James A.T., Vaidya D., Sodawala M., Verma S.: Selection of bus chassis for large fleet operators in India: An AHP-TOPSIS Approach. Expert Systems with Applications. 2021, 186, 115760, DOI: 10.1016/J.ESWA.2021.115760.

[21] Karasan A., Kaya İ., Erdoğan M., Budak A.: Risk analysis of the autonomous vehicle driving systems by using pythagorean fuzzy AHP. Advances in Intelligent Systems and Computing. 2020, 1029, 926–934, DOI: 10.1007/978-3-030-23756-1_110.

[22] Kristina J., Čedomir D., Dimitar K.: Application of Fuzzy Topsis and Ahp Method in Evaluating Vehicle Roadworthiness Performance. Proceedings of the European Automotive Congress EAEC-ESFA 2015, 2016, 69–79, DOI: 10.1007/978-3-319-27276-4_7.

[23] Lei F., Lv X., Fang J., Li Q., Sun G.: Nondeterministic multi-objective and multi-case discrete optimisation of functionally-graded front-bumper structures for pedestrian protection. Thin-Walled Structures. 2021, 167, 106921, DOI: 10.1016/J.TWS.2020.106921.

[24] Meyer M.D., Miller E.J.: Urban Transportation Planning: A Decision–Oriented Approach, McGraw-Hill Series in Transportation, 1984.

[25] Obeidat M.S., Altheeb N.F., Momani A., Al Theeb N.: Analysing the invisibility angles formed by vehicle blind spots to increase driver's field of view and traffic safety. International Journal of Occupational Safety and Ergonomics. 2020, DOI: 10.1080/10803548.2020.1807126.

[26] Osorio-Tejada J.L., Llera-Sastresa E., Scarpellini S.: A multi-criteria sustainability assessment for biodiesel and liquefied natural gas as alternative fuels in transport systems. Journal of Natural Gas Science and Engineering. 2017, 42, 169–186, DOI: 10.1016/J.JNGSE.2017.02.046.

[27] Patil M., Majumdar B.B.: An investigation on the key determinants influencing electric two-wheeler usage in urban Indian context. Research in Transportation Business & Management. 2021, 100693, In Press, DOI: 10.1016/J.RTBM.2021.100693.

[28] Saaty T.L.: Transport Planning with Multiple Criteria - the Analytic Hierarchy Process Applications and Progress Review. Journal of Advanced Transportation. 1995, 29(1), 81–126, DOI: 10.1002/atr.5670290109.

[29] Saaty R.W.: The analytic hierarchy process - What it is and how it is used. Mathematical Modelling. 1987, 9(3-5), 161–176, DOI: 10.1016/0270-0255(87)90473-8.

[30] Sonar H.C., Kulkarni S.D.: An Integrated AHP-MABAC Approach for Electric Vehicle Selection. Research in Transportation Business & Management. 2021, 100665, In Press, DOI: 10.1016/J.RTBM.2021.100665.