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Review

Urban quality in the city of the future: A bibliometric multicriteria assessment model

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ABSTRACT

Assessing the quality of urban areas is considered as a difficult task. The main reason lies in the multidisciplinary nature of the field, and in the complexity of components that must be accounted for. This study aims to identify the most discussed topics in literature by weighing the main themes currently under investigation and defining their potential interdependencies. We provide a theoretical and conceptual framework to analyze contributions in literature on urban quality assessment in the city of the future by combining a bibliographic analysis and a multi-criteria approach. In detail, we reviewed literature and implemented a methodological approach, which combines a bibliometric analysis and the Analytic Hierarchy Process (AHP).

According to the principal keywords "urban quality assessment" and "future city", we initially identified in SCOPUS database 1024 articles and a selection of most cited sub-keywords. Then we fine-tuned the research according to a sequential approach. We performed a statistical analysis on preliminary results and implemented a relative AHP model to obtain a priority ranking of the most relevant sub-keywords. This approach allows for analyzing articles, by combining multiple keywords with the identification of the degree of relationship among the different sub-keywords with respect to the main topic.

1. Introduction

According to an estimate by the United Nations, the world population is expected to reach 9.8 billion units in 2050 with about 68% of them living in urban areas (United Nations, 2017/2018). An uncontrolled growth of cities can have mixed effects on citizens' well-being, the environment and the economy, and gives rise to extensive sustainability challenges. Due to the increase in migration and urbanization it may emerge a significant number of problems related to energy and resource use, human activities and environmental coordination (Cui, 2018). In 2014 the European Union along with establishing important targets (revised in 2018) to reduce climate change effects, and improve renewables share and energy efficiency by 2030, emphasized the urgent need to enhance citizens' quality of life and city's operations (European Commission, 2014). The main concern resides in the consideration that cities can be very attractive due to the opportunities, jobs and services they offer, but at the same time, they can become a concentration of health hazards and risks. Cities represent one of the major sources of energy resources consumption and serious contributors to greenhouse gas (GHG) emissions due to the inefficiency of built environment and the intensity and density of economic and social activities. Issues as air and water pollution, environmental degradation, ineffective mobility, traffic congestion, waste disposal, health decrease, social inequality, are already associated to contemporary cities and largely discussed in literature (Bibri and Krogstie, 2017). For these reasons, local authorities and Governments need to design sustainable solutions and processes to mitigate environmental, social and economic threats to guarantee livable conditions in densely populated urban areas and metropolitan areas (Hely and Antoni, 2019). They are becoming aware of the need to identify and implement new management strategies, which combine the maximization of the trade-off between positive and negative effects of urbanization with sustainable development and environmental concerns. Towards this end, there is a perspective change in the conception, planning and development of the built, infrastructural, operational, and functional forms of cities.

The assessment of urban quality becomes a key issue for urban planners and local authorities in setting targets to achieve the objective of future sustainable development in cities. The evaluation of urban sustainability is of increasing interest in several fields of research, such as urban and regional studies, regional science, regional economics, architecture, politics, environment, sociology. Nonetheless, it is considered as a serious effort to be made due to the complexity in defining this multi-faceted concept and developing measurement tools, which guarantee to increase coherence among the values underlying

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objectives and goals (Faria et al., 2018). Notions such as urban quality, livability, quality of life and sustainability are often overlapping, and their definitions are still not universally accepted and clear, meaning that there is a certain degree of confusion among researchers and policy makers (Stanković et al., 2017). As Oppio et al. (2018) showed in their work, addressing urban quality is a complex issue, which encompasses multiple aspects and multiple stakeholders, in which the built environment plays a fundamental role and the dualism between human and environmental dimensions represents the core of analysis. The Institute for Environment and Development and the World Business Council for Sustainable Development (IIED and WBCSD, 2002) illustrated the concept of sustainable development as the goal of the integration of economic development, environmental integrity, social concerns and effective governance systems. According to the sustainable development paradigm, a society should maximize the well-being of the current generation through a fair distribution of its costs and benefits, without decreasing the possibility for future generation to achieve their needs (Kaklauskas et al., 2018). A multi-dimensional and comprehensive framework to measure urban quality of cities might provide guidance to urban planners and policy makers to evaluate place quality, identify its weaknesses and highlight its strengths. City rankings represent a relevant tool to investigate the different performances of cities within the same region with respect to the three main pillars of sustainability, and to identify those areas to be improved.

To assess urban quality, research studies often adopt both indicator-based frameworks and rating systems. They are similar in nature as they ground on the selection and measurement of some indexes or indicators, which are subsequently aggregated according to a set of criteria. These approaches are the most used by practitioners, as they are well known and well established in literature; nonetheless, they lack for an integrative perspective (Cohen, 2017). Although in the European Union the development of these ranking systems (e.g., the European Smart Cities ranking, the European Green Capital Award, the European Green City Index, Europe Quality of Life Index, etc.) has been widely supported, they still present some methodological gaps as showed by Akande et al. (2019). Firstly, they do not properly define the ranking theme, which is a milestone in designing the theoretical framework and the characteristics of the ranking. Secondly, they need a city selection criterion in order to guarantee a homogenous comparison based on population density, economic characteristics, wealth, climate and history; thirdly, data used to obtain the ranking have to be coherent and consistent in order to ensure credible results; and, finally, a weighting methodology, which accounts for the interrelationship among indicators, has to be identified properly.

Furthermore, existing literature reviews have mainly focused on the analysis of assessment tools, which provide an overall and holistic approach, and consequently they disregarded potential useful research findings, which focus on specific fields. Verma and Raghubanshi (2018) analyzed challenges in the design and development of urban sustainability indicators through literature review and bibliometric analysis, and focused on papers closely related to urban sustainability indicators. A relevant strand of literature has instead focused on more specific aspects, such as built environment (Deng et al., 2019), urban mobility and transportation (Tsiropoulos et al., 2019), green infrastructure (Gavrilidis et al., 2019), water management (Van Leeuwen et al., 2012), air quality (Li and Zhou, 2019), waste management (Lupo and Cusumano, 2018; Wilson et al., 2015; Chifari et al., 2018), economic development (Fung and Kennedy, 2005), ecosystem health (Su et al., 2019) and smartness (Lim et al., 2018). Whereas Discoli et al. (2014) investigated the quality of urban life by focusing on urban services and infrastructures and specifically to their relationships with the environment in order to visualize the environmental state of cities.

It is worth noting that there is evidence in literature of a growing number of studies devoted to the evaluation of urban livability within cities (Papachristou and Rosas-Casals, 2019; Zhan et al., 2018), and this testifies that communities' perception of urban spaces may assume a significant role in the design of future sustainable neighborhoods, characterized by higher degree of vitality, which embody a sense of community (Stanislav and Chin, 2019). The opinions of local stakeholders about the different categories comprising quality of life represent an important resource to improve the performance of the city, especially in cases of limited economic resources (Khalil, 2012).

Due to the growing interest in this area and the growing number of studies developed during the last decade, there is an urgent need for a systematic, state-of-the-art literature review on the assessment of urban quality.

This paper aims at covering this gap in literature, identifying the most discussed topics in urban quality assessment, by weighing the main themes currently under investigation, and defining their potential interdependencies. It provides a novel theoretical and conceptual framework to analyze, organize and evaluate literature reviews on urban quality by an integrated approach based on bibliographic analyses and multi-criteria valuation approaches. In detail, we reviewed the academic literature on the assessment of urban quality in the future city and we implemented a rigorous methodological approach, which combines bibliometric and systematic analysis with the Analytic Hierarchy Process (AHP). This approach allows for analyzing articles, which adopt multiple keywords organized in a hierarchical structure, and identifying the degree of relationship among different sub-keywords with respect to the main topic. This semi-qualitative analysis returns an objective numerical result, which is useful to define the most relevant contributions in the assessment of urban quality in the city of the future, as well as to identify potential gaps in literature and future developments. As highlighted by De Felice et al. (2018), the number of contributions citing keywords and sub-keywords is not always a proper predictor of the efficacy of sub-keywords in refining systematic search and conveying information on their relative importance with respect to main search string and topic.

The aim of the paper is therefore to twofold: first to better structure literature reviews in order to identify and classify the more widely investigated issues and those issues, which require further investigation; second to find evidence of possible relationships among keywords and sub-keywords and assess their relative importance with respect to a set of pre-determined criteria, acquired from literature. The approach here proposed can contribute to improve the efficacy of both systematic review process and its pyramidal structure. In the definition of priority targets for planning strategies and in the construction of valuation criteria, it might be *de facto* extremely useful to start from existing studies, which need to be properly selected and ranked in terms of relevance to the topic. As a thorough search of literature is a key component of such reviews, our topical search strategy relies on a hierarchical structure validated by experts' judgments. In our tree-like structure, keywords and subject heading terms are combined according to a bottom-up, weighted-sum aggregating procedure, designed to maximize the likelihood of identifying all relevant studies.

The remainder of the paper is organized as follows. Section 2 presents the systematic literature review analysis used to create the database and present the *meta*-analysis; Section 3 introduces the Analytical Hierarchy Process (AHP) applied to weight the sub-keywords identified; Section 4 provides an overview of the methodological approach and illustrate the hierarchical model; in Section 5 results are illustrated and discussed; Section 6 concludes.

2. Systematic literature review

To structure the systematic literature review according to Brown (2007) we started from a clearly formulated question and created a reproducible search record to analyze data collected from literature, critically selected, whose significance is evaluated by adopting systematic and reproducible methods (Glasziou et al., 2001). Through the specification of a "criterion-based selection" process, in a systematic review process unrevealed criteria for literature selection are not used

in order to avoid any possibility of bias or prejudice (Ruhlandt, 2018).

The contributions included in our review are illustrated and discussed according to the systematic review protocol proposed by Brown in 2007, which consists of a three-stage procedure: planning, conducting and reporting the review. The first stage (planning the review) is composed of other sub-phases: firstly, it is necessary to verify whether other existing reviews investigated similar research questions; secondly, a literature scoping and mapping has to be carried out to identify main research fields, potential overlapping and future developments. In this phase, we defined a dynamic protocol, which allows for introducing ongoing changes on search criteria and research setting to optimize the review process and improve its coherence and exhaustiveness (D'Alpaos and Bragolusi, 2018a).

The second stage (conducting the review) aims to identify relevant keywords and search string, develop selection criteria and quality checklist in order to guarantee a minimum quality threshold and refine the research. According to a sequential approach, the quality of the contributions is assessed, and the ones not considered as relevant are excluded. Then, in order to better compare themes and carry out a deeper analysis a database is constructed, and all final contributions are classified by title, author/s, publication date, source, methodology and relevance for inclusion using specified software like Microsoft Excel. In the third stage (reporting of the review), descriptive and thematic analyses are provided, and results and study limitations are discussed in order to update the state of the art.

To carry out our review, we integrated Brown's protocol (2007) with the approach proposed by Wolfswinkel et al. (2013), who starting from the guidelines explicated by Webster and Watson (2002), provided a systematic guide for obtaining a rigorous literature review by implementing the Grounded Theory method. Their approach is composed by five flexible stages: a) "define", in which fields of research, sources and specific search terms have to be identified; b) "search", in which the initial sample is created; c) "select", in which the initial sample is refined according to specific criteria; d) "analyze", in which main data and information are extracted from the selected articles; and e) "present", in which knowledge gained from the analytical stage is carefully represented (Wolfswinkel et al., 2013).

To complement the systematic literature review process and identify potential relationships among main issues, keywords and the main topic, following De Felice et al. (2018), we integrated the systematic literature review methodology with a hierarchical multi-criteria approach, namely the Analytic Hierarchy Process (AHP).

We informed our modeling into three major phases: (1) the *structuring phase*, in which the research objective keywords and sub-keywords were identified; (2) the *evaluation phase*, in which the AHP method was used to calculate the relative weights of keywords; (3) the *discussion phase*, where results were analyzed and discussed accordingly.

In detail, the final database produced in the *structuring phase*, which we organized into 5 sub-steps according to the roadmap of systematic review analyses, was analyzed in the following step via the AHP. Each sub-step is described in more detail in what follows.

Identify research objective: the aim of this phase is to define the objective of the research and to identify a suitable research approach by answering the following questions: What do you want to describe and why?; Which database do you search for?; When do you search?; Do you need some geographic boundaries?

Identify keywords: this phase involves the identification of the general aspects more frequently analyzed and the most commonly used keywords. This step is fundamental to split relevant from irrelevant publications and to create the initial database.

Primary article analysis: the aim of this phase is to refine the research by taking into account only articles published in journals and excluding other publication types because of their less scientific value. The articles are classified and analyzed by authors' country, publication year and subject area in order to obtain a firstly general characterization of primary results.

Identify sub-keywords: in this phase, by adopting a pyramidal search structure sub-keywords, which qualify better the issue, are identified.

Create database: in this phase, the final tabular database is created by including the articles in which the keywords previously identified are cited. In detail, articles are classified according to the most cited sub-keywords.

In order to identify properly the research questions and the primary search strings, we conducted a preliminary literature review on the concept of urban quality and its assessment methods.

As mentioned already, academic literature has largely analyzed the issue of urban sustainability and all its diverse facets, especially with respect to the definition of indicators by which evaluate the quality of life in cities. Nonetheless, a common assessment framework, which standardizes guiding principles is still lacking, due to the complex multi-faced and subjective nature of the topic.

It is commonly agreed in literature that sustainable development encompasses three main pillars and calls for convergence among economic development, social equity and environmental protection. Methods for urban quality assessment are usually based on some combination of the above three key categories: economic, environmental and social (Gibson, 2006; Ciegis et al., 2009; Huang et al., 2009; Shen et al., 2011; Estoque and Murayama, 2014; Michael et al., 2014; Tran, 2016).

More recently, Cohen (2017) highlighted that several contributions on sustainability assessment add extra dimensions, such as institutional, urban form, cultural or technological, to the traditional three pillars in order to better define the complexity of the problem and adopt an integrative approach to consider potential intersections between the pillars. Cohen's review (2017) suggests that a common standardized lexicon of objectives, indicators or principles is necessary in order to provide a more integrative approach and holistic vision in which sustainability principles guide a goal-based framework. The evaluation of urban quality should not disregard economic, social and environmental analysis, but at the same time, it has to take into account other spatial, managerial, institutional or technological considerations. Feleki et al. (2018) pointed out the need for a more holistic and systematic way to describe sustainability, and proposed a methodological analysis to fill the gap between traditional sustainability assessment tools and realistic characterization of urban areas. In light of a detailed literature review focused on European cities, they introduced a fourth pillar, the spatial dimension, which is strongly related to the structure, culture, heritage, social patters and professional activities of cities.

Findings of our preliminary literature review show that there are several well-known and frequently used rating systems (i.e., LEED-ND, BREEM Communities, CASBEE-UD, DGNB-NSQ, Pearl Community for Estidama, IGBC township, GBI township), which provide a balanced assessment among sustainability pillars (Komeily and Srinivasan, 2015; Dawodu et al., 2017). These rating systems provide evaluations of sustainability through a 100 or more-point system, where criteria are structured into main categorizes and evaluated adopting equal or differential weighting approaches (Kaur and Garg, 2019).

In addition to the above mentioned, researchers developed and applied different methods to assess urban sustainability, according to two basic approaches: a) an objective approach, usually based on quantitative or secondary data (aggregate data), obtained at different spatial scales, and b) a subjective approach, based on qualitative or primary personal data collected by social survey methods, which take into account people qualitative judgments with respect to the different elements of urban life (Garau and Pavan, 2018). It is worth noting that the latter might be characterized by personal biases due to individual's feelings (Chen et al., 2016). Weziak-Bialowolska (2016) analyzed possible interrelations between citizen characteristics, neighborhoods and satisfaction with life in 79 European cities, and found that satisfaction varies considerably both inside cities and across Europe. Some contributions pointed out that the selection of criteria is a delicate process

and it involves both quantitative and qualitative indicators to guarantee a holistic vision of the problem and provide a connection with the territory (Ballas, 2013; Esmaeilpoorarabi et al., 2016; Esmaeilpoorarabi et al., 2018; Kaklauskas et al., 2018).

A more recent strand of literature is focused on the role of Information and Communication Technologies (ICT) in the implementation of sustainable and smart cities (Mora et al., 2017). By examining the intersection between these two concepts, Martin et al. (2019) developed the concept of the urban smart-sustainability fix, and argued that cities should integrate the goals of digitalization and environmental protection by using technologies to provide more efficient infrastructure services and produce lower resource consumption. In this respect, smart development represents an innovative, disruptive and useful response to the challenge represented by sustainability, and provides an efficient optimization tool of urban system operation and management aimed at enhancing citizens' quality of life. The concept of smartness involves six broad city characteristics (i.e., economy, people, governance, mobility, environment and living) and aims at producing more intelligent, interconnected and efficient services or utilities (e.g., education, healthcare, real estate, transportation) (Mosannenzadeh and Vettorato, 2014). Although nowadays, indicators that account for the smartness level of a city are taking up in rating systems, this strand of literature is still poor of contributions (Ahvenniemi et al., 2017; Bibri and Krogstie, 2017). Huovila et al. (2019) proposed a guide for city managers to select the indicators to assess properly city sustainability by comparing seven recently published standards for smart sustainable cities. Stankovic et al. (2017) and Myeong et al. (2018) developed an AHP model to measure cities' smart performances and established a link between their determinants and the subjective perceptions of citizens' life satisfaction. In addition, Yigitcanlar et al. (2018) highlighted the fragmentation of literature on smart city theories and practices, and developed a new city model by identifying the linkages between key drivers of smart cities and related desired outcomes, such as productivity, wellbeing or governance.

Once we completed the preliminary literature review, thanks to which we framed the issue and identified the general aspects more frequently analyzed and the most commonly adopted assessment approaches, we conducted a systematic review on Scopus database in order to identify the most relevant articles on urban quality assessment and create a tabular database. We firstly introduced the search term with the following primary keywords "(TITLE-ABS-KEY (*urban* AND *quality* AND *assessment* AND *future* AND *city*))" and we identified 1024 contributions. We then limited the publication date within the period 2000–2019 to restrict findings to the timeframe in which sustainability and urban quality concepts gained popularity in the scientific community (Kates et al., 2001). We introduced additional filters with respect to language (i.e., English) and publication type (i.e., peer-reviewed article). We did not include any territory/country or subject area filters to avoid the potential loss of relevant elements and valuable insights. Despite cities around the world face different realities and challenges depending on their own context, research on urban quality assessment may produce findings interesting to different backgrounds (Cohen, 2017).

Once we concluded the analysis of primary results, by adopting a pyramidal search structure we complemented primary keywords and search strings with a second-level keywords and search strings (*air* OR *water* OR *waste* OR *land use* OR *green space* OR *built environment* OR *infrastructure*) recognized as relevant to the specific research topic under investigation.

In detailed, we initially identified 434 documents in SCOPUS database, grouped in different document types as reported in Table 1.

We then limited the number of documents to 369 by introducing language, publication year and document type filters. At this stage, we excluded the articles which we considered as not relevant after reading abstract or full text, and specifically those contributions in which none of the second-level keywords is cited.

Table 1
Documents classification.

Document type	Number
Article	295
Conference paper	81
Review	34
Book chapter	10
Conference review	7
Book	2
Article in press	2
Note	2
Editorial	1

In the next phase, we carried out a *meta*-analysis to structure our review, and finally we conducted a further analysis based on AHP model to better structure the review and create a ranking of the most relevant articles. Through the proposed multi-criteria approach, it is possible to analyze and compare the relative importance of the most cited sub-keywords and rank articles by taking into account horizontal citations among them.

2.1. Meta-Analysis

To structure the review and create the database to be subsequently analyzed, we performed *meta*-analysis, which showed an increasing interest among researchers for the assessment of quality of life in cities.

Starting from 2001, when sustainability science was identified as a unique discipline (Kates et al., 2001), our findings reveal an increasing number of published articles, with an annual growth rate of 7.5%, (Fig. 1). Before 2005, the number of publications related to the field was less than 10, afterwards it increased significantly until 2015. Whereas, from 2015 to 2019 the trend begun to stabilize. Our analysis reveals that during the last decade there was a strong interest for the research topic.

In addition, the analysis of the number of citations per year confirmed the increasing interest towards the research topic starting from 2000, with a peak after 2012 (Fig. 2).

We also conducted an analysis by country, from which it emerged that nowadays more urbanized and developed countries are paying great attention to the issue of future sustainable development and urban governance.

As shown in Fig. 3, United States produces the 21.4% of publications, followed by China (12.7%), United Kingdom (10.6%) and Australia (8.4%). It worth mentioning that Italy is fifth in this ranking, probably due to the strong interest on sustainability and to the need of new planning strategies for the governance of urban areas and large historical heritage. Germany, the Netherlands, Austria, India and Spain follow.

As urban quality is a multidisciplinary topic with a crosscutting nature, we did not refine further our *meta*-analysis by subject study.

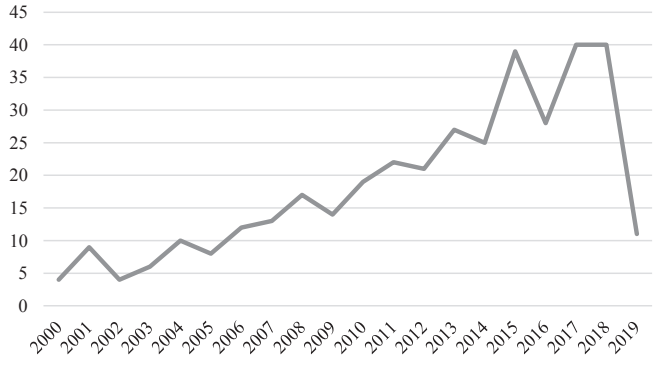

Fig. 1. Number of publications by year.

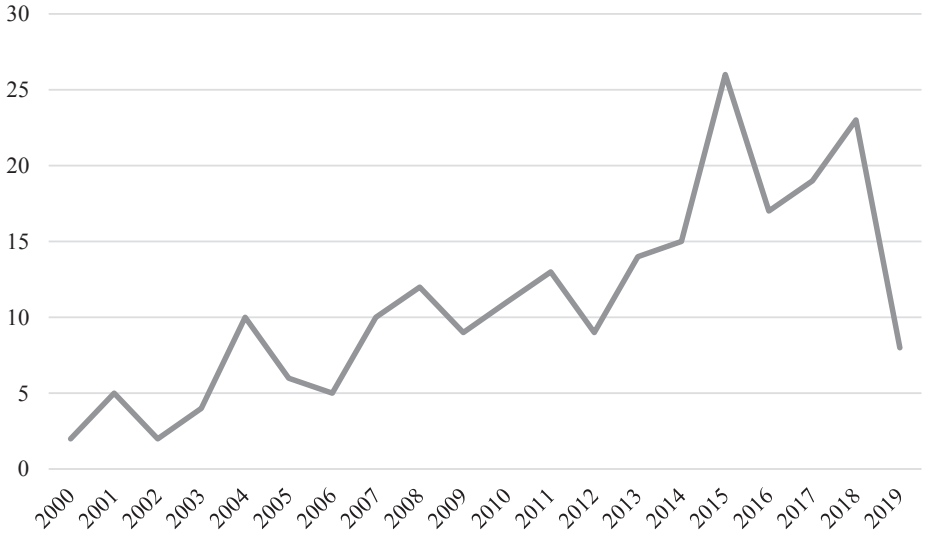

Fig. 2. Article citations by year.

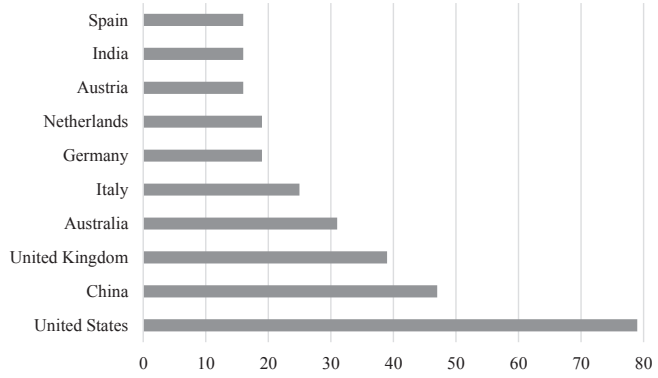

Fig. 3. Number of publications by country.

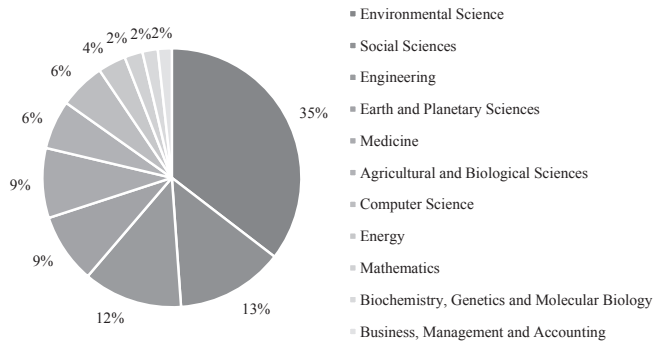

Fig. 4. Number of publications by subject area.

Nonetheless, we developed an analysis by subject area (Fig. 4).

This analysis shows that about half of the documents refer to Environmental Sciences, followed by Social Sciences (20.9%), Engineering (19.2%) and other study areas such as Biology and Earth Sciences. It is worth to highlight that Business, Management and Accounting represent the 2.7% of publications and Decision Sciences counts less than 2%.

The analysis of the most cited keywords is a key factor in our setting. In Fig. 5, we reported a limited number of keywords, but it worth noting that most of them relates to environmental aspects, which proves that they play a dominant role in the assessment of urban quality.

We identified the following sub-keywords to implement the further steps of our search according to the results of the *meta*-analysis and

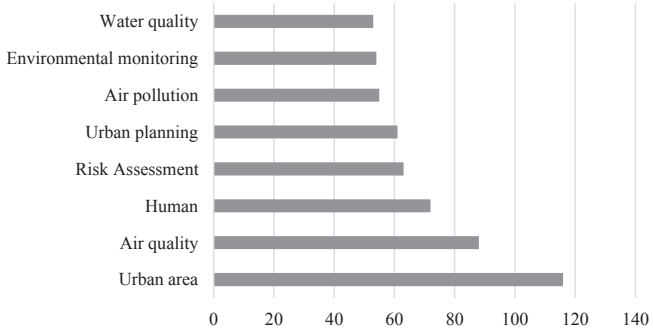

Fig. 5. Most cited keywords.

preliminary literature:

1. Air
2. Water
3. Waste
4. Land Use
5. Greenspace
6. Built environment
7. Infrastructure

We then created the final database in order to classify the 257 articles, which analyze and mention issues referring to the selected sub-keywords. Fig. 6 shows that Air and Water are the most cited, followed with a great detachment by Infrastructure, Land Use, Built

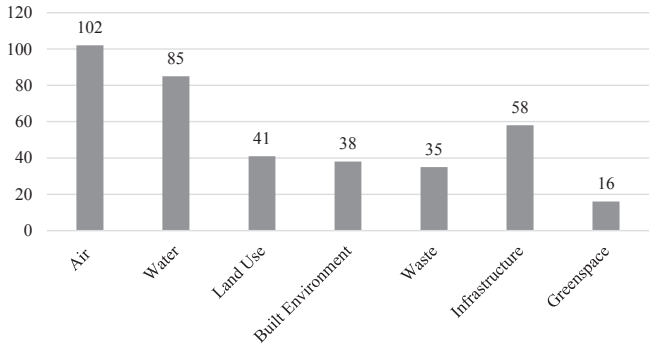

Fig. 6. Number of articles by sub-keyword.

Environment, Waste and Greenspace.

An analysis of literature based on the most cited keywords is not always adequate and sufficient. In this case, where multiple disciplines and aspects are involved, the decision to limit the analysis to the most cited keywords might lead to incomplete and not comprehensive conclusions. With the aim of investigating in a more comprehensive and detailed way the existing literature, in this paper we provide a hierarchical model to weight the seven sub-keywords and search for potential relationships among them.

3. Analytical Hierarchy process

Decisions related to the assessment of urban quality in future cities can be addressed as a decision-making problem, where multiple aspects, often conflicting, must be accounted for. Multi-criteria Decision Making (MCDM) methods have been extensively proposed in literature to support urban planners in the definition of new sustainable policies (Ellen et al., 2016; Lombardi et al., 2017; Myeong et al., 2018; Oppio et al., 2018). Suganthi (2018) presented a literature review on MCDM methods implemented to assess sustainable development, and implemented fuzzy AHP, VIKOR and DEA analyses to rank structural investments for sustainability improvement.

Among MCDM methods, the Analytic Hierarchy Process (AHP), proposed by Saaty in the Eighties (Saaty, 1980), proved to be a successful technique to address complex decisions and obtain a priority ranking of alternatives (Bahadori et al., 2017; D'Alpaos and Bragolusi, 2018b; D'Alpaos and Bragolusi, 2019), and many are its applications in this research area. Haider et al. (2018) proposed a hierarchical-based framework to assess the sustainability of a small-sized neighborhood in British Columbia by aggregating indicators throughout a fuzzy synthetic evaluation and obtain an overall sustainability index. Ameen and Mourshed (2019) developed a stakeholder-driven structured methodology based on AHP to identify and rank context-relevant sustainability indicators and highlighted that indicator priorities are strongly related to urban context. Jato-Espino et al. (2018) focused on the analysis of the contribution of cities' land cover configuration to sustainability, and provided a Sustainable Urban Surface Rating System (SURSIST) to evaluate urban surfaces with respect to a list of indicators defined in accordance to the Sustainable Development Goals (SDGs). These indicators were identified, weighted and finally aggregated to obtain a composite index of city urban skin by combining CORINE Land Cover (CLC) maps, with the AHP and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS).

The AHP allows for measurement of tangible and/or intangible criteria and factors and deconstructs the initial problem into hierarchical levels, with unidirectional relationships among levels. The goal of the decision problem is at the top of the hierarchy, whereas criteria and sub-criteria, which contribute to the goal, are placed at lower levels. Alternatives under investigation are at the bottom level (Saaty, 2000; Saaty and Peniwati, 2012; D'Alpaos and Bragolusi, 2019). Criteria and alternatives relative importance is determined through pairwise comparisons: experts provide their subjective preference on the dominance of one criterion/alternative over another with respect to the goal by expressing semantic judgments, which are then converted into numerical values according to Saaty's fundamental scale (Saaty, 1980).

Pairwise-comparisons are reported in square matrices of preferences, where the dominance coefficient a_{ij} represents the relative importance of the component on row i over the component on column j (Saaty, 1980; Saaty, 2000; Saaty and Peniwati, 2012). The weights/priorities are determined according to the Perron-Frobenius eigenvalue approach, and pairwise comparisons of the elements placed at each hierarchical level are performed with respect to their relative importance towards their parent node (Saaty, 2000). Differently from other MCDM methods, the AHP tolerates some inconsistency in expert judgments. To test for the consistency of pairwise comparison matrices, the inconsistency index IC is determined:

$$IC = \frac{\lambda_{max} - n}{n - 1} \quad (1)$$

where λ_{max} is the maximum eigenvalue and n is the rank of the matrix. IC less than 0.10 is considered as acceptable (Saaty, 1980). It is worth noting that IC is null when expert judgements are perfectly consistent, i.e. $\lambda_{max} = n$ according to the Perron-Frobenius theorem.

Via a weighted-sum aggregation procedure throughout the hierarchical levels, alternatives global ranking is obtained (Saaty, 1980; Saaty, 2000; Saaty and Peniwati, 2012) and tested for rank reversal (i.e., the solution is validated via a sensitivity analysis).

4. Research method

In the second phase of the modeling, i.e. *the evaluation phase*, we combine the findings of the structuring phase with a multi-criteria decision-making model to weigh the most relevant topics and define their interdependencies. Following the seminal work by De Felice et al. (2018), at this stage, we need to define a proper hierarchy, to structure the decision problem by taking into consideration the keywords identified in the prior phase. The final objective is to rank the keywords by implementing the AHP model and use this ranking to analyze and discuss the contributions (*discussion phase*). We organized the evaluation phase into the following three main steps.

Weighting of sub-keywords: the aim of this phase is to analyze in further detail the relevance of sub-keywords. The information on the number of articles in which keywords are cited might not be representative of their relative importance. In this respect, multi-criteria approaches can represent useful methodologies to address this issue. In detail, the AHP allows for evaluating the relative weights of sub-keywords with respect to predetermined criteria, identified through the preliminary literature review. To weigh keywords, we involved a panel of experts in urban quality assessment (see below).

Identification of sub-keywords relationships: after weighing the keywords, we analyzed all the articles in the database in order to organize and rank them. At this stage, it is fundamental to verify the existence and degree of possible relationships among different sub-keywords, identify the number of articles that cite more than one sub-keyword and provide some graphical descriptions to directly represent the proportion of these relationships.

Articles analysis based on keywords ranking: the purpose of this step is to analyze contributions in literature with respect to the most relevant sub-keywords identified by implementing the above multi-criteria approach. The citation analysis is important but not necessarily sufficient; therefore, we implemented a further articles analysis with respect to the most relevant research areas.

After conducting the systematic literature review and creating the final database, to identify the key factors and define the hierarchy, we selected among policy-makers, professionals and academicians at national and international level, a pool of fifteen experts in environmental, economic and social sciences, architecture, urban planning and innovation technologies. Due to the impossibility of gathering the entire panel in a workshop, as experts were geographically scattered, we involved them in a Delphi survey process and phrased elicitation questions in a qualitative way, which did not require specific expertise in MCDM (D'Alpaos and Bragolusi, 2018b). Through two-round dynamic discussion, the panel of experts developed the set of criteria to structure the decision problem, validated the hierarchy and weighted sub-keywords. The decision problem was disaggregated into three hierarchical levels (goal, criteria and alternatives) and four decision nodes. As shown in Fig. 7, at the last hierarchical level, there are the seven sub-keywords, which represent alternatives to be evaluated, at the intermediate level there are the selected criteria, and the top level there is the goal, i.e. "Urban Quality Assessment in the City of the Future".

The criteria considered can be described as follows.

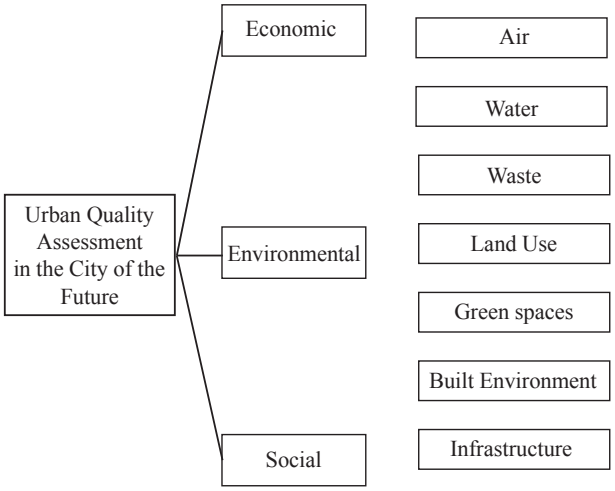

Fig. 7. AHP model.

- Economic criteria: refer to business environment, economic growth, costs and productivity, employment, connectivity and wealth;
- Environmental criteria: relate to natural resources and account for their use and maintenance over time. They capture "green" factors such as energy, pollution, emissions, etc.;
- Social criteria: refer to social performances, including quality of life for human beings and communities.

In order to rapidly generate all the pairwise-comparison matrices and control for their consistency, we implemented the AHP model on the *Superdecison* software, and obtained clusters, nodes and links as shown in Fig. 8. We asked each expert to express his/her judgments and

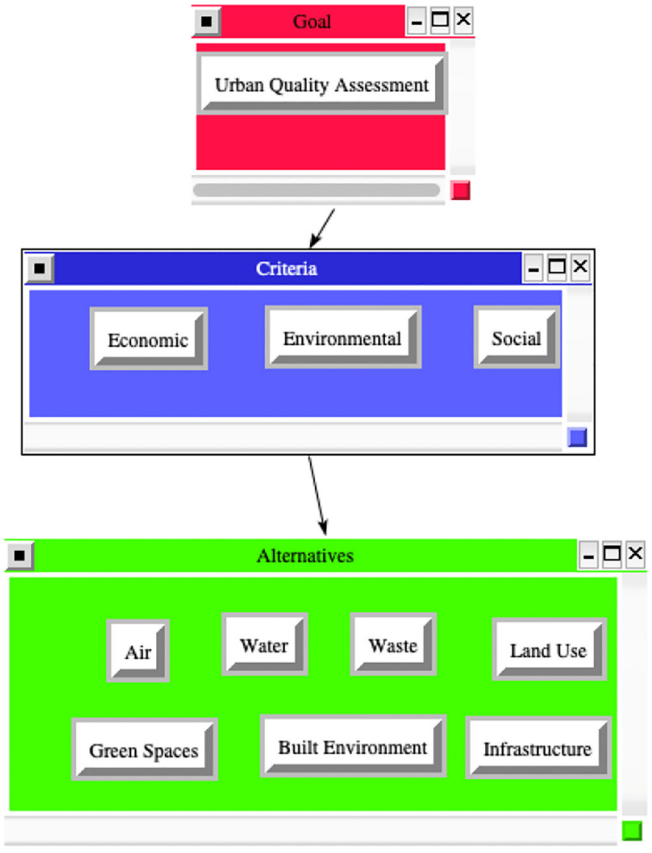

Fig. 8. AHP model implemented in *Superdecision* software.

Table 2
Criteria pairwise comparison matrix.

	Economic	*Environmental*	*Social*	*Priorities*
Economic	1	1/3	1/2	0.169
Environmental	3	1	1	0.443
Social	2	1	1	0.387

fill the pairwise-comparison matrices. We then aggregated individual judgments by calculating the geometrical mean in order to have a single and representative judgment for the entire group (Xu, 2000; Grošelj and Zadnik Stirn, 2012). Experts compiled 4 pairwise-comparison matrices: one to compare criteria with respect to the goal (Table 2), and three to compare alternatives with respect to criteria. Table 3 reports one of these matrices as an example. We then computed the consistency index for each pairwise comparison matrix and verified it is less than 0.1 ($IC < 0.1$).

To obtain the final overall priority vector (Fig. 9), we multiplied local priorities of elements in a node by local priorities of the corresponding parent node and aggregated bottom-up. Table 4 illustrates overall criteria priorities expressed in both normalized and ideal forms (last two columns respectively).

5. Results and discussion

As it emerged from the preliminary literature review, the different aspects involved in urban quality definition might present some relationships, whose strength might be an interesting issue to address. To investigate these relationships, we identified the number of articles, which combine more than one sub-keyword, as shown in Table 5: high numbers reveals quite strong relationships among the sub-keywords combined one another. The most important relationships are between Air, Water, Infrastructure and Built Environment: 31 articles refer to Air and Infrastructure, 27 articles to Air and Built Environment, 23 articles to Water and Infrastructure. From our analysis, it emerged that Water has a quite strong relationships with Waste, Land Use and Built Environment as well. Whereas, Land Use and Greenspace, do not have any relationship according to our approach.

Fig. 10 reports in a bubble diagram the above sub-keyword relationships. The number of times different sub-keywords are cited conjointly is directly proportional to bubbles dimension.

Before proceeding with the final analysis of the results obtained by implementing the AHP model, we firstly carried out an extensive reading of contributions based on the number of citations. Table 6 provides a synoptic table of articles with more than 100 citations.

The above seven articles where published in the period 2003–2015 and their content varies from literature reviews to applications and theoretical-methodological investigations. In detail, Gascon et al. (2015) investigated the existence of a beneficial relationship between existing green and blue spaces and mental health. They analyzed 28 studies on long-term mental health benefits of residential green and blue spaces following the PRISMA statement guidelines for systematic reviews and *meta*-analysis. They concluded that these benefits should be taken into account by planners in future urban plans, and specifically in designing characteristics and functions of green and blue areas.

Luo et al. (2009) provided an extensive review of studies on urban soils in China, focusing on trace metal pollution. Being an important component of urban ecosystems related to human health, soil quality is strongly related to plant, human and animal health. Soil plays in fact a key role in preserving biodiversity, enhancing plant and biological productivity, and reducing environmental damages. Luo et al. (2009) argued that a comprehensive assessment of urban soil quality represents an important step for a better city planning and a sustainable management of urban soil resources.

Harlan and Ruddell (2011) reviewed studies from 2005 to 2010 on

Table 3
Pairwise comparison matrix of alternatives with respect to *Environmental* criterion.

	Air	*Water*	*Waste*	*Land Use*	*Greenspace*	*Built Environ.*	*Infrastru.*	*Priorities*
Air	1	2	3	5	1	3	5	0.556
Water	1/2	1	1	1/2	2	1	1/2	0.099
Waste	1/3	1	1	1/3	1	1/2	1/2	0.070
Land Use	1/5	2	3	1	1/3	1	1	0.148
Greenspace	1	1/2	1	3	1	1/2	1/2	0.093
Built Environment	1/3	1	2	1	2	1	1/2	0.111
Infrastructure	1/5	2	2	1	2	2	1	0.141

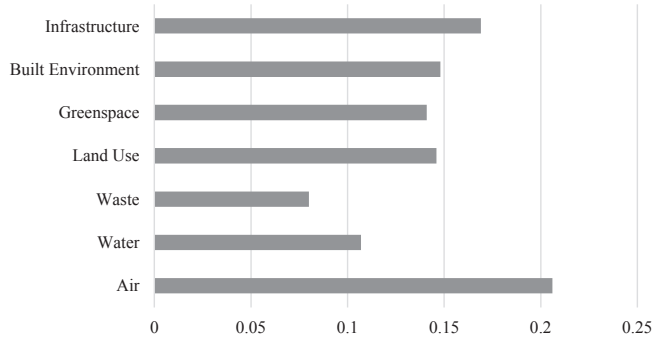

Fig. 9. Final sub-keywords weights.

mortality and morbidity related to two climate hazards in cities: increasing temperature and air pollution. They analyzed risk management action plans implemented by cities to decrease climate change impacts, and concentrated on environmental outcomes, health co-benefits provided and the presence of barriers. Harlan and Ruddell (2011) discussed the identification and evaluation of the cost-benefit ratio produced as the biggest challenge to the diffusion of mitigation strategies.

Krewski et al. (2009) analyzed and produced country estimates of the risks of death related to the diffusion of fine particulate air pollution in the U.S.A., taking data from the American Cancer Society, a major player in the debate on the setting of National Ambient Air Quality Standards (NAAQS).

Gupta et al. (2006) developed a method to monitor and forecast air pollution through the assessment of particulate matter air quality, which accounts for the effects of wind speed, cloud cover and mixing height. They tested the method on 26 urban areas, and provided an empirical relationship between Aerosol Optical Thickness (AOT) and $PM_{2,5}$ mass.

Jim and Chen (2003) proposed a comprehensive greenspace framework to fulfill fundamental landscape ecology requirements. In detail, they analyzed positive environmental-social effects of different green elements on moderating microclimate and satisfying recreational demand.

Finally, Van Herzele and Wiedemann (2003) contributed to the development of methodological approaches aimed at green space monitoring, and useful in the design of sustainable policies for improving livability of cities. In fact, they presented a "touchstone" indicator for development towards sustainable green supply in Flemish cities. This indicator was implemented in a GIS-model and it is composed of different parameters. Van Herzele and Wiedemann (2003) investigated the relationship between supply of green spaces and social needs with the aim of creating a bridge between scientific theories and planning practices. To pursue this objective, they developed an integrated monitoring tool to study those existing green spaces (their distribution, connection and quality), which can be easily used by local authorities to make decisions on future planning strategies.

Once we obtained the final priority ranking of sub-keywords, we refined our search by selecting contributions in which "air, infrastructure and built environment" are reference keywords because of their high priority in the ranking. In addition, we introduced the number of citations as second selection criterion. We finally selected 9 core papers, grouped according to the reference sub-keywords (Table 7).

Most articles referring to air were above described being part of the most cited; an exception is made for the contribution by Lumbreras et al. (2008). Lumbreras et al. (2008) developed a tool for supporting the local government in the assessment of air quality and pollutant emissions from the transport sector in Madrid under different scenario hypotheses. They evaluated a set of measure intended to reduce pollutant emissions and considered different control strategies, such as fleet renewal, use of biofuels and decrease in traveled distances due to private car mobility reduction. Through a regression analysis, Lumbreras et al. (2008) compared the efficiency of pollution reduction measures and their impact on different areas within the city center in order to identify the most likely future scenario.

With respect to "infrastructure", we reported in Table 7 the two most cited articles.

Wu et al. (2015) discussed how to measure electric vehicles' (EV) energy consumption. They proposed a system to collect in-use EV data and vehicle driving data installed in an EV conversion vehicle, used as test vehicle. The collected data showed that EV was more efficient when driving on in-city routes than on freeway routes, and that the EV user tried to balance the trade-off between travels time and energy consumption. Based on these results, they developed an analytical model to estimate EVs' instantaneous power in real time. Their model has a potential as both a research tool and resource for EV users. In fact, due to the potential high diffusion of EVs in the future, the analysis of the relation between EV's energy efficiency and EV drivers' behavior can be beneficial to the design of traffic assignment and new strategies for

Table 4
Local weights and overall priority.

	Economic0.169	*Environmental0.443*	*Social0.387*	*Overall Priority*	*IdealPriority*
Air	0.079	0.556	0.113	0.206	1.000
Water	0.119	0.099	0.111	0.107	0.521
Waste	0.094	0.070	0.085	0.080	0.389
Land Use	0.227	0.148	0.110	0.146	0.711
Greenspace	0.095	0.093	0.218	0.141	0.686
Built Environment	0.170	0.111	0.181	0.148	0.718
Infrastructure	0.213	0.141	0.181	0.169	0.820

Table 5
Matrix of relationships.

	Air	Water	Waste	Land Use	Greenspace	Infrastructure	Built Environment
Air		17	8	11	4	31	27
Water			27	22	2	23	19
Waste				6	–	4	11
Land Use					4	15	17
Greenspace						6	2
Infrastructure							17
Built Envir.							

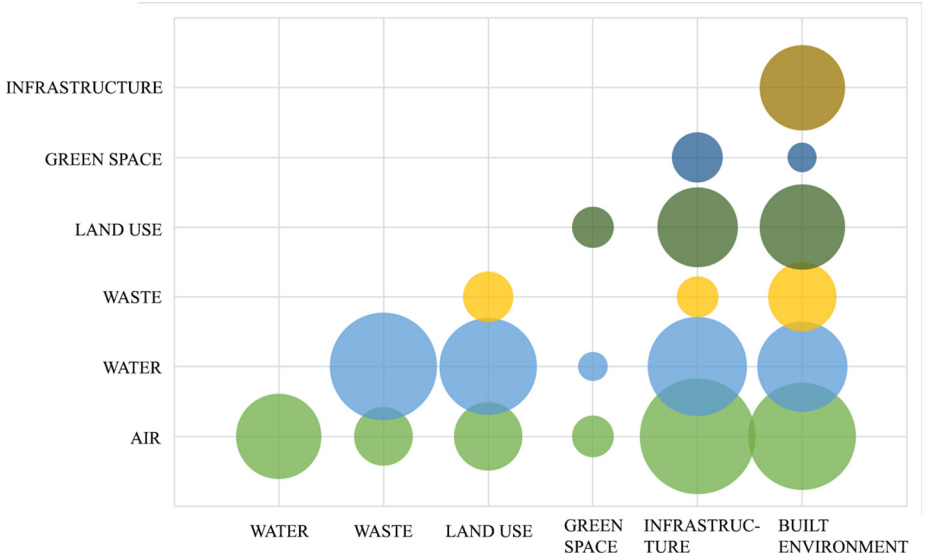

Fig. 10. Bubble diagram of sub-keywords relationships.

Table 6
Synoptic table of contributions exhibiting more than 100 citations.

Authors	*Title*	*Year*	*Citations*
Gascon M., Mas M.T., Martínez D., Dadvand P., Forns J., Plasència A., Nieuwenhuijsen M.J.	Mental health benefits of long-term exposure to residential green and blue spaces: A systematic review	2015	150
Luo X.-S., Yu S., Zhu Y.-G., Li X.-D.	Trace metal contamination in urban soils of China	2012	257
Harlan S.L., Ruddell D.M.	Climate change and health in cities: Impacts of heat and air pollution and potential co-benefits from mitigation and adaptation	2011	111
Krewski D., Jerrett M., Burnett R.T., Ma R., Hughes E., Shi Y., Turner M.C., Pope III C.A., Thurston G., Calle E.E., Thun M.J.	Extended follow-up and spatial analysis of the American Cancer Society study linking particulate air pollution and mortality	2009	303
Gupta P., Christopher S.A., Wang J., Gehrig R., Lee Y., Kumar N.	Satellite remote sensing of particulate matter and air quality assessment over global cities	2006	299
Jim C.Y., Chen S.S.	Comprehensive greenspace planning based on landscape ecology principles in compact Nanjing city, China	2003	162
Van Herzele A., Wiedemann T.	A monitoring tool for the provision of accessible and attractive urban green spaces	2003	235

infrastructures planning.

Conine et al. (2004) analyzed the shift in greenway planning from a single-objective scheme, focused on environmental conservation, to a multi-objective paradigm aimed at providing multiple benefits, such as recreational opportunities, environmental protection and greener transportation routes. Based on the outcomes of a real project for Concord city in North Carolina, they demonstrated that a systematic approach in the definition of greenway paths represents an efficient and effective strategy. Their modeling further implemented in GIS, provide local authorities and planners with valuable information bases to design a well-connected and balanced urban plan.

We followed the same procedure for the sub-keyword "built environment". Zou et al. (2017) conducted a critical and extensive review on the use of Building Information Modelling (BIM) and BIM-related digital technologies for managing multiple risks related to Architecture, Engineering and Construction (AEC) projects. They argued that BIM can be used as a systematic risk management tool in the development process, but represents a well a platform, which enables other BIM-based tools to provide further risk analysis, such as automatic rule checking, knowledge-based systems, reactive and proactive IT-based safety systems. Lazauskaite et al. (2015) presented future development instruments for suburban rural settlements, which reflects perceptions of individuals. They identified subjective and objective indicators of suburban residential environment, developed a model, which integrates them via a multiple-criteria decision method, and applied this model to different Lithuanian cities (Vilnius, Kaunas, Klaipeda).

Inel et al. (2008) developed a seismic risk assessment study for a typical mid-size city in Turkey using existing methodologies, accounting for nonlinear behavior, and providing additional contributions based on buildings data obtained through a field survey. They

Table 7
Papers referring to the three most relevant sub-keywords with the highest citations number.

Sub-keyword	*Authors*	*Title*	*Year*	*Citations*
Air	Harlan S.L., Ruddell D.M.	Climate change and health in cities: Impacts of heat and air pollution and potential co-benefits from mitigation and adaptation	2011	111
	Krewski D., Jerrett M., Burnett R.T., Ma R., Hughes E., Shi Y., Turner M.C., Pope III C.A., Thurston G., Calle E.E., Thun M.J.	Extended follow-up and spatial analysis of the American Cancer Society study linking particulate air pollution and mortality	2009	303
	Lumbreras J., Valdés M., Borge R., Rodríguez M.E.	Assessment of vehicle emissions projections in Madrid (Spain) from 2004 to 2012 considering several control strategies	2008	46
	Gupta P., Christopher S.A., Wang J., Gehrig R., Lee Y., Kumar N.	Satellite remote sensing of particulate matter and air quality assessment over global cities	2006	299
Infrastructure	.			
	Wu X., Freese D., Cabrera A., Kitch W.A.	Electric vehicles' energy consumption measurement and estimation	2015	83
	Conine A., Xiang W.-N., Young J., Whitley D.	Planning for multi-purpose greenways in Concord, North Carolina	2004	73
Built Environment	Zou Y., Kiviniemi A., Jones S.W.	A review of risk management through BIM and BIM-related technologies	2017	30
	Lazauskaite D., Šarkiene E., Skripkiene R.	The Assessment of Development Scenarios for Suburban Metropolitan Districts under the Multiple Criteria Methods	2015	3
	Inel M., Senel S.M., Toprak S., Manav Y.	Seismic risk assessment of buildings in urban areas: A case study for Denizli, Turkey	2008	10

assembled their data in a GIS and identified the potential most critical sub-districts in the worst earthquake scenario. Their procedure can be a preparatory step for recovery studies in order to identify buildings priority order for seismic retrofitting.

6. Conclusions

Research interests on urban quality assessment have increased over recent years due to its usefulness in the design and implementation of urban planning policies aimed at developing a smart and sustainable urbanism. By involving environmental, economic and social aspects, urban quality is a very complex phenomenon, which requires to be addressed by implementing a multidimensional approach. Based on this principle, this paper propose a multi-criteria decision model to support a comprehensive and rigorous systematic literature review on urban quality assessment. The method provided, which is structured into several methodological steps, couples bibliographic evaluation models, normally adopted in systematic reviews, with multi-criteria decision-making models.

As starting point, we introduced in SCOPUS database a search string with primary keywords according to which we identified 434 publications.

The results of a preliminary analysis, which restricted the number of articles to 369, showed that the interests in the topic have increased mostly over the last decade. US, China and UK are the driving nations by number of publications and Environmental Science is the most frequent subject area.

In addition, thanks to this analysis, we selected seven sub-keywords mostly representative of key issues involving urban quality assessment: Air, Water, Waste, Land Use, Greenspace, Built environment and Infrastructure.

In order to obtain a priority ranking of sub-keywords, find evidence of possible relationships among keywords and sub-keywords and assess their relative importance with respect to a set of pre-determined criteria, we developed an AHP model. Through pairwise comparisons performed by a panel of 15 experts in a Delphi survey process, the relative importance of sub-keywords in relation to the three sustainability pillars (economic, environmental and social) was determined. According to expert judgments, the most important sub-keywords are air, infrastructure and built environment, respectively.

Furthermore, we carried out a horizontal co-citation analysis in order to identify any possible relationship between sub-keywords. Air, water, infrastructure and built environment are the most cited horizontally. This seems reasonably due to the strong cause-effect relationship between air pollution issues and greenhouse gas emissions, extensively caused by transportation and built environment. We finally provided in a synoptic table a synthetic description of the most cited articles, which were critically discussed in detail as well.

Our findings reveal that air represents the most relevant aspect to be analyzed according to both expert opinions and literature analysis, immediately followed by infrastructure. Whereas, experts have attributed to water and waste a smaller importance, despite they are becoming critical issues in the design and operation of sustainable cities. Water is the second most cited sub-keyword, and thus it is perceived as a relevant issue by researchers; whereas there is lack of contributions (in relative terms) on waste with respect to its role in the assessment of urban quality and the design and implementation of circular-economy oriented policies for the cities of the future.

The novelty of the paper resides in the approach proposed. The analysis of relationships between keywords and sub-keywords performed via the AHP can contribute to the efficacy of both the systematic review process and its pyramidal structure and provide a comprehensive and holistic view on the state-of-art. Our topical search strategy relies on a hierarchical structure validated by experts' judgments, where keywords and subject heading terms are combined according to a bottom-up aggregating procedure, designed to maximize the

likelihood of identifying all relevant studies.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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