APPLICATION OF MULTICRITERIA DECISION-MAKING METHODS IN THE ROAD CONSTRUCTION AND MAINTENANCE PROJECT MANAGEMENT

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ABSTRACT

Decision-making process is structural and inseparable part of construction project management as a series of related activities aimed at achieving the set goals. The complex nature of construction projects, the large number of involved stakeholders, conflicting goals and interests make the decision-making process in the construction field poorly structured problems that are effectively solved by applying different multicriteria decision-making methods. In this paper is presented a bibliometric review of Web of Science (WOS) database related to the using of multicriteria decision-making methods in construction project management in general, with a special emphasis on the management of road construction and maintenance projects, an analysis of different unique and hybrid approaches to multicriteria decision-making, as well as guidelines for future research.

KEYWORDS

Construction, Project management, Decision-making, Multicriteria methods, Road construction, Maintenance, Bibliometric analysis.
1. INTRODUCTION

Decision making support is the key to the success of construction projects because successful construction project management can solely be achieved with an effective decision-making process throughout the entire project life cycle. The dynamic nature, uncertainty, the occurrence of risks, the large number of stakeholders involved, different interests and goals are just some of the reasons for the complexity of construction projects. These facts about the nature of the construction project make decision-making at any stage of its life cycle complex and poorly structured problems (Jajac et al., 2015). In order to cope with this complexity, project managers indispensable establish a decision support system (DSS) based on multi-criteria decision-making (MCDM) methods.

Due to accelerated development of modern cities, increasing traffic congestion and the need for urban expansion, the authorities are increasingly faced with the problem of managing road construction and maintenance projects in urban and nonurban areas as a special type of construction projects. Road infrastructure projects are among the most expensive investment projects that depend on many technical, economic, social, spatial and environmental aspects in which the choice of the most favorable solution is almost impossible without the application of multicriteria analysis. Road maintenance is regularly carried out under conditions of limited financial resources, and in order to maintain their durability, serviceability and quality, it is particularly important to plan the investment of the provided funds according to the priority maintenance rank. Therefore, multicriteria decision-making (MCDM) methods are increasingly used both in construction project management in general and in the management of road construction and maintenance projects.

In this regard, this paper aims to present a comprehensive review of the worldwide literature through bibliometric analysis of the collected data creating in that way a quality basis for new research that can improve existing knowledge and models of road construction and maintenance project management. For easier understanding of the research subject, the general concept and classification of multicriteria decision-making (MCDM) methods are presented in the continuation of this paper.

1.1 General concept, distribution and classification of multicriteria decision-making (MCDM) methods

Successful management of the previously described projects depends on the quality of the decisions made, and the decision-making process itself depends on the availability of information, which must be timely and accurate. In order to enable each member of the project team to deliver the necessary information in a timely manner and to reduce uncertainty when making decisions, today the previously mentioned decision support systems (DSS) are increasingly being used. The development of decision support systems was simultaneously accompanied by the development of multicriteria and multi-attribute decision-making, i.e. the development of multi-criteria analysis, which according to Cinelli et al. (2020) defines as the process of ranking alternative solutions based on multiple criteria by creating a preference model.
Despite the fact that each problem of multicriteria decision-making is unique and requires a special approach to its solution, the general concept of multicriteria decision-making methods consists of seven steps, among which are the establishment of a decision-context, definition of objectives and criteria, identification of alternatives, development of the performance matrix, selection and application of a suitable decision-making method, determination of criteria weights and interpretation of the results and application of sensitivity analysis (Yannis et al., 2020).

In the relevant literature, it is possible to find different classifications of multicriteria decision-making methods. According to Zhu et al. (2019) multicriteria decision-making methods can be divided into pairwise comparison methods, distance (ratio) to reference point methods, outranking-based methods, multiple attribute utility functions, fuzzy set methods and their variants. In accordance with the aforementioned classification, the basic settings of the most well-known methods of multicriteria decision-making within individual classification groups are briefly presented in the continuation of this paper.

**Pairwise comparisons methods**

Analytical Hierarchy Process (AHP) as the best-known method of pairwise comparison is gaining more and more attention as a technique for analyzing complex situations and making correct decisions (Darko et al., 2019). The AHP method was developed by Thomas L. Saaty in 1970, and was presented in 1980 as a method that includes both qualitative and quantitative criteria in the decision-making (Saaty, 1980). The reason for the popularity of this method is its ability to reflect the way people think and make decisions by simplifying the decision problem. Complex and unstructured decision-making problems are broken down into their constituent parts within a hierarchical structure and assigned values according to their relative importance. By synthesizing the results obtained in this way, a priority list is determined in which the variables with the highest priority have the greatest influence on solving the observed problem (Smith and Tighe, 2006; Jajac, 2010).

Despite the many advantages of the AHP method, in 1996 Saaty developed the analytical network process (ANP) method as a generic form of the AHP method that includes network dependence between (Saaty, 1996). Feedback connections within the network enable more precise prioritization and greater accuracy and efficiency of forecasting, although on the other hand, the ANP method is often not possible to use in conditions of uncertainty and risk, and due to its complexity, it requires additional software to solve multicriteria (Lu et al., 2007).

**Distance (ratio) to reference point methods**

The best-known methods based on measuring the distance from the reference point are named as “the technique for order of preference by similarity to ideal solution (TOPSIS)” and “Višekriterijska optimizacija i kompromisno rješenje (VIKOR)”. The TOPSIS method was created in 1981 as a concept for measuring the distance between a positive-ideal and a negative-ideal solution as two hypothetical solutions (Benayoun, Roy i Sussman, 1966). In
that case, the optimal solution to the multicriteria decision-making problem is the solution with the smallest distance from the positive ideal solution and the largest distance from the negative ideal solution (Opricović, 1986).

VIKOR is a frequently used method for solving various decision-making problems, especially those that depend on a large number of quantitative (Azhar et al., 2021). As such, the VIKOR method is focused on the selection of alternatives and their ranking in relationship with conflicting criteria. Since there is no alternative that satisfies all observed criteria at the same time, the goal of this method is to find an acceptable compromise solution closest to the ideal solution.

**Outranking-based methods**

The ELECTRE method was created in 1966 as a response to shortcomings in the application of other multicriteria decision-making methods (Hwang i Yoon, 1981). This method was later renamed the ELECTRE I method and as such is used today in making decisions with maximum advantages and minimum conflicts in function of various criteria. After that various variants of this method were developed among that ELECTRE I, ELECTRE IV, and ELECTRE IS as methods commonly used for solving selection problems, ELECTRE II, ELECTRE III, ELECTRE IV, and ELECTRE SS used for solving ranking problems, while ELECTRE TRI is a well-known method for solving sorting problems. All listed variants of ELECTRE the methods are based on the same concept, and are applied depending on the problem of multicriteria decision making (Brans et al., 1984).

Along with the ELECTRE, the PROMETHEE method is one of the most famous methods that belong to this classification group. The concept of the PROMETHEE method is based on the comparison of different variant solutions based on defined qualitative and quantitative criteria by applying one of the six preferential functions. As with the ELECTRE method, the PROMETHEE method has several variants, and the choice of a particular variant depends on the type of decision (Huang et al., 1984). PROMETHEE I is a variant of the PROMETHEE method that enables a partial ranking of variant solutions, while the PROMETHEE II method provides a total ranking of alternative solutions based on positive or negative preference flows that show how dominant some variant solutions are in relation to others. In parallel with these variants, the PROMETHEE III method was developed, in which the ranking of alternative solutions is based on intervals, then the PROMETHEE IV method, which is intended for solving continuous decision-making problems, and the PROMETHEE V method, which is a combination of the PROMETHEE II method and integer programming, applying a set of defined constraints when defining the final solutions to the observed problem.

**Multiple attribute utility functions**

Based on the construction of an expression that represents the decision maker's preference based on the utility function, the representative methods of this classification group are the method of simple additive weighting (SAW) and multi-attribute utility theory (MAUT) (Zhu, Meng and Min, 2019). The SAW method was introduced in 1968 as one of the simplest methods of multi-attribute decision-making, which is used to evaluate a number of
alternatives in relation to defined decision-making criteria, and as such is particularly suitable when the defined criteria are mutually independent. In 1972 the multi-attribute utility theory (MAUT) based on assigning the utility of each possible consequence and determining the greatest possible utility was created. Unlike other multicriteria decision-making methods, by assigning utility in such a way MAUT enables decision-making in conditions of uncertainty. While among the disadvantages of this method, the need for a large amount of input data and high precision in the decision-maker's preferences can be highlighted (Yannis et al., 2020).

Based on the presented concept and classification of multicriteria decision-making methods, the research methodology is described in detail in the continuation of this paper which aims to provide a comprehensive overview of the application of the described methods in construction project management and road construction and maintenance projects, the shortcomings of previous research and possible directions for future research.

2. RESEARCH METHODOLOGY

In order to present a comprehensive overview of the application of the previously described multicriteria decision-making (MCDM) methods, this research begins in the wider field of construction and narrows down to the application of MCDM methods in construction project management and more precisely in road construction and maintenance projects, as shown in Figure 1.

A systematic literature review chosen for research method requires the formulation of research questions and a detailed explanation of all research steps that provide answers to
the questions posed (Denyer and Tranfield, 2009). For this purpose, the following research questions were formulated:

- What is the application of multi-criteria decision-making methods in construction project management?
- What approaches to multicriteria decision-making in road construction and maintenance management can be found in the relevant literature?

In order to find answers to the formulated questions, the adopted research methodology consists of a total of six steps, among which are the definition of the research questions, the selection of the search base, the definition of the search limits for the application of multi-criteria methods in the field of construction in general, the adaptation of the limits to the field of construction project management, focusing the research on road construction and maintenance projects and at the end the selection of several papers (a total of 20 papers which, according to the author, can show the general situation) and their detailed analysis according to the different approaches to multi-criteria decision-making that are used in them. The described methodology is shown in Figure 2.
In this research, the Web of Science database was used as one of the largest and highest quality databases of relevant scientific data. On the basis of the collected data, a quantitative review of the literature obtained by bibliographic analysis with the help of the VosViewer.
software is given in the continuation of the work. The collected data are visually presented in order to facilitate the perception of the current state of the observed scientific field.

3. RESEARCH RESULTS

3.1 Overview of the application of MCDM methods in Construction Project Management

Based on the previously presented research methodology, a bibliometric analysis of 634 articles found in the field of construction project management will be presented below in order to show trends in this research topic. The resulting search string containing the Boolean operators in this phase of research included following: "decision" AND “support” AND “system” AND “2010/2022” AND “project management".

Figure 3 shows the distribution of found works according to the years of publication, where it is possible to observe a significant increase in the number of researches in this area from 2010 to the present. The largest number of papers was published during 2020 and 2021, which indicates a positive trend and the needs for research in the observed area.

![Figure 3. Distribution papers by publication year](image)

The obtained results of bibliometric analysis show an increasing presence of DSS in civil engineering, construction building technology and management which can be seen from Figure 4 that shows the distribution of analyzed papers by Web of Science categories.
Among the types of analyzed publications, the most represented are articles (303 publications, 80%), followed by proceeding papers (56 publications, 15%), early access (10 publications, 3%) and finally book chapters (3 publications) and review articles (6 publications) in the smallest share of 1% (Figure 5).

Using VOSviewer software in Figure 6 visualization of keywords in this area of research is shown. The main keywords are shown in rectangles where the rule is that the larger the rectangle, the more often the keyword appears in the set of WOS publications.
In Table 1, is presented analysis of publications in the field of MCDM application in construction project management where it can be seen that this topic is most interesting to researchers in Iran in the share of 15.01% of the total number of found publications, followed by China with a share of 11.2%, Lithuania with 7.6%, USA with 7.12%, Spain with 5.09% and other countries.

Table 1. Distribution of the analyzed papers by countries

<table>
<thead>
<tr>
<th>ID</th>
<th>Country</th>
<th>Publications</th>
<th>Citations</th>
<th>Total link strenght</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Iran</td>
<td>59</td>
<td>559</td>
<td>5030</td>
</tr>
<tr>
<td>2</td>
<td>Lithuania</td>
<td>30</td>
<td>1225</td>
<td>3359</td>
</tr>
<tr>
<td>3</td>
<td>R China</td>
<td>44</td>
<td>729</td>
<td>2744</td>
</tr>
<tr>
<td>4</td>
<td>Australia</td>
<td>16</td>
<td>145</td>
<td>1743</td>
</tr>
<tr>
<td>5</td>
<td>USA</td>
<td>28</td>
<td>357</td>
<td>1735</td>
</tr>
<tr>
<td>6</td>
<td>Canada</td>
<td>16</td>
<td>181</td>
<td>1668</td>
</tr>
<tr>
<td>7</td>
<td>Croatia</td>
<td>10</td>
<td>69</td>
<td>511</td>
</tr>
<tr>
<td>8</td>
<td>Egypt</td>
<td>10</td>
<td>78</td>
<td>947</td>
</tr>
<tr>
<td>9</td>
<td>England</td>
<td>15</td>
<td>158</td>
<td>1275</td>
</tr>
<tr>
<td>10</td>
<td>France</td>
<td>5</td>
<td>214</td>
<td>290</td>
</tr>
<tr>
<td>11</td>
<td>Germany</td>
<td>7</td>
<td>97</td>
<td>505</td>
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<tr>
<td>12</td>
<td>Greece</td>
<td>9</td>
<td>89</td>
<td>304</td>
</tr>
<tr>
<td>13</td>
<td>India</td>
<td>12</td>
<td>159</td>
<td>1134</td>
</tr>
<tr>
<td>14</td>
<td>Italy</td>
<td>10</td>
<td>70</td>
<td>566</td>
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<tr>
<td>15</td>
<td>Malaysia</td>
<td>13</td>
<td>98</td>
<td>1242</td>
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<tr>
<td>16</td>
<td>Pakistan</td>
<td>5</td>
<td>28</td>
<td>498</td>
</tr>
<tr>
<td>17</td>
<td>Peru</td>
<td>5</td>
<td>11</td>
<td>1016</td>
</tr>
<tr>
<td>18</td>
<td>Poland</td>
<td>12</td>
<td>62</td>
<td>318</td>
</tr>
</tbody>
</table>
Figure 7. Visualization of citation density of found publications according to authors in VOSviewer software is shown. According to Van Eck and Waltman (2022): “Each point in the item density visualization has a color that indicates the density of items at that point. By default, colors range from blue to green to yellow. The larger the number of items in the neighborhood of a point and the higher the weights of the neighboring items, the closer the color of the point is to yellow. The other way around, the smaller the number of items in the neighborhood of a point and the lower the weights of the neighboring items, the closer the color of the point is to blue”.

By introducing a criterion that filters the found publications only to those whose subject of research is road projects, the answer to the third research question is given by 20 found publications, the detailed analysis of which is presented in the rest of this paper.
3.2 Analysis of different approaches to multicriteria decision-making in the road construction and maintenance project management

The papers found in the last phase of the search are shown in Table 2. For the sake of clarity and analysis of different approaches to multicriteria decision-making in the road construction and maintenance project management, the papers are detailed analysed according to the paper title, publication year, authors, journal in which they were published, and author's country.

Table 2. List of selected papers in field of Application of MCDM in Road Construction and Maintenance Projects

<table>
<thead>
<tr>
<th>No.</th>
<th>Paper Title</th>
<th>Publication Year</th>
<th>Authors</th>
<th>Reference</th>
<th>Journal</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>“Scientific approach using AHP to prioritize low volume rural roads for pavement maintenance”</td>
<td>2022</td>
<td>Nautyal, A.; Sharma, S.</td>
<td>(Nautyal and Sharma, 2022)</td>
<td>“Journal of quality in maintenance engineering”</td>
<td>India</td>
</tr>
<tr>
<td>8</td>
<td>“A hybrid ranking approach based on fuzzy analytical hierarchy process and data envelopment analysis: Road maintenance and transport organization of Iran”</td>
<td>2018</td>
<td>Salehian, F.; Razmi, J.; Jolai, F.</td>
<td>(Salehian et al, 2018)</td>
<td>“Journal of intelligent &amp; fuzzy systems”</td>
<td>Iran</td>
</tr>
<tr>
<td>9</td>
<td>“Study on the Status Evaluation of Urban Road”</td>
<td>2013</td>
<td>Yu, J.F.; Wang, L.; Gong, X.</td>
<td>“Intelligent and integrated”</td>
<td></td>
<td>China</td>
</tr>
<tr>
<td>No.</td>
<td>Title</td>
<td>Year</td>
<td>Authors</td>
<td>Conference/Proceedings</td>
<td></td>
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</tr>
<tr>
<td>1</td>
<td>Intersections Traffic Congestion Base on AHP-TOPSIS Modal</td>
<td></td>
<td></td>
<td>(Yu et al, 2013)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>“Application of analytic hierarchy process (AHP) for sustainable pavement performance management in Qatar”</td>
<td>2021</td>
<td>Sirin, O.; Gunduz, M.; Shamiyeh, M.E.</td>
<td>(Sirin et al, 2021)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>“Planning support concept to implementation of sustainable parking development projects in ancient Mediterranean cities”</td>
<td>2014</td>
<td>Jajac, N.; Marović, I.; Mladineo, M.</td>
<td>(Jajac et al, 2014)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>“A decision support system based on Electre III for safety analysis in a suburban road network”</td>
<td>2014</td>
<td>Francello, G.; Carta, M.; Fadda, P.</td>
<td>(Francello et al, 2014)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>“Comprehensive Evaluation For Urban Public Transport Network Based on TOPSIS”</td>
<td>2020</td>
<td>Gabriel, T.M.; Daniela, R.</td>
<td>(Gabriel and Daniela, 2020)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>“Decision support for management of urban transport projects”</td>
<td>2013</td>
<td>Chen, F.; Wu, Z.H.</td>
<td>(Chen and Wu, 2013)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Including only the previously presented papers a keyword analysis was visualized and shown in Figure 7.

Figure 7. Visualization of keywords for a narrower field of research

The selected papers were further analyzed according to specific approaches to multicriteria decision-making, and they were divided into two groups, depending on whether in the given models a particular method of multicriteria decision-making is applied independently, which represents a unique approach, or it is used in combination with others in the form of a hybrid approach to multicriteria decision-making.

3.2.1 Single Multicriteria Decision - Making Approaches

In single approach to multicriteria decision-making, only one method is self-sufficient for choosing a single optimal solution. Therefore, in the analyzed papers such single approaches are often based on the AHP, ANP, ELECTRE and TOPSIS methods.
AHP

In order to improve pavement performance, extend its life, and reduce pavement maintenance costs, Sirin, Gunduz, and Shamiyeh (2020) use a unique multicriteria decision-making approach based on the AHP method to determine factors affecting pavement construction during the planning, construction, and maintenance phases. By reviewing the literature, the authors identified a total of 29 factors that influence pavement performance, and using the AHP method, they were compared and ranked according to their relative importance.

Road infrastructure during exploitation is exposed to various deterioration processes, which requires an efficient road infrastructure management system in order to maintain the designed performance and ensure the continuous provision of transport services. An integral part of such a road infrastructure management system is a decision support system based precisely on multicriteria decision-making methods. Selih et al. (2008) designed a decision support system for the maintenance, repair and rehabilitation of highways that need to be rebuilt within a given time period based on the AHP method.

In addition to city roads and highways, the development and investment in rural roads has a significant impact on the growth and development of the economies of developing countries. To prioritize rural road investment, Dalal, Mohapatra and Miltra (2010) also proposed a unique multicriteria decision-making approach based on the AHP method to rank the rural roads of Orissa based on their relative importance for meeting regional needs. In the first phase of this research AHP method is used to estimate the quantitative measure of backwardness of the blocks of the region through the block underdevelopment index (BNDI), while in the second phase of the model, the obtained index is used together with other identified criteria to rank the maintenance priorities of individual rural roads.

Nutiyal and Sharma (2020) also presented a multicriteria decision-making approach for prioritizing rural road pavement maintenance through an example of 203 rural roads with light traffic loads in the state of Himachal Pradesh in India. The AHP method was used to determine the relative weight of criterion according to its relative importance, as well as for the final ranking of these roads according to the priority of their maintenance.

ANP

Khahro et al. (2021) designed an economically viable and flexible pavement maintenance management system through which the overall priority ranking was obtained using the Analytical Network Process (ANP) and each ranking was confirmed by sensitivity assessment using the Super Decision tool. The benefit of the proposed model is the inclusion of high-priority parts in maintenance plans, especially where the maintenance budget is limited. Thus, this single multicriteria decision-making model can be of great help to road designers in making better decisions about pavement maintenance management plans.
ELECTRE

With the aim of developing a decision support system (DSS) in road safety planning, Francello, Carta and Fadda (2014) provide a unique approach to the analysis and ranking of critical sections of suburban roads in Sardinia from a safety perspective using the ELECTRE III multicriteria decision-making method. By ranking the sections of the observed highway according to the need for emergency interventions using the ELECTRE III method, a stable solution was obtained, where variations in the weights of the criteria do not lead to significant changes.

Solečka (2014) used ELECTRE III method as one of the most popular methods for ranking alternatives in the integration of the urban public transport system in Krakow. The described ranking used a group of economic, technical, environmental and social criteria.

Gabriel and Daniela (2019) analyzed the technical condition of the road network in Romania using the ELECTRE method. In this case, the ELECTRE method was applied to four sections of the state road with the aim of identifying those sections with the most difficult conditions regarding the technical condition of the road. In this way, the authors propose an efficient approach to achieve a balance between maintenance, repair and rehabilitation activities and activities that can be carried out within the available funds in order to achieve the maximum return on investment.

TOPSIS

Nodrat and Kang (2017) developed a tool for prioritization of maintenance and rehabilitation activities on Afghan roads by considering criteria such index of pavement condition, road width, traffic volume, residential importance as well as maintenance and rehabilitation costs. The presented tool called “Maintenance and Rehabilitation Activity Prioritization (MRAP)” is based on the TOPSIS method and as such serves to generate various databases for further use in ArcGIS.

Chen and Wu (2013) proposed a comprehensive urban public transportation network assessment approach based on the TOPSIS method used to build an urban public transportation network assessment model. The evaluation model of the urban public transport network based on TOPSIS is very objective, includes several parameters, is easy to operate, scientific assessment and as such provides an excellent basis for deciding on the planning of the urban public transport network.

Due to certain shortcomings of the traditional TOPSIS method developed by Hwang and Yoon in 1981, Shuai and He (2012) tested an improved TOPSIS method for asphalt pavement performance evaluation. The main feature of the improved TOPSIS method is the use of the vertical distance between the evaluation object and the computation of the positive ideal solution as the basis for ranking the alternatives instead of the Euclidean distance. In this case too, the improved TOPSIS method resulted in an overall ranking of asphalt pavement maintenance priorities through a unique multicriteria decision-making approach.
3.2.2 Hybrid Multicriteria Decision - Making Approaches

Since often one method of multicriteria decision-making is not able to provide an overall ranking of priorities, and in order to avoid the shortcomings of only one used method of multicriteria decision-making, it is most often combined with others, creating hybrid approaches of multicriteria decision-making. Therefore, in the continuation of the paper, an overview of various combinations of multicriteria decision-making methods used in the management of construction and maintenance of road infrastructure will be given.

DELPHI + AHP

Khademi and Sheikholeslami (2010) designed a hybrid approach for prioritizing maintenance, improvement and upgrading of roads in Gilan based on a combination of the Delphi technique and AHP. The Delphi technique was used for the preliminary procedure of determining the list of experts whose opinion will be included in the AHP method used to generate the list of priorities of the observed roads.

AHP + PROMETHEE

Kilić Pamuković et al. (2020) presented a new decision support system (DSS) for selecting the most important spatial units for asphalt pavement maintenance. The proposed model is based on a hybrid multicriteria decision-making approach in which the AHP method is used to determine the weights of social, technical and economic criteria, while the PROMETHEE method is applied to rank priorities and introduce restrictions. The used methodology enables the ranking of road infrastructure according to the requirements for improving their condition.

AHP + ELECTRE

Sayadinia and Beheshtinia (2020) designed hybrid multicriteria decision-making approach based on combination of AHP, ELECTRE II, ELECTRE III, ELECTRE IV and Copeland techniques for road maintenance prioritization. The AHP method is used to determine the weight of various criteria obtained by reviewing the literature and talking to experts as input data for ranking roads using the ELECTRE II, ELECTRE III and ELECTRE IV methods. Finally, the Copeland technique is used to integrate the results and achieve a comprehensive ranking of the observed roads.

AHP + TOPSIS

Yu et al. (2013) combine the AHP and TOPSIS methods for the construction of a comprehensive evaluation model and evaluation of the traffic congestion status of intersections. Ouma et al. (2015) compared Analytical Hierarchy Process (AHP) and TOPSIS for prioritization of pavement maintenance and repairs. By using different sets of fuzzy functions, the proposed hybrid approach enables decision makers to create an efficient and objective pavement maintenance prioritization system.
AHP + VIKOR

Chundi et al. (2021) used a combination of AHP and VIKOR methods to rank road pavement maintenance priorities in the state of Odisha. The goal of this hybrid approach was to create a pavement management system for determining the priority of the observed pavements and arriving at maintenance measures within the road network taking into account their actual condition. In the proposed model, criteria weights are obtained using the AHP method and are used as input data for ranking in the TOPSIS method, which provides the final pavement maintenance plan.

FAHP + DEA

Salehian et al. (2018) proposed a hybrid approach based on Fuzzy Analytic Hierarchy Process (FAHP) and Data Envelopment Analysis (DEA) to measure transportation efficiency in road fleets of Iranian provinces. In doing so, the FAHP method is used to determine the weight of the input and output criteria, and the priority of the criteria is implemented as a constraint in the DEA model. The proposed hybrid approach is applied in road maintenance and transportation organization in Iran, and the validation results of the proposed model proved its effectiveness.

AHP + SAW + PROMETHEE

Jajac et al. (2014) designed a decision support concept in the implementation of a sustainable parking project in ancient Mediterranean cities. Stakeholders involved in the decision-making process determined the weights of the criteria using the AHP and SAW methods. The data obtained in this way were used in the PROMETHEE II method for ranking priorities, while finally the PROMETHEE V method enabled the definition of individual phases of project implementation.

AHP + SAW + ANN

In the relevant literature, it is also possible to find hybrid approaches to multicriteria decision-making, which are based on a combination of multicriteria methods and artificial neural networks (Artificial Neural Networks, ANN). Thus, Jajac et al. (2015) propose a concept based on these methods in the planning phase of a city transport project. The weights of the selected criteria were determined using the AHP method based on the opinions of the participants involved in the group decision-making process. The obtained criteria weights are further used in the SAW method to determine the priority of the selected road elements. The tested ANN model further identifies only those elements of the road infrastructure whose condition needs to be improved. The final result of the described model is a good basis for improving the planning process in the management of urban road infrastructure projects.

Based on the briefly presented research, it is evident that among them a total of 10 analyzed papers propose a unique approach to decision-making using only one multicriteria decision-making method, while the remaining 10 analyzed papers propose hybrid approaches to multicriteria decision-making combining several methods at the same time. According to the
analysis, the frequency of application of individual methods according to unique and hybrid approaches is shown in Table 3.

Table 3. The frequency of application of certain methods in unique and hybrid approaches to multicriteria decision-making

<table>
<thead>
<tr>
<th>Multicriteria Decision Making Method</th>
<th>Single MCDM Approaches</th>
<th>Hybrid MCDM Approaches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analytic Hierarchy Process (AHP)</td>
<td>36,4 %</td>
<td>88,9 %</td>
</tr>
<tr>
<td>Analytic Network Process (ANP)</td>
<td>9,1 %</td>
<td>0%</td>
</tr>
<tr>
<td>Elimination and Choice Expressing Reality (ELECTRE)</td>
<td>27,3%</td>
<td>11,1%</td>
</tr>
<tr>
<td>The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)</td>
<td>27,3%</td>
<td>22,2%</td>
</tr>
<tr>
<td>Preference ranking organization method for enrichment evaluation (PROMETHEE)</td>
<td>0%</td>
<td>22,2%</td>
</tr>
<tr>
<td>Visekriterijumska optimizacija i kompromisno rješenje (VIKOR)</td>
<td>0%</td>
<td>11,1%</td>
</tr>
<tr>
<td>Simple Additive Weighting (SAW)</td>
<td>0%</td>
<td>22,2%</td>
</tr>
<tr>
<td>Fuzzy Analytic Hierarchy Process (FAHP)</td>
<td>0%</td>
<td>11,1%</td>
</tr>
</tbody>
</table>

The previously presented data indicate that the AHP method is the most common method of multicriteria decision-making in single approaches with a share of 36,4% as well as in hybrid approaches with a share of 88,9%. The ANP method was applied in one paper representing a single approach while in the hybrid approach it was not represented. Furthermore, the share of ELECTRE and TOPSIS methods in unique approaches is 27,3%, and in hybrid 11,1% and 22,2% while PROMETHEE, VIKOR, SAW and FAHP according to the results of this analysis are not used as independent methods of multicriteria decision making but are exclusively combined with others in hybrid MCDM models.

Among the analyzed papers it is also possible to notice how the proposed road project management models based on the described single or hybrid approaches to multicriteria decision-making mostly result in a ranking list of priorities, i.e. a construction or maintenance plan for the observed roads. However, according to Majstorović and Jajac (2022) effective management of road network maintenance in conditions of limited financial resources is achieved through three interconnected management functions of planning, implementation and monitoring and control. Project monitoring and control throughout the entire project life cycle is the process of checking whether the project is proceeding in accordance with the plan, and therefore without monitoring and control, planning has no full meaning.

Therefore, existing road construction and maintenance management models can be improved by combining the analyzed unique or hybrid approaches to multicriteria decision-making and project monitoring and control methods. In case of deviation from the plan obtained by applying the selected multicriteria decision-making methods, monitoring and control methods will serve as a feedback link to planning when all activities from the planning phase are re-examined and redefined. In this way, it is possible to connect planning,
implementation and monitoring and control of the project as three fundamental and inseparable management functions into an effective road construction and maintenance management system, which reflects the possible directions of future research.

4. CONCLUSION

The decision-making process is the integral and inseparable part of construction project management. The complexity of poorly structured problems stems from the complexity of construction projects, the solution of which necessarily requires the application of multicriteria decision-making methods. This paper provides a bibliometric analysis of papers in the field of the application of multicriteria decision-making methods in the construction project management in general, with a special emphasis on the management of road construction and maintenance projects. The results of a systematic review of the relevant literature indicate the high frequency and effectiveness of certain methods of multicriteria decision-making in the form of unique approaches to multicriteria decision-making or in combination with other methods, thus creating hybrid approaches to multicriteria decision-making. All analyzed management models based on the described single or hybrid approaches to multicriteria decision-making are mainly based on planning and as such result in a management plan. However, since an effective construction project management system must, in addition to planning, also contain management functions of implementation and monitoring and control, existing models can be improved by combining existing multicriteria decision-making approaches and project monitoring and control methods which reflects the direction of future research and the original scientific contribution of this paper.

This research is partially supported through project KK.01.1.1.02.0027, a project co-financed by the Croatian Government and the European Union through the European Regional Development Fund—the Competitiveness and Cohesion Operational Programme.

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