symmetry

MDPI

Editorial

Civil Engineering and Symmetry

Edmundas Kazimieras Zavadskas [1,2], Romualdas Bausys [3] and Jurgita Antucheviciene [1,*]

1 Department of Construction Management and Real Estate, Vilnius Gediminas Technical University, Sauletekio al. 11, LT-10223 Vilnius, Lithuania; edmundas.zavadskas@vgtu.lt
2 Institute of Sustainable Construction, Vilnius Gediminas Technical University, Sauletekio al. 11, LT-10223 Vilnius, Lithuania
3 Department of Graphical Systems, Vilnius Gediminas Technical University, Sauletekio al. 11, LT-10223 Vilnius, Lithuania; romualdas.bausys@vgtu.lt
* Correspondence: jurgita.antucheviciene@vgtu.lt; Tel.: +370-5-274 -5233

Received: 2 April 2019; Accepted: 2 April 2019; Published: 5 April 2019

check for updates

Abstract: A topic of utmost importance in civil engineering is finding optimal solutions throughout the life cycle of buildings and infrastructural objects, including their design, manufacturing, use, and maintenance. Operational research, management science, and optimisation methods provide a consistent and applicable groundwork for engineering decision-making. These topics have received the interest of researchers, and, after a rigorous peer-review process, eight papers have been published in the current special issue. The articles in this issue demonstrate how solutions in civil engineering, which bring economic, social and environmental benefits, are obtained through a variety of methodologies and tools. Usually, decision-makers need to take into account not just a single criterion, but several different criteria and, therefore, multi-criteria decision-making (MCDM) approaches have been suggested for application in five of the published papers; the rest of the papers apply other research methods. The methods and application case studies are shortly described further in the editorial.

Keywords: multiple-criteria decision-making (MCDM); hybrid MCDM; fuzzy sets; rough sets; D numbers; 3D modelling; image processing; experimental testing; civil engineering; manufacturing engineering; transportation; logistics

1. Introduction

A topic of utmost importance in civil engineering is finding optimal solutions throughout the life cycle of buildings and infrastructural objects, including their design, manufacturing, use, and maintenance. Operational research, management science, and optimisation methods provide a consistent and applicable groundwork for engineering decision-making. Real-world decision problems are usually solved by applying a multi-criteria decision making (MCDM) framework, which means that decisions are constructed by considering multiple criteria or points of view and taking them into account. Therefore, MCDM has become a universal tool for the solution of real-world problems. The MCDM method review, performed by Mardani et al. [1], distinguished 15 fields of real-world problems: Energy, environment and sustainability, supply chain management, material selection, quality management, geographic information systems, construction and project management, safety and risk management, manufacturing systems, technology and information management, operations research and soft computing, strategic management, production management, and tourism management.

The evolution of the MCDM methods has been directed to take into account the uncertainty of the initial information. Due to the different application areas, modern decision-making solutions quite frequently include linguistic valuations of the different aspects of the considered alternatives. This information type is characterised by not-strictly-defined meanings. Symmetry-based techniques play quite an important role in considering systems involving uncertainty in the information. Considerable research concerning decision-making has been performed by applying neural networks, fuzzy logic, and interval numbers. The success of these approaches relies on the fact that all these methods are derived through utilising the appropriate symmetries. Therefore, different fuzzy approaches have been proposed to model this type of information. For the most popular MCDM methods, such as DEMATEL, PROMETHEE, TOPSIS, AHP, ANP, VIKOR, COPRAS, ARAS, and WASPAS, fuzzy extensions have been proposed [2–4].

Neuro-fuzzy systems have been proposed to cover more complicated formulations of decision-making problems. A comprehensive review, concerning numerous innovation aspects in neuro-fuzzy systems and the applications of these systems in various real-life issues, is presented in [5].

Intensive research has been performed in order to extend their capabilities, concerning the more accurate modelling of the uncertain and vague initial information in decision-making problems. The various "fuzzy" approaches have been proposed to model different aspects of the information uncertainty. Neutrosophic sets, recently introduced by Smarandache, opened up new possibilities for representing the uncertain and inconsistent information encountered in decision-making formulations [6]. Fuzzy-rough sets have been applied in various fields, such as expert systems, knowledge discovery, information system, inductive reasoning, intelligent systems, data mining, pattern recognition, decision-making, and machine learning [7].

Additionally, fuzzy sets have been intensively applied in decision-making problems modelled within the aggregation operator framework. Various aggregation operators under different fuzzy sets are reviewed in [8].

The methodological aspects of the decision-making problems in civil engineering, concerning the combination and integration of fuzzy and probabilistic models to deal with the uncertainties, were discussed in [9].

Research into the development of new MCDM methods has been directed towards hybrid MCDM approaches. The most popular hybrid MCDM methods demonstrate advantages over the traditional ones in solving complicated problems, which involve stakeholder preferences, interconnected or contradictory criteria, and uncertain environments. The evolution of the new hybrid MCDM approaches, such as multiple rule-based decision-making (MRDM), which can be characterized by relevant knowledge for supporting systematic improvements based on influential network relation maps (INRM), has been studied in [10–12].

Extensive reviews dedicated to the application of the MCDM methods in different fields of human activity are presented in [13–17]. Applications in areas such as transportation, supplier evaluation and selection, the tourism and hospitality industries, service quality evaluation, and the circular economy in the context of the supply chains are discussed in these publications. The particular aspects concerning cultural heritage object preservation, including economic, historical, archaeological, religious, technological, and research indicators are considered in [18]. For the solution of this problem, analytic hierarchy process (AHP) and evaluation based on distance from average solution (EDAS) methods are applied. The issue of the conceptual design of a bridge structure by a modified fuzzy Technique for Order of Preference by Similarity to Ideal Solution method, under uncertainty, is solved in [19]. The effective material selection for civil engineering objects is performed by an Analytic Hierarchy Process (AHP) and a fuzzy Multi-Objective Optimisation on the Basis of Ratio Analysis (MOORA) [20]. The distinctive features of the application of hesitant fuzzy and single-valued neutrosophic sets are taken into consideration in [21,22].

2. Contributions

The current Special Issue collects eight articles. They all are original research articles; no review articles or technical reports have been published in the current issue.

The papers contribute to decision-making techniques for civil engineering problems involving symmetric, asymmetric, or non-symmetrical information. The suggested methodologies and tools mainly include novel or extended multiple-criteria decision-making models and methods under uncertain environments. Additionally, three papers published in the current issue do not apply MCDM methods. They contribute to problems related to symmetry by offering other solution methods.

The topics of the Special Issue gained attention mostly in Europe, as well as in Asia. Thirty-four authors from eight countries contributed to the Issue (see Figure 1).

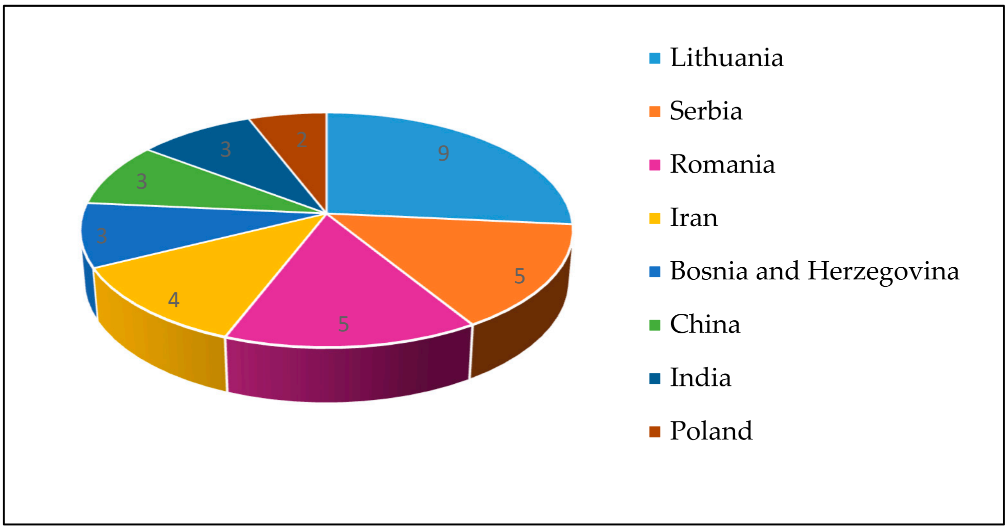

Figure 1. Distribution of authors by countries.

The distribution of papers, according to author affiliations, is presented in Table 1. Co-authors from Lithuania contributed to four papers, together with co-authors from Serbia, Bosnia and Herzegovina, India, and Iran. Authors from Poland, Rumania, and China contributed with a single paper each. Researchers from Serbia, together with co-authors from Bosnia and Herzegovina, contributed one more paper.

Table 1. Publications by countries.

Countries	Number of Papers
Poland	1
Rumania	1
China	1
Bosnia and Herzegovina–Serbia	1
Iran–Lithuania	2
India–Lithuania	1
Bosnia and Herzegovina–Serbia–Lithuania	1

The papers concerning related analysis methods or decision-making approaches are classified into several groups, as presented in Figure 2. Five of the eight papers apply MCDM methods and, mostly, they propose models and techniques under uncertain environments (i.e., fuzzy or rough models). Individual articles that do not deal with multiple-criteria decisions apply other approaches: Experimental testing, image processing, and 3D modelling.

The case studies and application examples of the proposed approaches dealing with symmetrical, asymmetrical, or non-symmetrical problems and presented in the current special issue, can be grouped into three research areas, consisting of 2,3 papers each (see Figure 3).

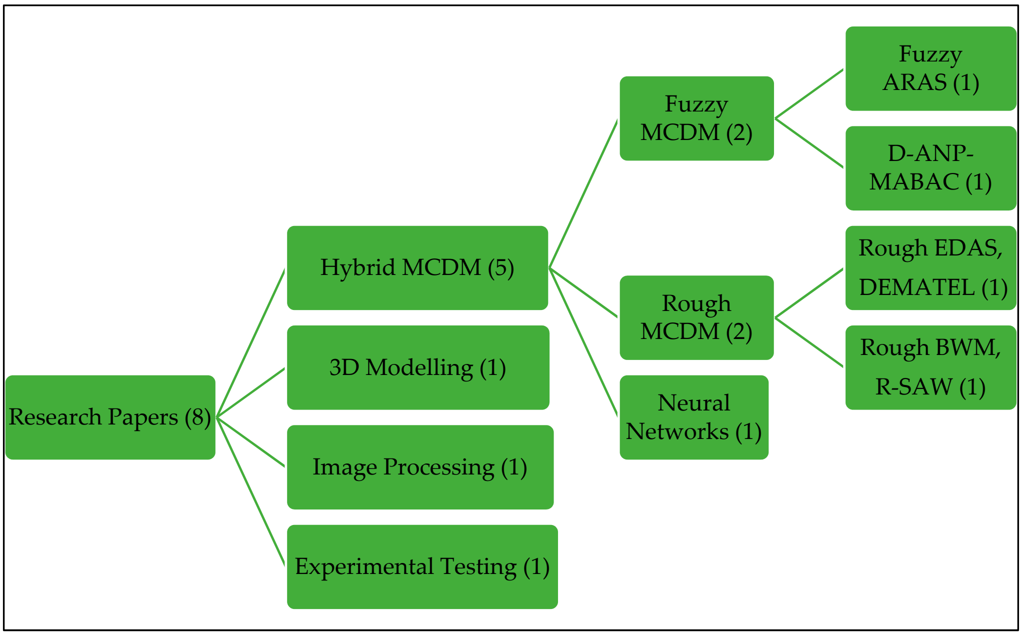

Figure 2. Decision-making approaches.

Figure 3. Research areas of case studies.

One group of papers is related to construction engineering and management. In one of the papers, the crucial problem, concerning construction management, is studied by applying a hybrid fuzzy D-ANP-MABAC model for risk evaluation of the construction projects, involving a combination of D-numbers, an analytical network process (ANP), and a multi-attributive border approximation area comparison (MABAC) method [23]. Another construction engineering paper does not apply MCDM methodology. The article aims to develop a systematic and practical approach to the early stages of the parametric design of roof shells; a compound of four concrete elements [24].

One of the most numerous research areas is Production/Manufacturing Engineering. Two papers in the area apply MCDM methodology. An oil and gas well drilling project evaluation is made by a proposed novel approach using an interval-valued fuzzy Additive Ratio Assessment (ARAS) method [25]. The paper makes a significant contribution to the literature, as an alternative method for the evaluation of this type of project. Next, for the mining industry, a hybrid multi-criteria model for shovel capital cost estimation, using multivariate regression and neural networks, is proposed [26]. One more proposal for flexible manufacturing systems is presented in a paper [27], which is aimed at a tool-wear analysis of the tool flank by applying image processing.

Another research area is Transportation and Logistics, involving three research papers. It is nice to mention that two of the papers suggest applying Rough MCDM methods. The supplier selection in a construction company is recommended to be made by utilising a combination of two extended methods: DEMATEL (Decision Making Trial and Evaluation Laboratory) for obtaining the relative weights of important criteria, and an EDAS (Evaluation based on Distance from Average Solution) method for the supplier evaluation and selection [28]. A combination of another two rough methods, rough BWM (Best–Worst Method) and rough SAW (Simple Additive Weighting), is provided for the selection of wagons in a logistics company [29]. However, the last paper from the special issue is not related to MCDM. It analyses the optimal organising of airplane passenger boarding/deboarding strategies as one of the potential possibilities to reduce the airplane turnover time by experimental testing [30].

3. Conclusions

The topics of this Special Issue have raised the interest of researchers both in Europa and in Asia; researchers from eight countries, including international collaborations, authored and co-authored papers published in this Issue.

Although multiple-criteria decision-making was one out of many announced topics, more than half of the papers (five papers out of the eight published papers) applied MCDM methods in their research. Therefore, multiple-criteria decision-making techniques proved to be well-applicable to symmetric/asymmetric information management.

Most approaches suggested decision models under uncertainty, proposing hybrid MCDM methods in combination with fuzzy or rough set theory, as well as D-numbers.

The application areas of the proposed MCDM techniques mainly covered production/manufacturing engineering, logistics and transportation, and construction engineering and management.

Author Contributions: All authors contributed equally to this work.

Acknowledgments: Authors express their gratitude to the journal Symmetry to offer an academic platform for researchers to contribute and exchange their recent findings in civil engineering and symmetry.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Mardani, A.; Jusoh, A.; Nor, K.M.D.; Khalifah, Z.; Zakwan, N.; Valipour, A. Multiple criteria decision-making techniques and their applications—A review of the literature from 2000 to 2014. *Econ. Res.-Ekon. Istraz.* **2015**, *28*, 516–571. [CrossRef]
2. Mardani, A.; Jusoh, A.; Zavadskas, E.K. Fuzzy multiple criteria decision-making techniques and applications—Two decades review from 1994 to 2014. *Expert Syst. Appl.* **2015**, *42*, 4126–4148. [CrossRef]
3. Kahraman, C.; Onar, S.C.; Oztaysi, B. Fuzzy Multicriteria Decision-Making: A Literature Review. *Int. J. Comput. Intell. Syst.* **2015**, *8*, 637–666. [CrossRef]
4. Yazdanbakhsh, O.; Dick, S. A systematic review of complex fuzzy sets and logic. *Fuzzy Sets Syst.* **2018**, *338*, 1–22. [CrossRef]
5. Rajab, S.; Sharma, V. A review on the applications of neuro-fuzzy systems in business. *Artif. Intell. Rev.* **2018**, *49*, 481–510. [CrossRef]
6. Khan, M.; Son, L.H.; Ali, M.; Chau, H.T.M.; Na, N.T.N.; Smarandache, F. Systematic review of decision making algorithms in extended neutrosophic sets. *Symmetry* **2018**, *10*, 314. [CrossRef]
7. Mardani, A.; Nilashi, M.; Antucheviciene, J.; Tavana, M.; Bausys, R.; Ibrahim, O. Recent fuzzy generalisations of rough sets theory: A systematic review and methodological critique of the literature. *Complexity* **2017**, *2017*, 1608147. [CrossRef]
8. Mardani, A.; Nilashi, M.; Zavadskas, E.K.; Awang, S.R.; Zare, H.; Jamal, N.M. Decision making methods based on fuzzy aggregation operators: Three decades review from 1986 to 2017. *Int. J. Inf. Technol. Decis. Mak.* **2018**, *17*, 391–466. [CrossRef]
9. Antucheviciene, J.; Kala, Z.; Marzouk, M.; Vaidogas, E.R. Solving Civil Engineering Problems by Means of Fuzzy and Stochastic MCDM Methods: Current State and Future Research. *Math. Probl. Eng.* **2015**, *2015*, 362579. [CrossRef]
10. Zavadskas, E.K.; Antucheviciene, J.; Turskis, Z.; Adeli, H. Hybrid multiple-criteria decision-making methods: A review of applications in engineering. *Sci. Iran.* **2016**, *23*, 1–20.

11. Zavadskas, E.K.; Govindan, K.; Antucheviciene, J.; Turskis, Z. Hybrid multiple criteria decision-making methods: A review of applications for sustainability issues. *Econ. Res.-Ekon. Istraz.* **2016**, *29*, 857–887. [CrossRef]
12. Shen, K.Y.; Zavadskas, E.K.; Tzeng, G.H. Updated discussions on "Hybrid multiple criteria decision-making methods: A review of applications for sustainability issues". *Econ. Res.-Ekon. Istraz.* **2018**, *31*, 1437–1452. [CrossRef]
13. Mardani, A.; Zavadskas, E.K.; Khalifah, Z.; Jusoh, A.; Nor, K. Multiple criteria decision-making techniques in transportation systems: A systematic review of the state of the art literature. *Transport* **2016**, *31*, 359–385. [CrossRef]
14. Keshavarz Ghorabaee, M.; Amiri, M.; Zavadskas, E.K.; Antucheviciene, J. Supplier evaluation and selection in fuzzy environments: A review of MADM approaches. *Econ. Res.-Ekon. Istraz.* **2017**, *30*, 1073–1118. [CrossRef]
15. Govindan, K.; Soleimani, H. A review of reverse logistics and closed-loop supply chains: A Journal of Cleaner Production focus. *J. Clean. Prod.* **2017**, *142*, 371–384. [CrossRef]
16. Correia, E.; Carvalho, H.; Azevedo, S.G.; Govindan, K. Maturity models in supply chain sustainability: A systematic literature review. *Sustainability* **2017**, *9*, 64. [CrossRef]
17. Mardani, A.; Jusoh, A.; Zavadskas, E.K.; Khalifah, Z.; Nor, K.M. Application of multiple-criteria decision-making techniques and approaches to evaluating of service quality: A systematic review of the literature. *J. Bus. Econ. Manag.* **2015**, *16*, 1034–1068. [CrossRef]
18. Turskis, Z.; Morkunaite, Z.; Kutut, V. A hybrid multiple criteria evaluation method of ranking of cultural heritage structures for renovation projects. *Int. J. Strateg. Prop. Manag.* **2017**, *21*, 318–329. [CrossRef]
19. Keshavarz Ghorabaee, M.; Amiri, M.; Zavadskas, E.K.; Turskis, Z.; Antucheviciene, J. Ranking of Bridge Design Alternatives: A TOPSIS-FADR Method. *Balt. J. Road Bridge Eng.* **2018**, *13*, 209–237. [CrossRef]
20. Ilce, A.C.; Ozkaya, K. An integrated intelligent system for construction industry: A case study of raised floor material. *Technol. Econ. Dev. Econ.* **2018**, *24*, 1866–1884. [CrossRef]
21. Yu, D. Hesitant fuzzy multi-criteria decision making methods based on Heronian mean. *Technol. Econ. Dev. Econ.* **2017**, *23*, 296–315. [CrossRef]
22. Bausys, R.; Juodagalviene, B. Garage location selection for residential house by WASPAS-SVNS method. *J. Civ. Eng. Manag.* **2017**, *23*, 421–429. [CrossRef]
23. Chatterjee, K.; Zavadskas, E.K.; Tamošaitienė, J.; Adhikary, K.; Kar, S. A Hybrid MCDM Technique for Risk Management in Construction Projects. *Symmetry* **2018**, *10*, 46. [CrossRef]
24. Dzwierzynska, J.; Prokopska, A. Pre-Rationalized Parametric Designing of Roof Shells Formed by Repetitive Modules of Catalan Surfaces. *Symmetry* **2018**, *10*, 105. [CrossRef]
25. Dahooie, J.H.; Zavadskas, E.K.; Abolhasani, M.; Vanaki, A.; Turskis, Z. A Novel Approach for Evaluation of Projects Using an Interval-Valued Fuzzy Additive Ratio Assessment (ARAS) Method: A Case Study of Oil and Gas Well Drilling Projects. *Symmetry* **2018**, *10*, 45. [CrossRef]
26. Yazdani-Chamzini, A.; Zavadskas, E.K.; Antucheviciene, J.; Bausys, R. A Model for Shovel Capital Cost Estimation, Using a Hybrid Model of Multivariate Regression and Neural Networks. *Symmetry* **2017**, *9*, 298. [CrossRef]
27. Moldovan, O.G.; Dzitac, S.; Moga, I.; Vesselenyi, T.; Dzitac, I. Tool-Wear Analysis Using Image Processing of the Tool Flank. *Symmetry* **2017**, *9*, 296. [CrossRef]
28. Stević, Ž.; Pamučar, D.; Vasiljević, M.; Stojić, G.; Korica, S. Novel Integrated Multi-Criteria Model for Supplier Selection: Case Study Construction Company. *Symmetry* **2017**, *9*, 279. [CrossRef]
29. Stević, Ž.; Pamučar, D.; Zavadskas, E.K.; Ćirović, G.; Prentkovskis, O. The Selection of Wagons for the Internal Transport of a Logistics Company: A Novel Approach Based on Rough BWM and Rough SAW Methods. *Symmetry* **2017**, *9*, 264. [CrossRef]
30. Qiang, S.; Jia, B.; Huang, Q. Evaluation of Airplane Boarding/Deboarding Strategies: A Surrogate Experimental Test. *Symmetry* **2017**, *9*, 222. [CrossRef]