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Review Article

A BIBLIOMETRIC DATA ANALYSIS OF MULTI-CRITERIA DECISION MAKING METHODS IN HERITAGE BUILDINGS

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Abstract. Numerous countries are trying to find the best solution for conservation, restoration or reuse of the heritage buildings, preserving their cultural, historical, ethnic and spiritual values. The scientists, researchers and government are analysing the problems concerning with heritage building's, like seismic issues, energy saving, sustainability, structures, materials and adaptive reuse. Since, heritage buildings' reuse and preservation are characterized by multiple criteria, a multi-criteria decision making (MCDM) methods are useful in finding rational solutions for the previously mentioned problems. The current paper aims to overview papers on the MCDM approaches application in regard to heritage buildings' reuse and preservation area. This study employs a bibliometric data analysis to explore state-of-the-art of the defined topic and an in-deep analysis – to synthesize the knowledge domain and critically evaluate a thorough literature in the analysed topic. As a result, scientific maps were created to reveal the knowledge domain of MCDM approaches in heritage buildings' reuse and preservation. Finally, research gaps and future research directions are identified. Results of the analysis shows that till now MCDM approaches are not widely used in solving heritage buildings reuse and preservation issues. Moreover, there is luck of complex problem solving approach in cultural heritage buildings area.

Keywords: heritage building, historic building, multi-criteria decision-making, multi-criteria analysis, AHP, fuzzy analysis, MCDM, literature review.

Introduction

Cultural heritage is a fundamental of irreplaceable spiritual, cultural, archaeological, historical, ethnic, mythological, social, economic and technical, technological value. Cultural heritage buildings usually have listed valuable properties, which must be preserved when refurbishing the building and reused for social and cultural goals. However, the refurbishment measures, which can be applied in cultural heritage buildings, are much more limited due to preservation of valuable properties of these buildings. Cultural heritage buildings differ from other buildings in two primary ways that can affect their preservation: 1) physical characteristics, as these buildings may have complex and unusual geometry, envelope construction lacking insulation layer, national construction methods and natural non-standardized materials used for construction of these buildings are heterogeneous in their composition, passive and natural ventilation is used; 2) conservation principles, as the refurbishment of cultural heritage buildings is governed by established conservation principles and practices, which require the protection of a historical value and distinguishing characters of a building (Webb, 2017). Since these differences, refurbishment used in newer and modern buildings may not be suitable for and may cause damage to cultural and traditionally constructed buildings, resulting in loss of cultural heritage.

The scientists, researchers and government are analyzing the problems concerning with heritage building's seismic issues, energy saving, sustainability, structures, materials and adaptive reuse. Since, cultural heritage buildings' reuse and preservation are characterized by multiple criteria, a multi-criteria decision making (MCDM) methods can be applied in finding rational solutions for cultural heritage buildings' reuse and preservation.

The current paper aims to overview papers on the application and use of MCDM approaches in regard to heritage buildings' reuse and preservation area. The last part of

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the paper is structured as follows. Section 1 presents related works on MCDM approaches application in regard to solving cultural heritage buildings issues and existing review studies on this topic. Section 2 presents a research methodology used in this paper. Section 3 presents obtained results of the study. Section 4 discusses the obtained results and the last section concludes the paper.

1. Related works

Heritage buildings present countries' and their communities' history and identity, which transmitted from generation to generation. Therefore, their conservation and restoration is the essential task of numerous countries. Over the last five years (2014–2018) a number of review papers have been presented dealing with historical and heritage buildings reuse and preservation. Fung, Tsang, Tam, Xu, and Mok (2017) analyzed historic building conservation. Gomes, Dionísio, and Pozo-Antonio (2017) and Sanmartín, Cappitelli, and Mitchell (2014) presented cleaning methods against graffiti vandalism. Meanwhile, Pozo-Antonio, Rivas, López, Fiorucci, and Ramil (2016) analyzed granite cleaning process. Much attention is being paid to heritage buildings structures, such as stainless steel for masonry repair and reinforcement (Corradi, Di Schino, Borri, & Rufini, 2018), assessment of heritage timber structures (Riggio, D'Ayala, Parisi, & Tardini, 2018). Moreover, authors analyzing seismic problems in heritage buildings, such as earthquake resistant techniques (Ortega, Vasconcelos, Rodrigues, Correia, & Lourenço, 2017). There are a number of review papers, in which researchers study heritage buildings issues based on integration of renewable technologies (Cabeza, de Gracia, & Pisello, 2018), sustainability in heritage (Sigmund, 2016), adaptive reuse in sustainable development (Tam, Fung, & Sing, 2016), energy efficiency (Berg, Flyen, Godbolt, & Broström, 2017; Gregório & Seixas, 2017; Webb, 2017; Martínez-Molina, Tort-Ausina, Cho, & Vivancos, 2016). Applications of Building Information Modelling (BIM) for heritage science (Pocobelli, Boehm, Bryan, Still, & Grau-Bové, 2018), nanomaterials application in preservation and restoration of stony materials (Sierra-Fernandez, Gomez-Villalba, Rabanal, & Fort, 2017) are presented.

Other important part of a topic in this research is concerning multi-criteria decision making (MCDM) methods. The usefulness of MCDM methods is recognized in a number of papers. They have been applied in different areas, like in health risk assessment (Habib, Makhoul, Darazi, & Couturier, 2019), expert and intelligent systems (He & Xu, 2019), statistical analysis (Krylovas, Kosareva, & Zavadskas, 2018), the success of performance appraisal (Maghsoodi, Abouhamzeh, Khalilzadeh, & Zavadskas, 2018), sustainable energy development issues (Siksnelyte, Zavadskas, Streimikiene, & Sharma, 2018), transportation (Radović et al., 2018), solving multi-criteria group decision making problems (Krishankumar et al., 2018), to assess air pollution (Zavadskas et al., 2018). Other of them are as follows: sustainability issues are analyzed (Shen, Zavadskas, & Tzeng, 2018; Zavadskas, Antucheviciene, Vilutiene, & Adeli, 2017; Zavadskas, Govindan, Antucheviciene, & Turskis, 2016), energy efficient (Kaya, Çolak, & Terzi, 2018; Cajot, Mirakyan, Koch, & Maréchal, 2017; Mardani et al., 2017a, 2017b) and renewable energy (Lee & Chang, 2018; Colak & Kaya, 2017; Kumar et al., 2017; Strantzali & Aravossis, 2016), green supply chain (Banasik, Bloemhof-Ruwaard, Kanellopoulos, Claassen, & van der Vorst, 2018), green technologies (Si, Marjanovic-Halburd, Nasiri, & Bell, 2016), a material choice for natural fiber composites (Noryani, Sapuan, & Mastura, 2018), sustainable material selection (Govindan, Shankar, & Kannan, 2016). de Almeida, Alencar, Garcez, and Ferreira (2017) analyzed MCDM approaches in risk management. Zavadskas, Antucheviciene, Turskis, and Adeli (2016) presented hybrid MCDM review in engineering field; Mardani et al. (2017a) reviewed SWARA and WASPAS methods; Ameyaw, Hu, Shan, Chan, and Le (2016) reviewed application of Delphi in construction engineering and management research. Gul, Celik, Aydin, Gumus, and Guneri (2016), Mardani, Zavadskas, Govindan, Amat Senin, and Jusoh (2016), Kang and Park (2014) have presented review of VIKOR. Govindan and Jepsen (2016) have analyzed ELECTRE techniques. Valipour, Yahaya, Md Noor, Antuchevičienė, and Tamošaitienė (2017) have applied SWARA-COPRAS method for risk assessment in deep foundation excavation project. Han and Wang (2018) applied grey DEMATEL in identifying barriers in off-site construction. Fuzzy MCDM was discussed by Mardani, Jusoh, and Zavadskas (2015) and applied for project risk evaluation by Asadi, Rezaeian Zeidi, Mojibi, Yazdani-Chamzini, and Tamošaitienė (2018). Shariati et al. (2017) applied fuzzy ANP in evaluating critical factors of nanotechnology in construction industry.

All mentioned and existing researches in different areas argue usefulness of MCDM methods as a valuable tool for decision makers. In this paper authors analyze usage of MCDM methods in heritage area for solving different problems. The authors of this paper understand MCDM as defined by Triantaphyllou (2000). We are not focusing on a particular MCDM method; however, use particular names of MCDM methods to make our search for relevant sources more meaningful.

Clearly, like every other approach, MCDM methods also have their own disadvantages and limitations. Govindan, Rajendran, Sarkis, and Murugesan (2015) identify that AHP limitation is that in different industries indices vary and may affect the conclusions. Ho, Xu, and Dey (2010), Özcan, Çelebi, and Esnaf (2011) identify the drawbacks of MCDM methods as follows: confusion with input-output criteria; the subjective evaluation of qualitative criteria; time-consumption in reaching consensus, like may be in AHP which uses pairwise comparison matrices; luck of consistency, like in TOPSIS, ELECTRE I and ELECTRE II methods. Moreover, according to Aruldoss, Lakshmi, and Venkatesan (2013), not all MCDM methods allow assignment of interval values to attributes. Kumar et al. (2017) presented a review of MCDM methods usage in sustain-

Table 1. Summary of previous studies on MCDM methods application in solving different problems in cultural heritage building area

Reference	Review period in years	Method of analysis and tools used	Number of analysed papers	Databases	Focus of the study	MCDM method applied	Main findings
1.	2.	3.	4.	5.	6.	7.	8.
Berg et al. (2017)	–	Manual	–	–	user-driven energy efficiency in historic buildings	–	SK, RG
Chen, Chiu, and Tsai (2018)	–	Manual	Papers and case studies	–	the adaptive reuse of historic buildings through MCDM	The analytic hierarchy process (AHP), Fuzzy Delphi method (FDM)	a decision-making model
Lucchi (2016)	–	Manual	Papers, case studies, collected data, technical studies, standards, practices, and policies	–	the decision making process on conservation, energy efficiency, and human comfort in museum buildings	the SOBANE strategy	a method for EEP assessment in museum buildings
Munarim and Ghisi (2016)	1970–2017	Manual	he most recent works	–	heritage buildings rehabilitation	–	SK

able renewable energy development. The following limitations have been observed within MCDM methods (Kumar et al., 2017): the failure in calculation of dynamic weights of the criteria in TOPSIS (Zhou & Lu, 2012); the failure of integrating multiple preferences in Weighted Sum Method (WSM); undesirable results when priorities or deprioritise the alternative which is far from average in Weighted Product Method (WPM); complex assignment of weights and complicated data collection based on experience in AHP; ELECTRE not universal and hard understandable; not difference between negative and positive values and attribute values should be monotonically increasing or decreasing in TOPSIS; VICOR difficult with conflicting situations and difficult to model a real time model. However, the mentioned drawbacks of MCDM methods are solved by applying hybrid methods, like fuzzy sets and TOPSIS.

MCDM methods application in solving different multi-dimensional problems in cultural heritage building area is also known. Some of them are presented in Table 1. As can be seen from the table, authors of this paper present each study according to the review period (Column 2), methods and tools used in the review (Column 3), number of analyzed papers (Column 4), databases used as a source of papers (Column 5), focus of the study (Column 6), MCDM method applied (Column 7) and main findings (Column 8). The main findings of analyzed studies are characterized on literature review contributions, proposed by Schryen, Wagner, and Benlian (2015). In this paper the following categorization, based on the obtained results, of reviews is used: systematizing knowledge in the analyzed area (SK), research gaps (RG), research trends and directions (RT), proposing a framework to close particular gaps (F) or a knowledge map or a network (KM).

As can be seen, an analysis of existing review studies on MCDM methods application in cultural heritage buildings area is not rich. Therefore, there is a need for comprehensive study of using MCDM methods in cultural heritage buildings area.

Since, we are going to use a bibliometric data analysis in our study, particular misuse and limitations of bibliometric data analysis are reviewed here. As presented in a number of papers, in the context of bibliometric data analysis, attention should be paid to proper uses and misuses. Moreover, as stated in Hammarfelt and Rushforth (2017), indicators are always constantly modified, (re)created, and criticized in the contexts of their usage. Haustein and Larivière (2015), have identified several reasons of improper use of bibliometric indicators. They are as follows: a) publishing in journals that count, b) salami slicing, duplicate publishing or self-plagiarism, c) honorary authorship and ghost authorship, d) self-citations, e) increasing the journal impact factor, and f) cumulative or personal impact factors. Moreover, as presented in Haustein and Larivière (2015), Rijcke, Wouters, Rushforth, Franssen, and Hammarfelt (2016), the usage of bibliometric indicators to evaluate research outputs and for funding and hiring decisions, foster unethical behavior of authors. Summing up, this research is necessary for our future studies in applying MCDM in heritage buildings area. Moreover, an in-deep analysis is used to supplement the bibliometric data analysis results in this research.

2. Research methodology

In this section, a methodology of reviewing papers on MCDM application in cultural heritage buildings area is presented. The review process is presented in Figure 1.

1. **Define a research question**. A research questions is defined in this step. According to Merschbrock and Munkvold (2012), Arksey and O'Malley (2005), this

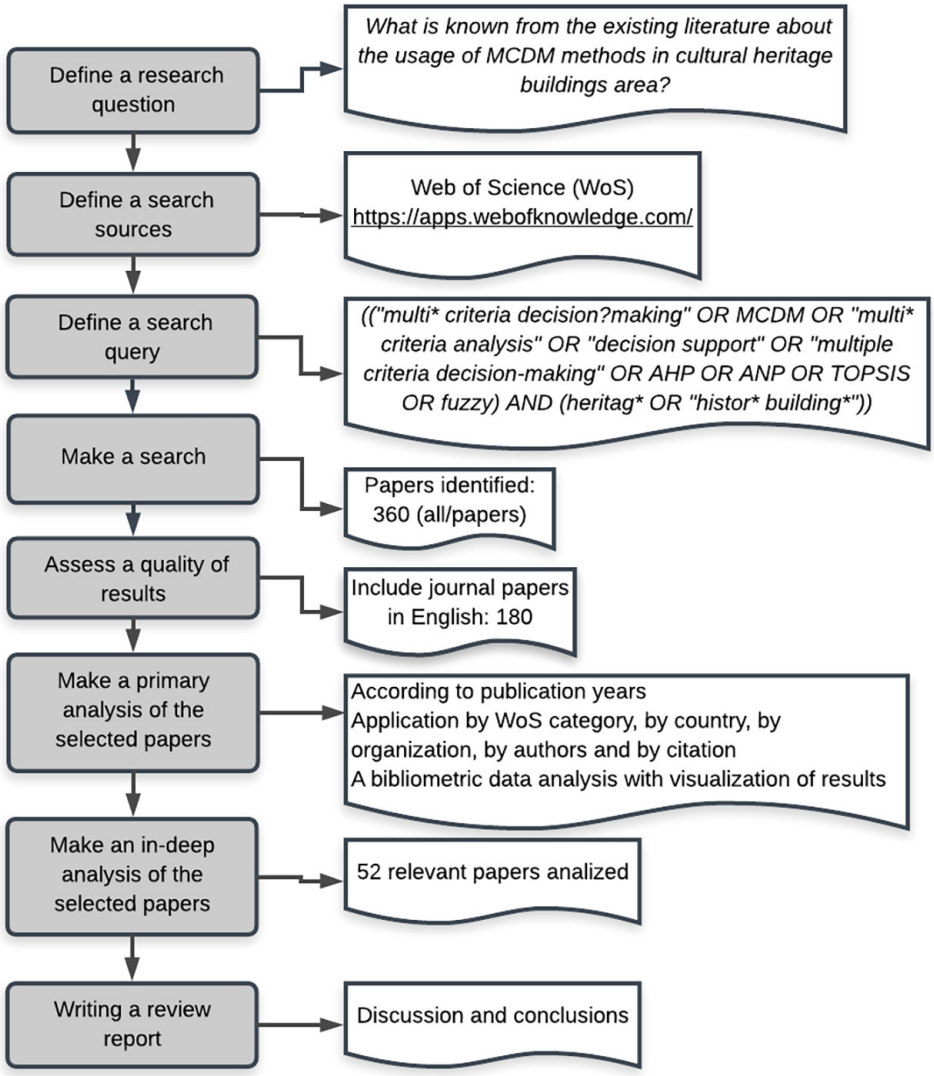

Figure 1. The methodology on the MCDM methods application in cultural heritage buildings area schema

study is a scoping study[1] and designed to examine the available journal papers and to determine the range of spreading and using of MCDM methods in cultural heritage buildings area. Our research question is: *What is known from the existing literature about the usage of MCDM methods in cultural heritage buildings area?*

2. **Define a search sources**. In order to review a certain amount of papers on MCDM methods application in cultural heritage buildings area, the Thomson Reuters Web of Science (WoS) (https://apps.webofknowledge.com/) core database was chosen, since the initial study of sources shows that it contains significant number of journal papers relevant to the research field. This justified the use of WoS as the source for data retrieval.

3. **Define a search query**. Searching keywords and their meaningful combinations are defined here. The following search query has been conducted from keywords:
((“multi criteria decision?making” OR MCDM OR “multi* criteria analysis” OR “decision support” OR “multiple criteria decision-making” OR AHP OR ANP OR TOPSIS OR fuzzy) AND (heritag* OR “histor* building*”))*
Note that into the search we have included the keywords AHP, ANP, TOPSIS and fuzzy, since according to Mardani et al. (2017); Zavadskas, Govindan, Antucheviciene, and Turskis (2016); Zavadskas et al. (2017), those methods and their extensions are among the most used MCDM methods in civil engineering, construction and building technology and sustainability. Therefore, their inclusion into the search query allows making a set of obtained results bigger.
4. **Make a search.** The searching process is performed according to the defined query in step 3. A set of 360 papers is obtained.

[1] A scoping study is designed in Arksey and O’Malley (2005): 1) to examine the extent, range and nature of research activity; 2) to determine the value of undertaking a full systematic review; 3) to summarise and disseminate research findings; 4) to identify research gaps in the existing literature.

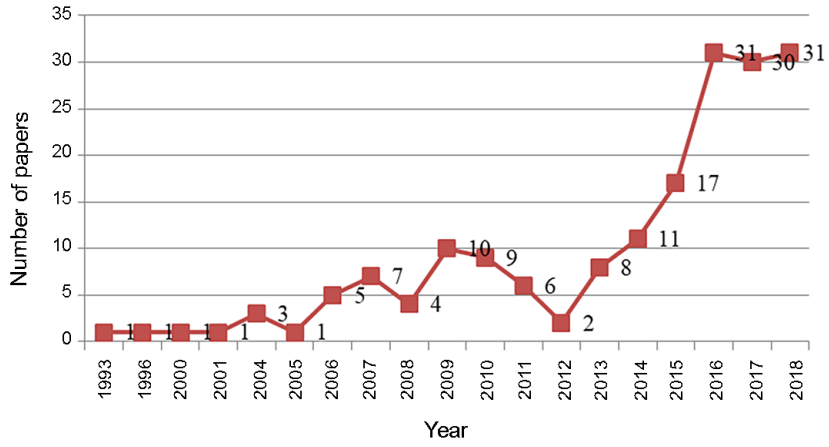

Figure 2. Overview of papers on MCDM methods application in cultural heritage buildings area according to years (WoS, 11 November 2018)

5. **Assess a quality of results.** Quality of results is assessed here. According to Kitchenham, Mendes, and Travassos (2007) there is no commonly agreed definition of "quality". Moreover, authors of this paper have refined the initial search results by including only papers from journals published in English language. The primary set of publications is refined to 180 papers.
6. **Make a primary analysis of papers.** A required data is extracted according to the research question. Papers are reviewed according to publication years and application by WoS category, by country, by organization, by authors and by citation. A bibliometric data analysis with visualization of results is performed. Moreover, during this step, papers for the in-deep analysis are selected.

   A number of tools, like VOSviewer, BibExcel, CiteSpace, CoPalRed, Sci2, VantagePoint and Gephi, are created for analyzing, mapping and visualization of a bibliometric data. We are not going to make a detailed review of visualization tools, because it is not the main aim of this paper. We are going to use VOSviewer[2] and Gephi[3], as advocated in Hosseini, Martek, Zavadskas, Aibinu, Arashpour, and Chileshe (2018).
7. **Make an in-deep analysis of the papers.** In this step, an in-deep analysis of the selected papers is performed by reading a full text of the selected papers.
8. **Writing a review report.** A review report is written and discussion is conducted.

3. Results of the analysis

In this section, the analysis results are presented.

3.1. A primary analysis of papers on MCDM methods application in cultural heritage buildings area

As can be seen from Figure 2, MCDM methods application in cultural heritage buildings are becoming more relevant in civil engineering, construction and building technology. In 2013–2018 a number of papers has increased.

In Figure 3, a comparison of two topics: MCDM methods application in cultural heritage buildings area and cultural heritage buildings, are presented. This figure allows us to evaluate MCDM methods application in cultural heritage buildings topic with more general topic of the cultural heritage buildings. As can be seen from Figure 3, the topic of cultural heritage buildings is widely analyzed in WoS categories as follows: engineering civil, construction building technology, materials science multidisciplinary, architecture, computer science interdisciplinary applications and computer science theory methods.

Considering that applications on topic of "heritage building" and "historic building" (1980–2018) have been published more than 1 039 journal papers in English, the use of MCDM methods to deal with heritage buildings consisted only 17% of total number. The biggest part of papers was published in 2016. Further, we present analysis of MCDM methods application in cultural heritage building area only.

The main considered categories of MCDM methods application in cultural heritage building area are presented in Figure 4. As can be seen from the figure, the five most popular WoS Categories are as follows: Environmental Sciences (32), Geosciences Multidisciplinary (30), Environmental Study (26), Engineering Civil (20) and Archaeology (18).

The bibliometric analysis of papers on MCDM methods application in cultural heritage buildings area according to countries (Figure 5) shows that the main five, working in the analyzed topic, countries are as follows: Italy (29), Australia (19), China (18), Spain (12) and Taiwan (12). Moreover, those countries cite each other. However,

[2] http://www.vosviewer.com/download
[3] https://gephi.org/

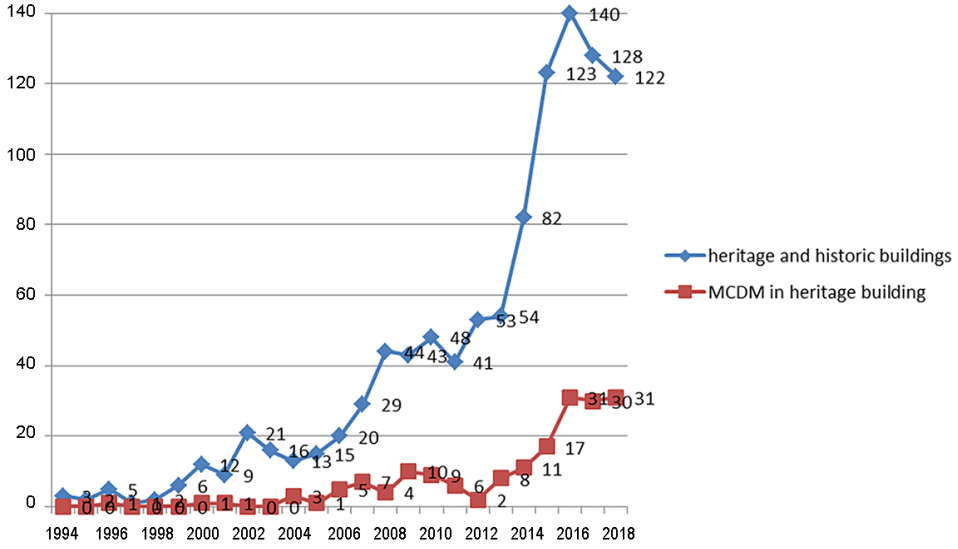

Figure 3. Comparing the topics of cultural heritage buildings with MCDM methods application in cultural heritage buildings area according to the number of papers published during the period of 1994–2018 (WoS, 11 November 2018)

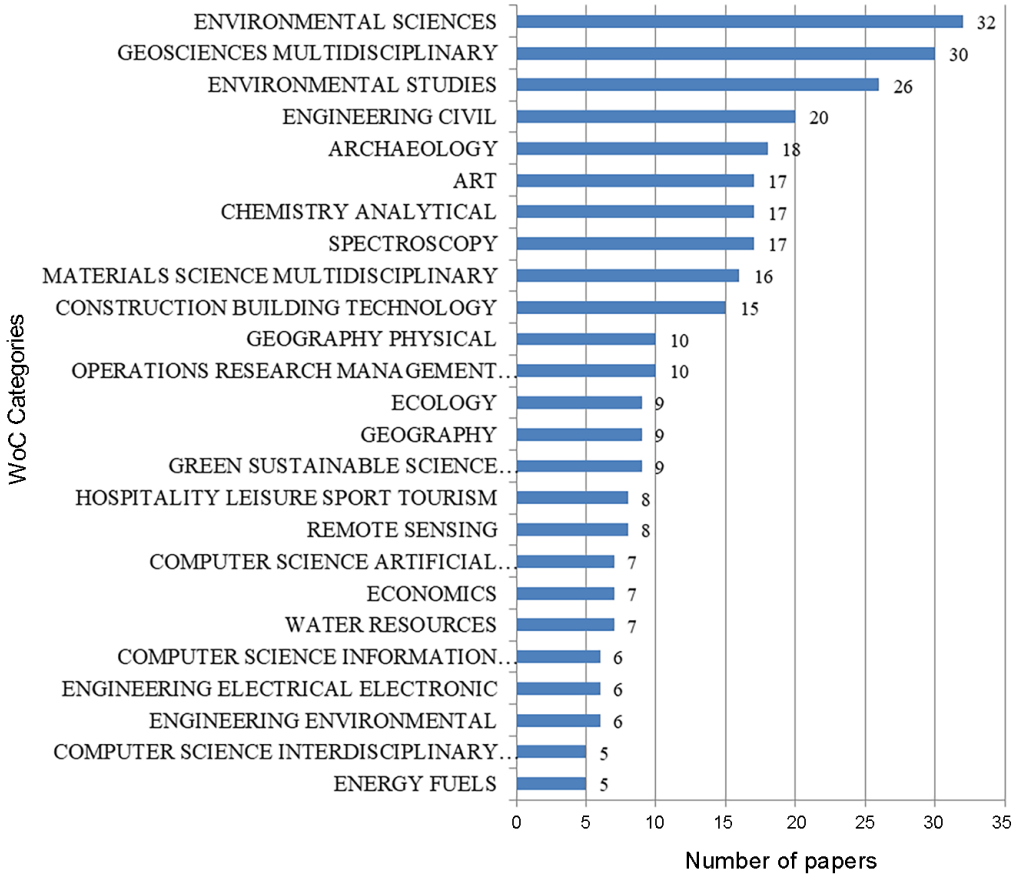

Figure 4. Overview of papers on MCDM methods application in cultural heritage buildings area according to WoS Category (WoS, 11 November 2018)

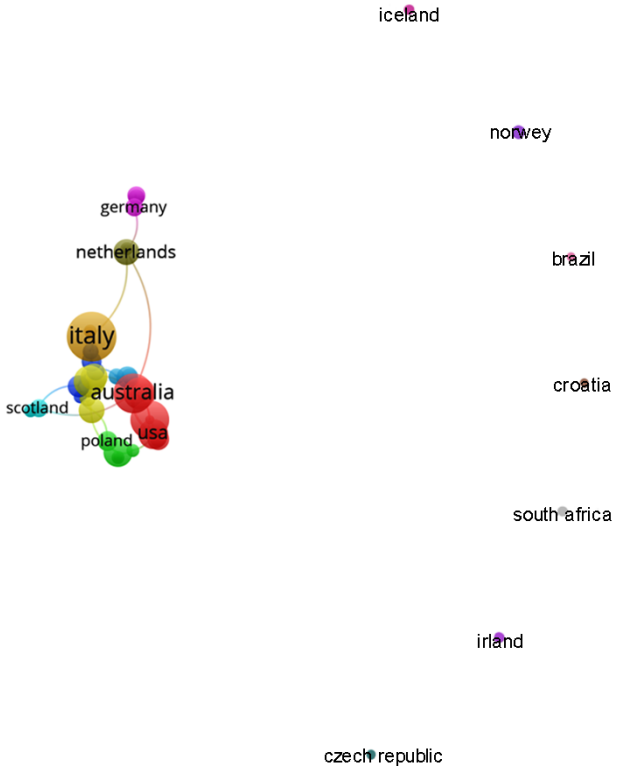

Figure 5. A map of MCDM methods application in cultural heritage buildings area according to countries (WoS, 11 November 2018)

as can be seen from Table 2, the distribution of priorities of countries according to the citation differs. The most five cited countries are as follows: Lithuania (314), Australia (288), Italy (153), Taiwan (150) and China (111).

This distribution of countries can be explained by a significant number of heritage buildings and traditional dwellings finding in analyzed countries, like in Europe countries. These countries appreciating their heritage sites and buildings, so the government, scientists, researchers are searching qualitative methods how properly to preserve this heritage.

A bibliometric data analysis of papers on MCDM methods application in cultural heritage buildings area according to organizations (Figure 6) shows that the main five organizations are as follows: Vilnius Gediminas Tech Univ (9), Chinese Acad Sci (7), Univ Seville (5), Alexandru Ioan Cuza Univ (4) and Sichuan Univ (4).

Table 3 presents an overview of MCDM methods application in cultural heritage buildings area according to organizations by number of papers and citations. The most cited five organizations are as follows: Vilnius Gediminas Tech Univ (276), Natl Taiwan Univ Sci Technol (80), Csiro Sustainable Ecosyst (79), James Cook Univ N Queensland (71) and Univ Gothenburg (63).

A co-authorship analysis of authors working in the topic of MCDM methods application in cultural heritage buildings is presented in Figure 6. It shows that the most papers having five authors are as follows: Kutut, V. (4), Turskis, Z. (4), Zavadskas, E. K. (4), De Toro, P. (3) and Nicu, I. C. (3). Figure 7 shows that there are 76 main clusters, covering research groups, which are working in the area of MCDM methods application in cultural heritage buildings area.

In Table 4, an overview of MCDM methods application in cultural heritage buildings area according to the

Table 2. Overview of MCDM methods application in cultural heritage buildings area according to countries (WoS, 11 November 2018)

Country	Number of papers	Number of citations
Lithuania	10	314
Australia	19	288
Italy	29	153
Taiwan	12	150
China	18	111
USA	11	105
Portugal	9	101
Turkey	8	95
Sweden	2	72
Spain	12	65
South Korea	6	64
Wales	3	47
Poland	5	42
Latvia	1	42
Scotland	4	41
England	6	37
Netherlands	8	35
Colombia	1	34
Finland	2	33
India	2	31

Table 3. Overview of MCDM methods application in cultural heritage buildings area according to organizations (WoS, 11 November 2018)

Organization	Number of papers	Number of citations
Vilnius Gediminas Tech Univ	9	276
Natl Taiwan Univ Sci Technol	3	80
Csiro Sustainable Ecosyst	3	79
James Cook Univ N Queensland	1	71
Univ Gothenburg	1	63
Univ Tras os Montes & Alto Douro	1	56
Chinese Acad Sci	7	52
Sichuan Univ	4	49
Seoul Natl Univ	2	45
Csiro	2	43
Riga Tech Univ	1	42
Swansea Metropolitan Univ	2	40
Acad Sinica	1	36
Natl Univ Tainan	1	36
Warsaw Univ Technol	2	34

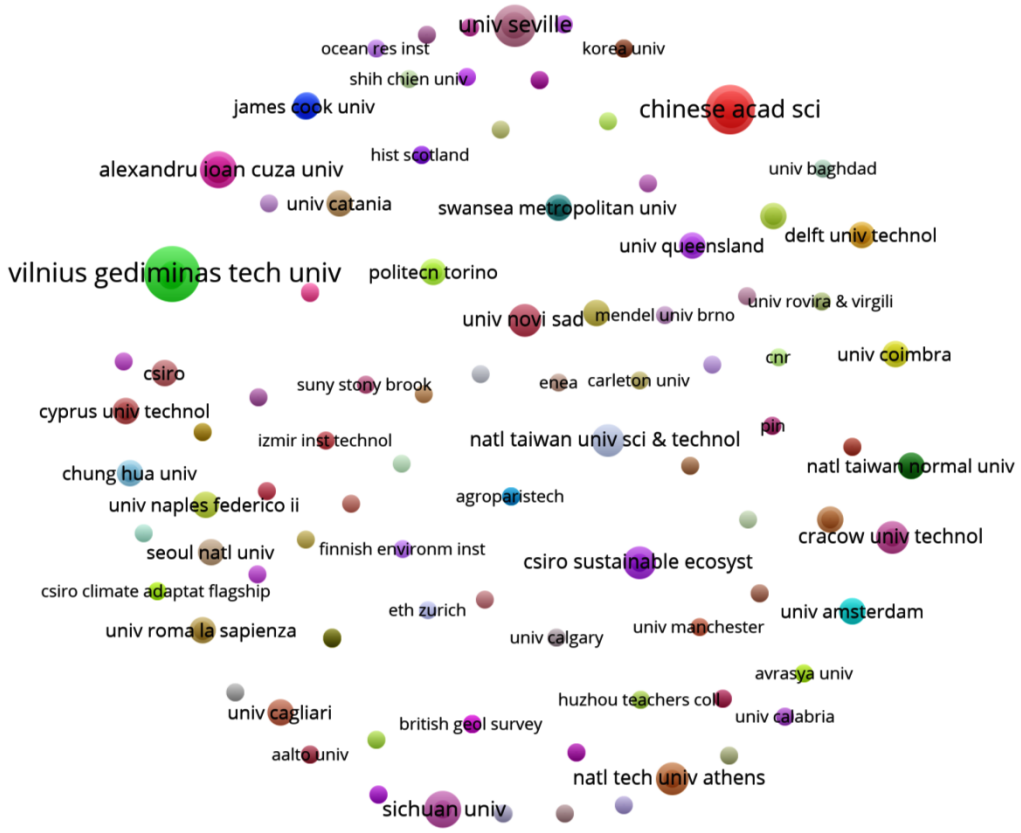

Figure 6. A map of MCDM methods application in cultural heritage buildings area according to organizations (WoS, 11 November 2018)

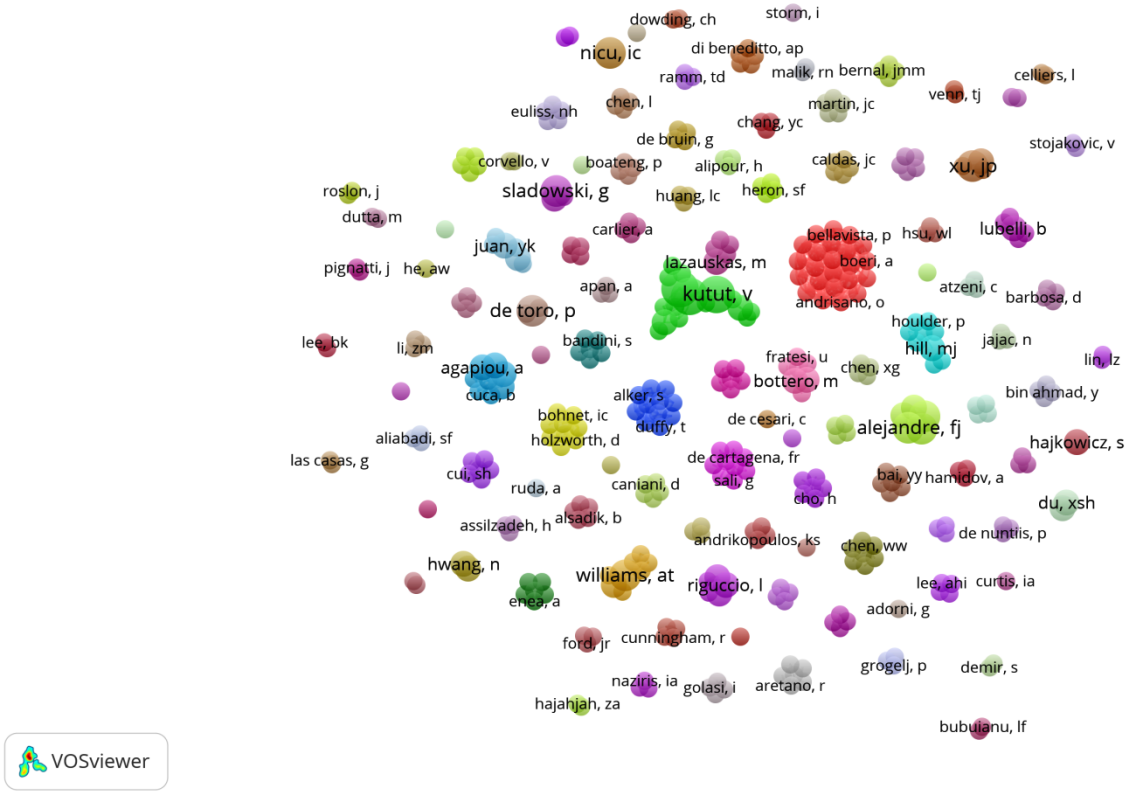

Figure 7. A map of MCDM methods application in cultural heritage buildings area according to authors (WoS, 11 November 2018)

Table 4. Overview of MCDM methods application in cultural heritage buildings area according to authors (WoS, 11 November 2018)

Author	Number of papers	Times cited
Zavadskas, E. K.	4	192
Turskis, Z.	4	168
Kaklauskas, A.	1	99
Seniut, M.	1	99
Tupenaite, L.	1	99
Kutut, V.	4	82
Burinskiene, M.	2	80
Curtis, I. A.	1	71
Wang, H. J.	2	66
Stenseke, M.	1	63
Fernandes, L. F. S.	1	56
Hajkowicz, S. A.	1	56
Pacheco, F. A. L.	1	56
Valle, R. F.	1	56
Varandas, S. G. P.	1	56
Hajkowicz, S.	2	55
Zeng, Z. T.	1	49
Williams, A. T.	3	47
Xu, J. P.	3	47
Hwang, N.	2	45
Lee, M. G.	2	45
Blumberga, A.	1	42
Blumberga, D.	1	42
Lazauskas, M.	2	42
Zagorskas, J.	1	42

number of citations per author, where the number of citations exceeds 35, is presented. As can be seen, the five most cited authors are as follows: Zavadskas, E. K. (192), Turskis, Z. (168), Kaklauskas, A. (99), Seniut, M. (99) and Tupenaite, L. (99).

The citation analysis of papers is presented in Figure 8 and Table 5. In Figure 8, a map of the relevant papers on MCDM methods application in cultural heritage buildings area is presented. From the figure we can see the most relevant papers with bigger citation in the center of the map.

In Table 5, the most 25 cited papers in November 11, 2018 on MCDM methods application in cultural heritage buildings area excluding self-citation are presented. Of course, those values changes over time. And if we check the citation rates at another time, they will differ; since citation rates are dynamic by their nature and depend on the field of interest at some point in time. As can be seen from Table 5 column Total Citations (November 11, 2018) and Total Citations (January 8, 2019), values differs. Certainly, collecting values of those attributes for a certain period of time, it is possible to identify various trends, like real importance of particular papers. Now, the table shows the most popular papers for the moment of November 11, 2018.

3.2. In-deep analysis of papers on MCDM methods application for cultural heritage buildings area

A detailed analysis of papers, dealing with MCDM methods application for cultural heritage building's issues, is

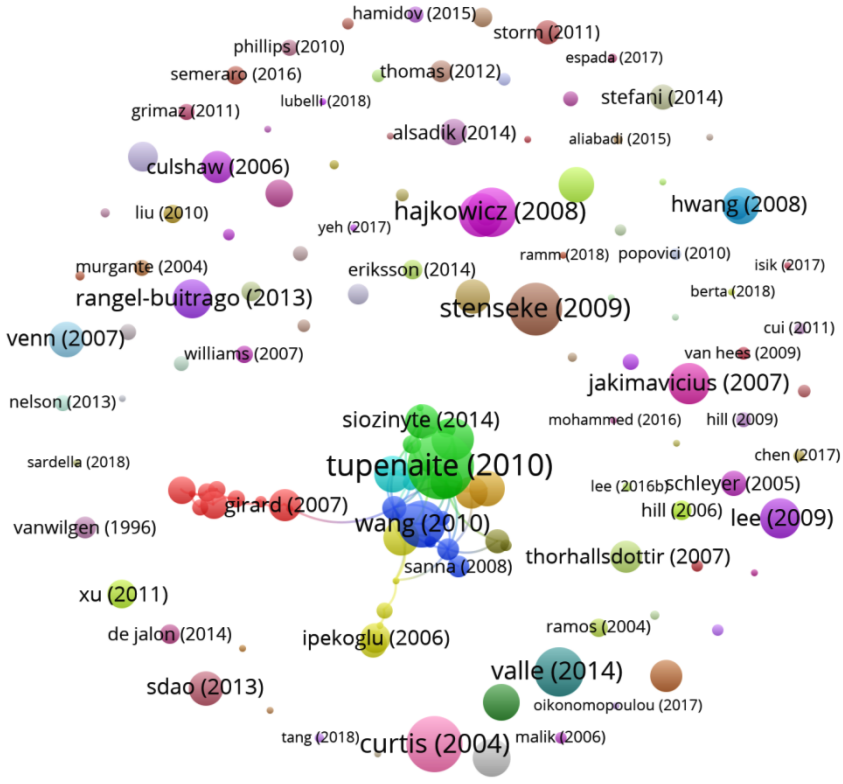

Figure 8. A map of papers on MCDM methods application in cultural heritage buildings area (WoS, 11 November 2018)

Table 5. Overview of most 25 cited papers on MCDM methods application in cultural heritage buildings area (WoS, 11 November 2018)

Reference	Publication year	Total Citations (November 11, 2018)	Total Citations (January 8, 2019)	Average per year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Tupenaite, Zavadskas, Kaklauskas, Turskis, and Seniut (2010)	2010	99	99	11	0	0	0	0	4	17	28	8	6	9	6	11	10
Curtis (2004)	2004	71	73	4.73	0	2	3	4	8	4	7	7	4	8	11	5	7
Stenseke (2009)	2009	63	65	6.3	0	0	0	2	2	7	5	5	15	10	4	3	10
Junior, Varandas, Fernandes, and Pacheco (2014)	2014	56	59	11.2	0	0	0	0	0	0	0	0	1	16	14	14	11
Hajkowicz (2008)	2008	56	58	5.09	0	0	1	3	12	10	5	5	4	7	4	2	3
Wang and Zeng (2010)	2010	49	49	5.44	0	0	0	0	2	1	3	7	6	3	13	8	6
Hajkowicz (2007)	2007	43	43	3.58	0	0	3	2	4	3	3	9	3	4	3	6	3
Zagorskas, Zavadskas, Turskis, Burinskienė, A. Blumberga, and D. Blumberga (2014)	2014	42	43	8.4	0	0	0	0	0	0	0	0	0	6	10	18	8
Jakimavicius and Burinskiene (2007)	2007	38	38	3.17	0	0	5	12	11	3	1	2	2	1	0	1	0
Lee, Chang, and Wang (2009)	2009	36	38	3.6	0	0	0	2	3	4	3	3	2	7	4	6	2
Feng, Liu, Euliss, Young, and Mushet (2011)	2011	33	33	4.13	0	0	0	0	0	0	2	9	2	9	5	2	4
Książek, Nowak, Kivrak, Rosłon, and Ustinovichius (2015)	2015	31	32	7.75	0	0	0	0	0	0	0	0	0	2	15	10	4
Bohnet et al. (2011)	2011	31	32	3.88	0	0	0	0	0	0	3	7	1	11	2	5	2
Kutut, Zavadskas, and Lazauskas (2014)	2014	28	30	5.6	0	0	0	0	0	0	0	0	1	7	5	10	5
Wang, Lee, Peng, and Wu (2013)	2013	28	28	4.67	0	0	0	0	0	0	0	2	2	12	4	2	6
Wu and Xu (2013)	2013	28	28	4.67	0	0	0	0	0	0	0	3	6	3	7	6	3
Siozinyte, Antucheviciene, and Kutut (2014)	2014	27	28	5.4	0	0	0	0	0	0	0	0	0	9	7	6	5
Sorvari and Seppälä (2010)	2010	27	27	3	0	0	0	0	0	0	2	3	5	4	3	7	3
Turskis, Zavadskas, and Kutut (2013)	2013	23	23	3.83	0	0	0	0	0	0	0	0	3	7	6	6	1
Dutta and Husain (2009)	2009	23	23	2.3	0	0	0	0	1	0	0	2	3	5	1	8	3
Girard and De Toro (2007)	2007	23	24	1.92	0	0	0	2	0	0	4	6	3	2	3	1	2
Thorhallsdottir (2007)	2007	23	23	1.92	0	0	0	1	4	1	1	1	1	5	7	1	1
Culshaw et al. (2006)	2006	23	24	1.77	0	2	1	7	1	2	0	1	4	1	4	0	0
Ipekoglu (2006)	2006	21	21	1.62	1	2	1	0	3	0	2	2	2	1	1	4	2

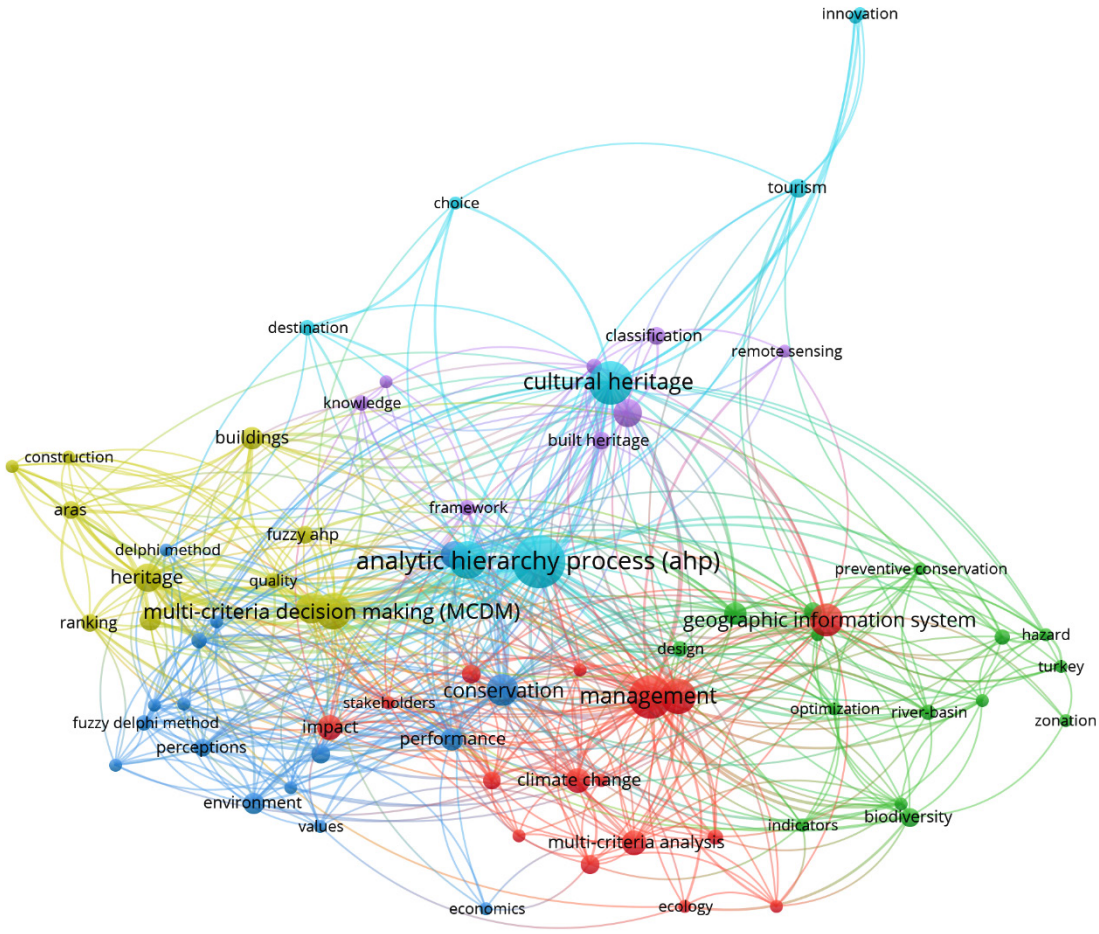

Figure 9. A map of keywords on MCDM methods application in cultural heritage buildings area (WoS, 11 November 2018)

presented here. According to the obtained bibliometric data, a map of keywords is created using VOSviewer and presented in Figure 9.

A keywords map was generated using authors' and WoS presented keywords. As a result, 1226 keywords were detected. And applying VOSviewer algorithms the result 102 keywords, with minimum number of occurrences equals to 3, is obtained. However, a received set of keywords should be refined one more time, since VOSviewer understands synonyms and same words with different orthography, like "modelling" and "modeling", "climate change" and "climate-change", etc., as different keywords. Therefore, the map created by VOSviewer was transferred to Gephi for the refinement of the primary set of keywords. In Gephi, similar terms (like "multi criteria decision making" and "MCDM", "AHP" and "analytic hierarchy process") were merged. A final map of keywords consists of 74 nodes (see Figure 9). It illustrates the main general areas of research determined in MCDM methods application in cultural heritage buildings area. Keywords with bigger number of occurrences are presented by bigger labels and they present main interests areas.

According to the in-deep analysis of a keywords map and keywords occurrences, the mostly used MCDM methods, their number of occurrences, average publication year and average citations are presented in Table 6. It can be seen from the table that the selected MCDM methods have been widely used in the period of 2014–2017.

According to the in-deep analysis of a keywords map and keywords occurrences, the mostly used places, where cultural heritage buildings have been assessed by a particular MCDM method, their number of occurrences, average publication year and average citations are presented in Table 7.

For the future in-deep analysis 52 papers (see Table 9) was selected by reading abstracts and full text of papers and eliminating inappropriate papers that contain relevant keywords, but don't fit the analyzed topic. In Table 9, we have presented an in-deep analysis of the selected 52 papers according to used MCDM method, main topic of the paper, and criteria used for the evaluation of alternatives.

The summary of the results of the used MCDM methods in 52 selected papers are presented in Table 9. As can be seen from the table, the three most used MCDM methods are AHP, ANP and fuzzy Delphi. Experts' evaluation is also popular. In 18 analyzed papers other MCDM methods are used, sometimes authors do not name them. Moreover, in 31 of analyzed papers a combination of several MCDM methods, like PROMETHEE and AHP, is used.

Table 6. The mostly used MCDM methods in cultural heritage topic

MCDM method	weight<occurrences>	score<avg._pub._year>	score<avg._citations>
Analytic hierarchy process (AHP)	44	2016.0167	7.49706
Fuzzy Logic	13	2013.3846	6.0769
ARAS	5	2016.6	8.4
Fuzzy AHP	5	2016.4	7
Analytic network process	4	2013.5	20.75
Fuzzy Delphi method	4	2014.75	19.25
Delphi method	3	2014	18.3333

Table 7. The mostly used places for the assessment

MCDM method	weight<occurrences>	score<avg._pub._year>	score<avg._citations>
China	6	2015.1667	6.5
Hong-Kong	3	2017.6667	0.3333
Turkey	3	2015	15.3333

The in-deep analysis of assessment criteria shows that cultural heritage buildings are evaluated by different aspects as follows Historical value, Artistic value, Technological value, Social value, Economic value, Location and accessibility.

4. Discussion

Heritage buildings are an important part of social, economic, historical, architectural and cultural identity of numerous countries. Cultural heritage buildings indicate spiritual, cultural, archaeological, historical, ethnic, social, economic and technological value, conveyed over time. Considering to invaluable values of heritage buildings, the scientists and government are trying to find the best possibilities for heritage buildings preservation and conservation.

Although, MCDM methods are widely used in different areas to choose an objective solution from possible, till now MCDM methods application in cultural heritage buildings area is weak. This can be stated by the small number of papers found in this area. The main topics of usage of MCDM in cultural heritage buildings are as follows: selecting appropriate reuse alternative, selecting appropriate refurbishment alternative, selecting suitable alternatives for refurbishment projects, determining level of hazards. The most used MCDM methods are as follows: AHP and fuzzy AHP, Delphi and fuzzy Delphi. Experts' knowledge is also used for the assessment of cultural heritage value and to select an optimal alternative for its conservation or refurbishment. Another popular approach in assessing cultural heritage value is using fuzzy analysis. Combination of several MCDM methods is useful in applying complex problem solving in cultural heritage buildings area.

However, as was obtained from the results of primary and in-deep analysis, there is luck of approaches on applying MCDM in cultural heritage buildings area. Moreover, existing researches and approaches are not interrelated. There is paid not enough attention for complex evaluation of cultural heritage buildings as in separate countries and regions as in global perspective. Existing researches and approaches are not interconnected and are not interrelated.

Conclusions

The analysis of papers on MCDM methods application in cultural heritage buildings area shows that, although, MCDM methods are widely used in many other areas, their usage in the field of cultural heritage buildings is weak.

As a primary analysis with bibliometric data visualization of the relevant papers shows, the three most popular WoS Categories are Environmental Sciences (32), Geosciences Multidisciplinary (30) and Environmental Study (26). The main three countries, working in the analyzed topic, are Italy (29), Australia (19) and China (18). However, the priorities of countries according to the citation are as follows: Lithuania (314), Australia (288) and Italy (153). The main three organizations, working on the analyzed topic, are Vilnius Gediminas Tech Univ (Lithuania) (9), Chinese Acad Sci (China) (7) and Univ Seville (Spain) (5). The three most cited authors are Zavadskas, E. K. (192), Turskis, Z. (168) and Kaklauskas, A. (99).

Considering that applications on topic of "heritage building" and "historic building" have been published more than 1 039 journal papers in English, the use of MCDM methods to deal with heritage buildings consisted only 17% of total number. The biggest part of papers was published in 2016.

Table 8. Results of the in-deep analysis of the papers

Reference	MCDM method used	Focus of the paper	Evaluating criteria
Uva, Sangiorgio, Ruggieri, and Fatiguso (2019)	AHP (Analytic Hierarchy Process)	The seismic vulnerability and damage assessment of heritage buildings (Ancient masonry churches)	Goal: Determine building vulnerability index Criteria: Element typology, Failure mechanism, Damage typology
Chen et al. (2018)	Fuzzy Delphi, ANP (Analytic Network Process)	The assessment process of historic building reuse	The most suitable reuse alternative of the museum was for community activities, followed in sequential order by commercial, education and exhibition, and composite use.
Liu, Zhao, and Yang (2018)	Fuzzy AHP	Industrial heritage	Historical value, artistic value, technological value, social value, economic value
Hsu, Lin, Chao, and Huang (2018)	Fuzzy Delphi, ANP	To combine museums operations management with cultural preservation, local industrial development, and local residents' goals.	community symbiosis, cultural inheritance, and regional revitalization
Bozic, Vujičić, Kennell, Besermenji, and Solarević (2018)	AHP	To rank the attractiveness of six cultural heritage sites in the island of Phuket to make recommendations for sites	Micro location and accessibility, artistic value, scenic/aesthetic, tourist infrastructure, tourist appeal, fitting in with other tourist assets in the vicinity
Lubelli, van Hees, and Bolhuis (2018)	The prototype decision support, based on experts judgments, tool developed	A recurrent hazard to ancient buildings in Europe and its relevance is expected to increase in the future, due to climate changes	Based on reduction of water flux in ingress, Based on stopping/reducing water transport higher up in the wall Based on evaporation increase Based on electro kinetic phenomena Additional/alternative methods, treat symptoms
Ma, Li, and Chan (2018)	AHP	To assess the value of non-World Heritage Tulou (NWHT) and provide grounds for the reuse of Tulou	Historical value (year of construction, popularity), aesthetic value (aesthetic value of structural spaces, aesthetic value of details and decorations, aesthetic value of surrounding environment), social value (historical status of clan, current influence of clan)
Berta, Bottero, and Ferretti (2018)	ANP, Multi-Attribute Value Theory (MAVT)	The requalification of the former Shougang/Er-Tong mechanical factory in Beijing, China	Initial priorities, environmental perspective, social perspective, economic perspective, urban planning perspective
Keyvanfar et al. (2018)	AHP	A sustainable historic waterfront revitalization	Social and cultural revitalization (identity, authenticity, safety and well-being, the sense of place, building gathering areas, the sense of enjoyment), physical and environment revitalization (habitat and natural preservation, pollution moderator, accessibility, dynamic site design, building walkable outdoor environment, providing facilities and amenities), economic and functional revitalization (mixed-use development, diversification, employment opportunities)
Berg (2018)	–	Preventive conservation and tourism in Norway's stave churches	–
Claver, García-Domínguez, and Sebastián (2018)	The Saaty fundamental scale, AHP	For assessing both the heritage value and the most compatible uses according to the characteristics of the asset	Technological singularity (technological exclusivity, technological innovation), functional singularity (layout, sizing of spaces, fitting out of the spaces), construction singularity (structure, construction technique, architectural or artistic style), historical singularity (socioeconomic impact on the setting, production tradition, antiquity), production singularity

Reference	MCDM method used	Focus of the paper	Evaluating criteria
Gholitabar, Alipour, and Costa (2018)	Fuzzy logic-qualitative comparative analysis (QCA), questioning	To assess the architectural value and the tourist and preservation potential of historical buildings in Porto/ Aveiro	Architecture, history, historical place, culture, attraction, aesthetics, local
Giuliani, De Falco, Landi, Bevilacqua, Santini, and Pecori (2018)	Some MCDM method (not named)	Italian grain silos and their reuse perspectives	Technical and economic feasibility, reversibility, structural, functional and aesthetic compatibility, interest of the community, compliance with urban regulations and building codes
Radziszewska-Zielina, Śladowski, and Sibielak (2017)	Fuzzy logic, some formulas	Planning the reconstruction of a historical building	Probability of carrying out the reconstruction, time spent carrying out the reconstruction [workdays], cost of carrying out the reconstruction [PLN]
Özdemir Işık and Demir (2017)	AHP, ELECTRE	Urban coastal areas and historical–cultural structures on the coastline of Trabzon	Increasing criteria (socialization, sportive activity, visual integrity), decreasing criteria (service quality, space utilization, coast connection, outdoor equipment, city promotion)
Prieto, Macías-Bernal, Chávez, and Alejandre (2017)	Fuzzy method, some	Maintenance planning in heritage buildings	–
Prieto, Silva, de Brito, Macías-Bernal, and Alejandre (2017b)	Fuzzy set theory and model assumptions	The assessment of the functional service life of built heritage applying statistical tools	Geological location, roof design, environmental conditions, constructive system, preservation, load state modification, live loads, ventilation, facilities, fire, inner environment, rainfall, temperature, population growth, heritage value, furniture value, occupancy
Turskis, Morkunaite, and Kutut (2017)	AHP, EDAS	Cultural heritage item preservation, renovation and adaptation to the social needs of people	Economic, historical, archeological, religious, technological, research and other perspectives
Guo et al. (2017)	Fuzzy AHP	The monitoring and early warning system and the long-term preventive preservation of the Mogao Grottoes	Lithology, cliff shape, dangerous body, fissure, Gully, earthquake, rainfall
Radziszewska-Zielina and Śladowski (2017)	Fuzzy modelling and structural analysis, The WINGS method (Weighted Influence Non-linear Gauge System)	Changing the function of a historical building through adapting it to new use	Economic benefits, benefits to society, benefits associated with the protection of the environment, benefits associated with the protection of cultural heritage, benefits of minimising the resources needed to bring the structure into compliance with the basic standards
Piñero, San-José, Rodríguez, and Losáñez (2017)	AHP	The rehabilitation of an historic city centre	Technical factors (technical status, need for emergency actions, risks), Socio-cultural factors (residents affected, non-residents affected, cultural value)

Continue of Table 8

Reference	MCDM method used	Focus of the paper	Evaluating criteria
Śladowski and Paruch (2017)	The DEMATEL method (Decision Making Trial and Evaluation Laboratory)	The problem of the failure of historical buildings	The lack of wall cladding in the form of plaster on either side; the deliberate damaging of the abutments of the exterior walls; the biological corrosion of the walls in the form of moss and lichen growths; the weakening of the structure of the mortar or loss of mortar in the bindings between the bricks; excessive moisture within the walls resulting from capillary action; the fire of the roof along with failure in the form of the collapse of the timber roof structure above the main nave of the Collegiate Church; the vertical and horizontal displacement of the external walls; the time of the building's construction – the first half of the XVII century; the influence of climatic factors, such as: rain, snow, high and low temperatures – thermal deformation of the vault; the cracks and scratch marks on the vaulted ceilings and brick walls, which makes it an effect of these factors
Chen, Yoo, and Hwang (2016)	Fuzzy AHP, Fuzzy SAW (simple additive weighting)	The process of a property-led urban conservation of a historic district in China, Wenming Historic Block in Kunming City	Management policy and regulation, public engagement and information openness, and traditional culture protection
Malian, Mahdineja, and Aslani (2017)	Fuzzy ANP, Fuzzy WLC (weighted linear combination)	The documentation of the great historical monument, Gorgan Wall, and its surroundings	–
Prieto, Silva, de Brito, Macías-Bernal, and Alejandre (2017a)	A fuzzy expert system, experts and historic records	Identifying the main anomalies that may occur in historical buildings, analysing their related causes, and estimating the influence of pathological situations on the buildings' functionality in south-western Spain	17 variables (vulnerabilities and external risks damages)
Jajac, Rogulj, and Radnić (2017)	PROMETHEE, AHP	Decision-making in planning a historic bridge rehabilitation project	Construction aspects, economic aspects and social aspects
Nicu (2016)	AHP	Cultural heritage sites assessment in Valea Oii catchment, North-eastern Romania	Proximity to streams, Roads, Villages, Landslides, Gullies
Naziris, Lagaros, and Papaioannou (2016)	AHP	Fire protection of cultural heritage structures	Reduce the probability of fire start, limit fire development in the fire compartment, limit fire propagation out of the fire compartment. Facilitate egress, facilitate firefighting and rescue operations, limit the effects of fire products, protection from forest fires
Seddiki, Anouche, Bennadji, and Boateng (2016)	PROMETHEE GDSS, the Graphical Analysis for Interactive Aid (GAIA) analysis, Delphi, Swing	Energy-efficient during renovations in masonry buildings with heritage values is certain	The implantation of the building and the climate zone; the internal organization (plans, sections); the plan of facades with full details; the area and volume of the building; the methods of construction of the building and the openings (load bearing elements, walls, nature of the connections, roof, flours, and windows type); the energy consumption and the technical equipment
Rosłon and Seroka (2016)	WSM (weighted sum method), AHP	Arranging the selected options of the foundation wall vertical water insulation technology in an existing model historic building	Net cost per 1 linear meter, time of works execution per 1 linear meter, popularity, durability, nuisance of works

Continue of Table 8

Reference	MCDM method used	Focus of the paper	Evaluating criteria
Danielová, Kumke, and Peters (2016)	Fuzzy logic approach	Virtual 3D reconstructions of archaeological sites of an ancient Roman temple named "Sanctuary of Diana" located in Nemi, Italy	–
Fernandes Rocha and Calejo Rodrigues (2016)	The definition of a multi-criteria decision support model through the systematization of the necessary maintenance information, some calculations	The design process that includes building maintenance benchmarked by the service behaviour with regard to pitched roofs	Importance indicator, easiness indicator, the maintainability index
Hapciuc, Romanescu, Minea, Iosub, Enea, and Sandu (2016)	AHP	The comparative assessment of the risk factors allowed the identification of the heritage monuments that belong to the highest flood susceptibility area	Slope, profile curvature, soil texture, land-use, lithology
Ibáñez, Bernal, de Diego, and Sánchez (2016)	Expert system, based on experts' knowledge and regulations, fuzzy analysis	Predicting the service life of buildings	Vulnerability (geological location, environmental conditions, constructive system), anthropic risks (population growth, heritage value, furniture value, occupancy), vulnerability (roof design, preservation), static structural risks a (load state modification, facilities), static structural risks b (dead and live loads, ventilation, fire, inner environment), atmospheric risks (rainfall, temperature)
Lee, Shiau, and Hsu (2016)	A participative action plan, focus group interviews, and Fuzzy Delphi	An evaluation and feedback system to identify planning evaluation criteria for natural and cultural scenic areas of indigenous tribes at Taiwan	Environmental (diversities of biology and landscape, culture of historical heritage, sensitivity to environment), Economic (value of economic activities, pattern of local industries, touring human service resources), Societal and cultural (extent of support from residents, education function, capability for innovation and feedback of local society), Political (protective policy of designated site, development plan, restriction on land uses)
Oppio, Bottero, Ferretti, Fratesi, Ponzini, and Pracchi (2015)	SWOT analysis, ANP	The art in cultural heritage management of thirteen castles in a mountainous region in the North of Italy	Civicware (initiative in/about the castle, Initiative for kids and schools, vitality, pride of population, demographic dynamics, permutation rate, poor appeal for events, tourist/local relationships), Software (distribution of events (based on summer/winter database), lack of distribution of events through the year), Ecoware (mountain dew ponds, pathways, protected sites, high quality of agricultural areas, vineyards and groves, hydrogeological risk), Hardware (highways entrances and exits, train stations; public transportation; availability of services (hotel, restaurants, post offices, shopping centres, banks, sports facilities); historical pathways; historical centres; Anthropic pressures), Org-ware (events promoted by municipality departments, network density, events promoted by external actors, hierarchy of relationships among actors, number of permanent actors), Fin-ware (revenues from tickets, income/events ratio)
Shehada, Ahmad, Yaacob, and Keumala (2015)	Experts, Fuzzy Delphi, ANP	Heritage buildings reuse selection in Palestine	Architectural value (building's existing physical stability, architectural features, ornamentations, building area changes, materials, by-laws, codes), Environmental value (location, possible environmental aesthetics, zoning, policies), Economic value (financial possibilities, sources, investments, profit margins, exemptions), Social value (reuse suitable with public interest, awareness, participation support), Cultural value (historical, artistic, integrity, originality)

Continue of Table 8

Reference	MCDM method used	Focus of the paper	Evaluating criteria
Zagorskas et al. (2014)	TOPSIS	Thermal insulation alternatives of historic brick buildings in Baltic Sea Region	Alternatives: Fibre glass and mineral wool (glass wool or rock wool), eco-friendly insulation (cellulose), polyurethane foams, aerogel, vacuum insulation panel. Criteria: cost of the material, EUR/m2; complexity of the installation; heat transfer coefficient, W/(m2 K); loss of space, cm; hydrophobic/moisture properties
de Jalón, Iglesias, Cunningham, and Díaz (2014)	AHP, the Likert scale	Agricultural water management needs in the study site of Doana (southern Spain)	Economic (rice production, other crops production, construction costs, water provision for other uses, tourism, feasibility, time required, fiscal sustainability, employment); Social (Recreation, social education, preserve heritage, reduce inequality); Environmental (habitat for birds, habitat for rest of species, water quality regulation, climate regulation)
Kutut et al. (2014)	ARAS, AHP	Suitable management of real estate objects in the historic city centre of Vilnius, Lithuania	Need for reconstruction, considering archaeological, historical, architectural, economic, social and other arguments
Siozinyte et al. (2014)	TOPSIS Grey (Technique for Order Preference by Similarity to Ideal Solution with grey numbers), AHP, experts' opinion	The rational vernacular building's modernization variant	Energy savings through added extra layer, relationship between heat loses and solar energy inflows, area of the room when extra layer added, wall's thermal insulation, influence of windows' change to all buildings appearance, ratio of building's façade and windows glazed surface area, satisfying the minimum daylight requirements, satisfying the building's thermal performance requirements, satisfying the requirements for building's in protected area, reflection of period
Vodopivec, Žarnić, Tamošaitienė, Lazauskas, and Šelih (2014)	AHP	Preservation of cultural heritage for castles in Slovenia	Economic, cultural, aesthetic, social, Architectural, symbolic, spatial, scientific, educational, spiritual, use, technological, age, risks, state of conservation, archaeological, integrity, authenticity, rarity, environmental, sentimental, newness, management, energy efficiency, landscape
Turskis et al. (2013)	Delphi, AHP and ARAS-G	The cultural heritage renovation projects in Vilnius city	–
Cui, Yang, Guo, Lin, Zhao, and Feng (2011)	ANP	Urbanisation-related pressures on the Old Town of Lijiang	Driving forces (GDP, total population, secondary industry, tertiary industry); Urbanization (urban land area, tourist population, urbanization rate, number of vehicles); Regional landscape (farmland area, patch density, SHDI, water area); Alleviation (ecosystem service, minority population ratio, primary industry, sewage treatment rate)
Kim, Yoo, Lee, Song, Kang, and Cho (2010)	Delphi, Stochastic Analytic Hierarchy Process (S-AHP) and knowledge-based experience curve (EC)	An alternative decision support model to prioritize restoration needs within the executable budget of 14 cultural heritages in Korea	1st hierarchy: importance of cultural heritage; degree of damage; management policy 2nd hierarchy: classification of designation; historical and architectural symbolism; regional and functional importance; location; severity; possibility of accidents; types; regulations; constructability; acceptable budget 3rd hierarchy: designation from central government; designation from local government; non-designation; academic significance; familiarity and preservation concerns; regional significance; functionality; main part; non-structural part; accessories; collapse hazard; deformation; progressive damage; visitors' exposure to hazards; viewing frequencies; degree of technical and functional constraints; physical damage; structural damage; priority of regulation; degree of civil appeal; appropriateness of restoration scheme; conservability of original form; confidence of cost request data; suitability of cost allocation

Continue of Table 8

Reference	MCDM method used	Focus of the paper	Evaluating criteria
Wang and Zeng (2010)	Fuzzy Delphi, ANP	Reuse selection of historic buildings	Cultural aspect: historical value, artistic value, conditions of integrity and/or authenticity. Economic aspect: potential market, financial sources, subsidize, initial investment and necessary investment in future maintenance, profits from market demand, benefits of exemption. Architectural aspect: Physical condition of the building, architectural character and evaluation, space gain and space change, structural analysis, technological value, materials and decorations of the building, building code. Environmental aspect: Site and situation, scenic/contextual value and the environmental effect, land use plan or zoning, regional development policies, potential environmental quality of the surroundings. Social aspect: compatibility of newly introduced uses with existing, public interest, social value, increasing public awareness, involvement and support, enhancing the role of communities. Continuity aspect: Adequate protection and management system, future change feasibility, ecological and cultural sustainability
Tupenaite et al. (2010)	SAW, TOPSIS, COPRAS, ARAS	The best project for granting	Suitability of the applicant, relevance of the operation in a holistic context, choice and efficiency of methodology, approach and technical solution, risk control, economic and financial aspects and feasibility of the operation, cross-cutting issues (sustainable development, gender equity, good governance), bilateral relations, main quantitative indicators of the projects
Dutta and Husain (2009)	Linear Additive Model revised	Need to take decisions on which heritage sites are to be protected for several heritage buildings in Calcutta, India	Historical value, architectural value, sociocultural value, signs of deterioration, accessibility, integrity, public opinion, local response and usability
Wang, Chiou, and Juan (2008)	The case-based reasoning (CBR)	Predict the actual restoration cost, solve order change problems, and reduce the budget review time in Taiwan were built in the Chin Dynasty (1685–1894) and the Japanese colonial period (1895–1945)	Case name, building type, structure type, roof material, material replacement ratio, building decoration, building height, construction damage degree, building area
Sanna, Atzeni, and Spanu (2008)	Fuzzy ratings	Conservation and exploitation project of archaeological sites	The materials durability factor, the respect for the landscape factor, the future cultural development factor, the economic advantage factor
Girard and De Toro (2007)	AHP	Spatial integrated assessment (ISA), applying it to the territorial context of San Marco dei Cavoti (a rural village in Southern Italy)	Geomorphology, natural resources and landscape set of criteria
Perng, Juan, and Hsu (2007)	Genetic algorithm-based decision support	The restoration budget allocation of historical buildings	–

Table 9. The mostly used MCDM methods in cultural heritage topic

MCDM method used	Number of times
AHP	20
Fuzzy AHP	3
ANP	8
Fuzzy Delphi	4
Delphi	3
Experts	6
EDAS	1
Fuzzy SAW	1
ELECTRE	1
Fuzzy WLC	1
PROMETHEE	2
WSM	1
TOPSIS	2
ARAS, ARAS-G	3
TOPSIS Grey	1
SAW	1
COPRAS	1
Other methods	18
Combination of methods	31

A primary and in-deep analysis of the relevant papers in MCDM methods application in cultural heritage buildings area shows that the main focuses of papers are as follows: selecting appropriate reuse alternative, selecting appropriate refurbishment alternative, selecting suitable alternatives for refurbishment projects, determining level of hazards. The most used MCDM methods are AHP and fuzzy AHP, Delphi and fuzzy Delphi. Experts' knowledge is also used for the assessment of cultural heritage value and to select an optimal alternative for its conservation or refurbishment. Another popular approach in assessing cultural heritage value is using fuzzy analysis. Combination of several MCDM methods is useful in applying complex problem solving in cultural heritage buildings area.

Moreover, it was determined that AHP was used for determinate the criteria weights importance. This method is commonly applied for all type of research of applications. Fuzzy, Fuzzy Delphi, ANP and Delphi approaches applied for adaptive reuse. PROMETHEE, ARAS, SAW, TOPSIS, COPRAS used for heritage buildings preservation and renovation.

Author contributions

Z. Morkunaite was responsible for the study, related works on MCDM methods application in cultural heritage buildings area collection and analysis. She has developed a review method schema and wrote the first draft of the article. D. Kalibatas was responsible for data interpretation, obtained results analysis, conducting discussion and conclusions. He has refined the text and prepared the paper for the submission to the JCEM journal. D. Kalibatiene has developed a query for relevant data extraction from the Web of Science database and visualizes it with the VOSviewer tool.

Disclosure statement

We declare that we have no any competing financial, professional, or personal interests from other parties.

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