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Sustainable Development of Civil Engineering, Construction and Building Technology

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Abstract: *Sustainable development of civil engineering, construction and building technology can be supported by fundamental scientific achievements and development theories. The current paper aims at over viewing the state of the art in terms of published papers related to theoretical methods that are applied to support sustainable evaluation and selection processes in civil engineering. The review is limited solely to papers referred to in the Clarivate Analytic Web of Science core collection database. As the focus is on development, it aims at reviewing how the papers on developments and applications have been distributed and journals. The articles are grouped by research domains, problems analyzed and the decision-making approaches used. The findings of the current review paper show that Devekionebt if applications have been constantly growing and particularly increased in the last three years, confirming the great potential and prospects of sustainable development of civil engineering, construction and building technology.*

Keywords: Civil Engineering; construction building technology sustainability; development; literature review.

I. INTRODUCTION

Civil engineering is based on fundamental scientific achievements. In the design and construction of engineering structures and buildings, theoretical methods are applied that are based on the fundamental sciences, such as mathematics, physics and chemistry. A number of review articles have been prepared dealing with the achievements in these areas of fundamental sciences and their application in civil engineering as well as in building and construction. Optimizations "inspired by nature" based on chemistry[1], physics[2] and other natural sciences[3] were described. Applications of gravitational search algorithms[4], simulated annealing[5] and central force metaheuristic optimization[6] as nature-inspired conceptual frameworks in engineering are presented. Much attention is being paid to vibration control and the health monitoring of buildings and engineering structures[7], including bridges [8] and high-rise buildings[9]. A comprehensive review of tuned mass dampers for the vibration control of structures was provided[10].

Continuing our overview of review articles, a number of review articles have been published to address specific civil engineering issues and information technology applications to assist in solving engineering problems. The usage of support vector machines in structural engineering was presented [11]. Neurocomputing, in terms of the application of artificial neural networks for civil infrastructure optimization, monitoring and control is reviewed[12]. A review of how automation in construction operations was applied and automated equipment was incorporated in building construction phases[13] is presented. Transportation systems and transport technologies are systematically assessed in[14].

As sustainable development is becoming more relevant, more and more publications are being published related to sustainability in construction. Sustainable, innovative and efficient structural design[15], sustainable building design[16], including sustainability in high-rise building design[17], and integrated planning for sustainable building[18] is acknowledged, as well as a model for the structural health monitoring of high-rise buildings[19], and the vibration control of smart structures[20] were discussed, including sustainability aspects. Sustainable urban design[21] is no less important for assuring overall sustainability. Ceravolo et al.[22] describe a methodology for assessing the time-dependent structural performance of electric road infrastructures. Katsigarakis et al.[23] present a sense–think–act methodology for intelligent building energy management. Wang and Szeto[24] present a multi objective environmentally sustainable road network design using Pareto optimization. Wang et al.[25] present a multi-objective path optimization for critical infrastructure links with consideration of seismic resilience. Bozza et al.[26] advocate alternative resilience indices for city ecosystems subject to natural hazards. Cahill et al.[27] study the effect of road surface, vehicle and device characteristics on energy harvesting from bridge–vehicle interactions.

In applying the principles of sustainability, besides technological and economic aspects, environmental and social aspects also need to be considered. Accordingly, when choosing the most effective project decisions, everyone is faced with the need to evaluate the performance of a number of criteria. Mixed information and a wide variety of information types can be managed by applying development methods]. The methods can be broadly classified into two categories: discrete MADM (multi-attribute decision-making) methods and continuous MODM (multi-objective decision-making) methods. This classification has risen from two schools of thought regarding what human choice is based on: a French school and an American school. The French school mainly promotes the outranking concept for evaluating discrete alternatives. The American school is based on multi-attribute value functions and multi-attribute utility theory. Lately multiple-criteria decision-making (MCDM) methods have been increasingly applied combining MODM and MADM techniques.

There are not many review articles aimed at analyzing MCDM (including MODM and MADM) for civil engineering applications. A very comprehensive paper was published by Kabir et al.[29]. Jato-Espino et al.[29] published a review article where an overview of the most widely-applied multi-criteria techniques and the main applications of the techniques to construction was provided.

Zavadskas et al.[30] reviewed the development of MCDM methods from 1772 to 2015. The first publication on multiple-criteria methods is considered a letter written by Franklin[31]. Pareto[32] publications played a particularly important role. Several Nobel prizes were awarded to Debrese (1959), Frisch (1969), Samuelson (1970), Arrow (1972), Nash (1994), Kantorovich and Koopmans (1975), Dantzig (1976), Sen (1998). The work of Simon (1978)[33] played a special role in the most up-to-date MCDM theory. Other important contributions were made by Saaty [34], Zeleny[35], Zadeh[36]. Zadeh[37] introduced the fuzzy sets theory. In 2015, Herrera-Viedma, a well-known scholar in the field of MCDM, prepared a special issue [38] evoted to the fifty-year theory of Zadeh. Kou and Ergu[39] prepared a special issue devoted to Satty's 90th anniversary and an overview article for pairwise comparison matrixes in multi-criteria decision-making[40]. Later Zavadskas et al. reviewed applications of MCDM methods in civil engineering until 2015. Applications in particular civil engineering areas were summarized in a number of papers. In 2016, Zavadskas et al.[41] reviewed the application of hybrid MCDM (HMCDM) methods in engineering. This article also gave an overview of the historical development of MCDM and the main publications on this topic. The focus of the article was on a broad overview, i.e., engineering applications on the whole, not focusing on building and construction. In another review article, Zavadskas et al.[42] presented a comprehensive analysis of the application of HMCDM methods for sustainability problems, including technology or product development/selection, personnel selection and company management, site selection, supply chains, etc. Yi and Wang[43] presented a multi-objective mathematical programming approach for construction laborer assignment with equity consideration. Pons et al.[44] published an article devoted to the application of MCDM methods for the assessment of sustainability in architectural and engineering design; Penades-Pla et al.[45] overviewed the sustainable design of bridges. Keshavarz Ghorabaee et al.[46] provided a broad overview of the application of MCDM methods in supply chains. Si et al.[47] reviewed the application of MCDM methods for the assessment of green technologies. Decision-making for green building, sustainable design, and energy related problems were overviewed[48]. Cerveira et al.[49] discussed wind farm distribution network optimization. These published review articles well illustrate the current state of the art in solving sustainability issues in civil engineering by applying MCDM, including MADM and MODM, methods. The whole and continuously increasing number of publications applying MCDM in civil engineering, construction and building technology is presented.

The combination of different approaches with the inclusion of MCDM methods is not a rare phenomenon. Cavalcante et al.[50] proposed a multi-criteria model based on the delay-time concept to provide the builder with a quantitative tool to support the decision-making process in building maintenance. The model proposed by Verma et al.[51] is a modified version of fuzzy TOPSIS applied in order to minimize the vagueness of visual inspection. This model ranks the alternative solutions based on similarity with fuzzy positive ideal solutions rather than the distance from fuzzy positive and negative ideal solutions. Baušys and Juodagalvienė [52], for the selection of garage locations, applied the AHP and an extension of the Weighted Aggregated Sum Product Assessment (WASPAS) approach, namely Weighted Aggregated Sum Product ASsessment with Single-Valued Neutrosophic Set (WASPAS-SVNS), constructed based on the single-valued neutrosophic set. Hosseini et al. [53] assessed the sustainability of technologies using a newly designed sustainability model based on AHP and MIVES (Modelo Integrado de Valor para una Evaluación Sostenible (that means the Integrated Value Model for Sustainable Assessment), including a simplified life-cycle assessment (LCA).

Discussion

A pressing task facing the world today is the sustainable development of cities and urban infrastructure addressed through the constructive interaction of environmental, economic and social factors. Sustainability priorities encompass integrated problems that address environmental protection, energy efficiency, optimized mobility, e-city technology and other fostering issues, including those appearing throughout all building life cycles, and deal with various levels of management and interest groups with different goals. From the mathematical point of view, these are multi-criteria group decision-making problems. In other words, the multi-criteria problems came from the multidimensionality paradigm conditioned by the ideology of sustainable development.

The most important advantage of the multi-criteria decision-making methods is their capability to address the problems that are characterized by conflicting goals. Therefore, the article was focused on the MCDM techniques and approaches that are being employed for decision-making in sustainability issues, particularly those related to the construction sector.

Usually, the selection of the most effective solution in construction-related problems is not such a simple task. The methods used in structural engineering do not allow for the assessment of the sustainability of alternative solutions. It has been noticed, that often alternative solutions and the results of numerical calculations have been validated by applying a MCDM method [63]. In particular, a sensitivity analysis was usually applied as a complementary approach to check that the results were not influenced by the judgments of decision-makers [54].

The results of the in-depth analysis revealed that AHP, fuzzy sets and TOPSIS methods are among the most well-known, not only during the last three decades, but also during last three years, and thus prevail in scientific articles. A rapid growth of AHP and TOPSIS applications was also recorded in Zyoud and Fuchs-Hanusch[55].

Generally, MCDM methods help the decision-maker to select objective solutions not influenced by the evaluation process. Real world problems are normally not defined exactly due to the uncertainty of human judgment; therefore, the extension of the classic methods enabling decision-making in uncertain environments has appeared, e.g., fuzzy TOPSIS. The popularity of fuzzy TOPSIS could be explained by one of the key advantages mentioned by Zavadskas et al. [56], i.e., the ability to deal with different types of values: crisp, interval, fuzzy or linguistic. Starting from the ideas presented in Zadeh's "Fuzzy Sets", published in 1965, the fuzzy logic theory has proved to have numerous applications and developments until now. Thus, the integration of fuzzy logic into classic methods provides a solution to handle subjective uncertain data and strengthens the comprehensiveness of the decision-making process.

This manuscript summarized carefully the papers that were available in the Web of Science core collection database, although a number of relevant works may have remained outside the scope of this study. However, the authors believe that this sample is representative, as the Web of Science core collection database is presented as the most accurate, objective, and complete resource available, and the articles included in it have passed a rigorous selection process inherent to high quality articles. Moreover, the authors limited the research on purpose; otherwise, the volume of the article would have increased significantly. On the other hand, the limitation specified above allows others in the future to get deeper into the subject, expand the sample and review those papers that are not mentioned in this article.

Conclusions

Sustainable decision-making in civil engineering, construction and building technology is based on fundamental scientific achievements and can be supported by multiple-criteria decision-making approaches. The current research justifies the need and usefulness of the application of MCDM methods for sustainable decision-making. It was identified that the number of publications on the topic of "sustainability" significantly increased in 2010. The number of publications on the topic "MCDM" began to grow starting from 2010. An analogous growth trend in publications applying MCDM methods has been observed in civil engineering and construction building technology Web of Science categories.

The aim of the article was to introduce the thematic issue, to summarize the latest research in the field under study. As a result, the paper provides a better understanding of recent research directions in topics of sustainable development and construction engineering and can assist in conducting further research and seeking information. The study shows that

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decision-making methods have been developing in the last three years and their application has had a positive effect. The inclusion of multi-criteria decision-making methods as a robust and flexible tool for assessing possible alternatives provides the possibility to select a rational solution more precisely, taking into account the trade-offs that inevitably exist between the various candidate solutions. The obvious efforts to combine several methods show that the scientific community is still searching for the proper combination of decision-making methods for the solution of concrete problems. Thus, this analysis helps to anticipate future directions for the development of multi-criteria decision-making methods. Thus, the authors intend to make a comparative analysis and a more rigorous investigation of the existing methods, such as a comparison of previous approaches in terms of pros and cons, in the near future. In the light of the above, expectedly, this study can be employed by scholars as a basis for further research.

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