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Multi-criteria Decision-Making methods to evaluate urban environmental quality: A scoping review

Métodos de tomada de decisão multicritério para avaliar a qualidade ambiental urbana: uma revisão abrangente

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Lianne Borja Pimenta
ORCID: https://orcid.org/0000-0003-3961-0183
Universidade do Estado do Pará, Brasil
E-mail: lianne.bpimenta@aluno.uepa.br
Norma Ely Santos Beltrão
ORCID: https://orcid.org/0000-0003-1991-2977
Universidade do Estado do Pará, Brasil
E-mail: normaely@uepa.br
Renata Melo e Silva de Oliveira
ORCID: https://orcid.org/0000-0002-1904-7533
Universidade do Estado do Pará, Brasil
E-mail: renata.oliveira@uepa.br
Dênis José Cardoso Gomes
ORCID: https://orcid.org/0000-0001-6441-6783
Universidade do Estado do Pará, Brasil

ABSTRACT

Urban quality of life is crucial for achieving the Sustainable Development Goals (SDGs). As cities worldwide strive to enhance this, it becomes essential to track their progress in Environmental Urban Quality of Life (EUQoL). This review examines the key performance criteria and indicators from 47 articles on the Science Direct Platform between 2019 and 2022. We explore nine decision-making techniques integrated with Geographic Information System (GIS) to assess EUQoL. These methods include Analytic Hierarchy Process, Technique for Order Preference by Similarity to Ideal Solution, Combined Compromise Solution, Best Worst Method, Weighted Aggregated Sum Product Assessment, Preference Ranking Method for Enrichment Evaluation, VIsekriterijumsko Kompromisno Rangiranje, Elimination and Choice Translating Reality, and Multiattribute Value Theory. Our findings provide a rich insight into EUQoL assessment tools, offering a robust guide for policymakers and urban planners to elevate city living standards.

Keywords: EUQoL Assessment; MCDM; Enviromnment; GIS

RESUMO

A qualidade de vida urbana é crucial para alcançar os Objetivos de Desenvolvimento Sustentável (ODS). À medida que as cidades de todo o mundo se esforçam para melhorar isto, torna-se essencial acompanhar o seu progresso na Qualidade de Vida Ambiental Urbana (EUQoL). Esta revisão examina os principais critérios e indicadores de desempenho de 47 artigos na Plataforma Science Direct entre 2019 e 2022. Exploramos nove técnicas de tomada de decisão integradas ao Sistema de Informação Geográfica (SIG) para avaliar a EUQoL. Esses métodos incluem Processo de Hierarquia Analítica, Técnica para Preferência de Pedido por Similaridade com a Solução Ideal, Solução de Compromisso Combinado, Melhor Pior Método, Avaliação de Produto de Soma Agregada Ponderada, Método de Classificação de Preferência para Avaliação de Enriquecimento, VIsekriterijumsko Kompromisno Rangiranje, Eliminação e Escolha Traduzindo Realidade e Multiatributo Teoria do Valor. As nossas descobertas fornecem uma visão rica sobre as ferramentas de avaliação da EUQoL, oferecendo um guia robusto para que os formuladores de políticas e planejadores urbanos possam elevar os padrões de vida nas cidades.

Palavras-chave: Avaliação EUQoL; MAM; Meio Ambiente; SIG

INTRODUÇÃO

In the 21st century, urbanization rates have been on the rise, making Environmental Urban Quality of Life (EUQoL) a top priority for achieving Sustainable Development as outlined in Agenda 2030 (2015). Sustainable urban development, a multifaceted challenge, requires a comprehensive approach that includes economic, social, and environmental aspects. The complex nature of urban issues, such as overcrowding, resource depletion, and urban expansion, emphasizes the need to strike a balance between economic growth, social inclusivity, and environmental preservation. As a result, the concept of sustainable urban development has taken center stage in modern discussions, aiming to address urgent urban problems while ensuring a sustainable future (Nae et al., 2019).

Cities worldwide grapple with various challenges, with urban sustainability at the forefront. This encompasses a wide range of social, economic, environmental, and cultural factors. An essential strategy to tackle these issues is the integration of Information and Communication Technologies (ICT), as proposed by Rodrigues and Franco (2020). By harnessing the potential of ICT, cities can transform into centers of efficiency, environmental sustainability, and social inclusiveness, thereby enhancing residents' well-being. Therefore, strategically incorporating ICT into urban frameworks can significantly mitigate challenges related to urban sustainability.

In Latin America, where urban centers accommodate 80% of the population, assessing EUQoL gains increased significance (UNDP 2030, 2015). The region faces the consequences of unplanned urban growth, coupled with rising demands for vital resources and services. Achieving a harmonious interplay between the pillars of the Triple Bottom Line - economic, social, and environmental - is essential for sustainable urban evolution in Latin America. Notably, the technological choices made by public service providers profoundly influence the Triple Bottom Line and overall urban sustainability (El Karim and Awadeh, 2020).

To effectively measure EUQoL, a comprehensive evaluation aligned with the UN's Sustainable Development Goals (SDGs) is indispensable. The 2030 Agenda, established by the United Nations in 2015, outlines 17 SDGs to be globally achieved by 2030. These integrated goals, introduced by the UN, advocate for a balanced approach to social, economic, and environmental advancement. Emphasizing SDG 11, which calls for inclusive, safe, resilient, and sustainable cities, is critical, especially as urban centers are now home to more than half of the global population (UN, 2023). Strengthening and reorganizing urban centers are thus crucial for societal resilience in the face of impending challenges.

Technical standards, such as those proposed by ISO, provide valuable insights for studies in this domain. These standards serve as robust benchmarks for cities striving to assess their progress toward sustainability. The global certification of cities, with São José dos Campos leading the way in Brazil, underscores the significance of these standards in bolstering sustainable urban policies and enhancing urban welfare.

This research conducts a scoping review (Arksey and O'Malley, 2005) of articles from 2019 to 2022 in the Web of Science repository. Scoping reviews, crucial for researchers exploring emerging or underexplored areas, can identify gaps in the literature, clarify terminology, and set boundaries for innovative research in intricate fields. This study zeroes in on the critical examination of Multi-criteria Decision Making/Analysis (MCDM/A) applications, integrated with spatial analysis in a Geographic Information System (GIS) context, concerning EUQOL. Given the multifaceted nature of urban management, MCDM/A emerges as an invaluable tool for informed decision-making.

Anticipated outcomes of this scoping review include identifying relevant research themes, methodologies, and Key Performance Indicators (KPIs) related to GIS and EUQOL. Furthermore, the review aims to uncover gaps in the current literature, highlight emerging research avenues, and discern spatial correlations between EUQOL variables and the Triple Bottom Line. By delving into existing literature, this review aspires to equip stakeholders with the insights needed for sustainable urban development that caters to the diverse needs of city residents.

MATERIAL AND METHOD

For this scoping review, we chose the Science Direct (SD) repository, a well-known database for academic literature. The key features of this database are presented in Table 01. We selected SD due to its extensive coverage of science, technology, and medicine. It hosts a variety of articles, books, and journals published by Elsevier and is accessible through the Science Direct (SD) platform.

Choosing the Bibliographic Database

Among the many platforms for scientific literature, SD, Scopus, and WoS are prominent choices. These platforms offer specific search options based on their unique metrics. In this study, we employ a scoping review, a type of systematic literature review that aims to gather scientific evidence on emerging topics (Gebre et al., 2021). The SD database contains over 1.4 million open-access titles spanning a wide range of disciplines, from life and physical sciences to engineering and humanities. Numerous studies have highlighted SD's reputation as one of the largest and most reliable online databases for peer-reviewed content (Babalola et al., 2019; Abul-elezz et al., 2020; Mengist et al., 2020; Debrah et al., 2022). To ensure the credibility of our review, we focused solely on peer-reviewed journal articles from SD.

Understanding Scoping Review

While the Scoping Review (SR) is used across different fields to provide a comprehensive overview of a specific topic during a designated period, a universally agreed-upon definition remains elusive (Daudt, 2010; Levac et al., 2010; Pham et al., 2014; Peterson et al., 2016). Nonetheless, the definition proposed by Arksey and O'Malley (2005) holds influence. They described a scoping review as a method to synthesize knowledge, identify trends, and spot gaps in existing literature. SRs are particularly valuable for their inclusivity, as they consider a broad range of literature and methodologies beyond the scope of traditional reviews (Levac et al., 2010; Pham et al., 2014). Daudt et al. (2013) refined this concept, highlighting the SR's role in mapping existing literature to identify key concepts, gaps, and to guide policy and research. Typically, the outcome of an SR is a narrative presentation with limited reliance on statistical methods (Peterson et al., 2016).

Structure of the Scoping Review

Despite the lack of a universally accepted SR definition, there is no rigidly set procedure either. Nevertheless, many researchers (Levac et al., 2010; Daudt et al., 2013; Pham et al., 2014; Colqhoum et al., 2014; Peterson et al., 2016; Gebre et al., 2021) frequently adopt the objectives and steps outlined by Arksey and O'Malley (2005). These guidelines are adaptable and can be applied to various topics, regions, and publication platforms. Marsov et al. (2022) further emphasized that SRs should encompass articles using diverse methodologies, ensuring a comprehensive exploration of findings. Thus, this study followed the steps proposed by Arksey and O'Malley (2005), as summarized in Table 1.

Table 1 – Steps for conduct a scoping review based on Arksey and O'Malley's framework (2005).

	Steps	Descriptions
1	Identify the research question	The foundation of any research lies in formulating a well-structured and clearly defined research question. This pivotal step dictates the subsequent research strategies and processes.
2	Identify relevant studies	This stage involves pinpointing relevant studies. It requires creating a strategic plan to navigate through electronic databases, selecting appropriate keywords, establishing a time frame, choosing languages, and making decisions about which file types to include or exclude.
3	Study selection	At this juncture, researchers establish criteria (often determined post-hoc) to assess the relevance of all citations. This evaluation is refined as their familiarity with the existing literature grows.
4	Charting data	This phase is dedicated to synthesizing, mapping, and categorizing the gathered material. Researchers typically employ a "narrative review" or "descriptive analysis" methodology to extract context-rich and information-oriented data from each study.
5	Collating, summarizing, and reporting the results	An analytical framework or thematic structure is crucial during this phase to showcase the comprehensive insights gathered from the literature. When presenting results, maintaining clarity and consistency is of utmost importance.
6	Consultation*	*Optional step. This step offers an opportunity for consumers and stakeholders to contribute by suggesting additional references, offering valuable insights, and providing a more comprehensive perspective beyond that of the primary investigators.

Scoping Review – Selection and Extraction

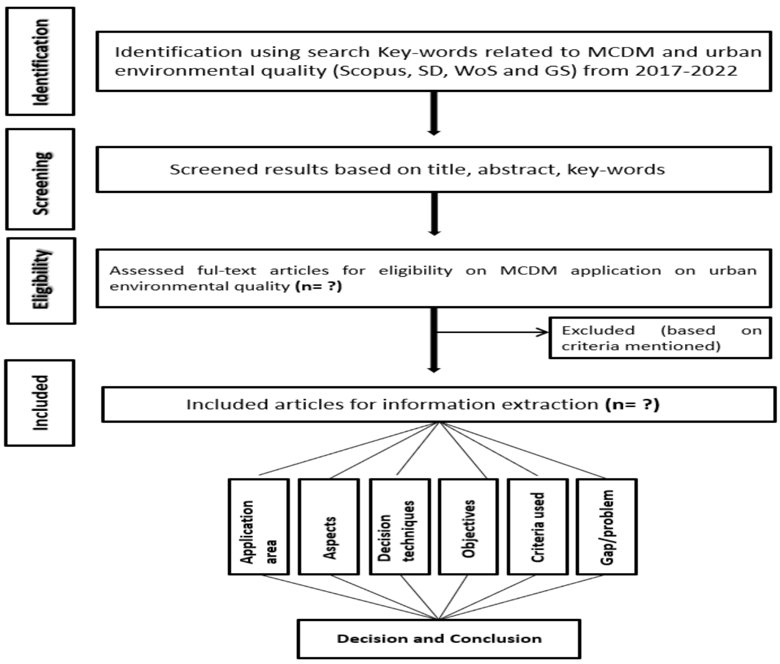
A systematic approach was employed to curate a compilation of pertinent sources and articles. The initial step involved conducting an exploratory search on the multidatabase platform, Science Direct, with a focus on publications from January 2019 to June 2022. A set of keywords, namely "quality of life assessment," "environmental impacts," "urban," and "MCDM methods," guided the search.

For this study, only scientific literature in the English language was considered. Given that English serves as the primary language for scientific discussions, this approach obviates the need for time-consuming translations from other languages. Inclusion criteria encompassed peer-reviewed works directly aligned with the search terms. The selection process for the scoping review unfolded in three phases: (1) Initial title screening; (2) Evaluation of abstracts; and (3) Comprehensive review of full-text articles.

Exclusion criteria were delineated as follows: i) Publications not written in English; ii) Publications consisting solely of abstracts; iii) Content not directly relevant to the research topic; iv) Works exclusively presented at conferences or seminars; v) Publications falling outside the specified timeframe; and vi) Studies that employed radar imagery.

A preliminary flowchart is presented below, detailing the scoping review process. This encompasses the stages of identification, screening, and determination of eligibility, along with the final count of included and excluded full-text articles. The flowchart also provides insights into subsequent stages of the process (Figure 1).

Figure 1 – Preliminary study flowchart



Source: Authors (2022).

RESULTS AND DISCUSSION

In the survey's initial phase, a set of chosen keywords was entered into the ScienceDirect database search. This action resulted in a total of 783 articles. Employing the methodology described in the preceding section and proceeding through the "abstract viewing" and "full text viewing" stages, the list was refined based on established criteria. This procedure enabled the identification of frequently used indicators and MCDM methods for assessing urban environmental quality. Following the application of all exclusion criteria, a final tally of 47 relevant articles remained. Detailed insights into the selection process and outcomes at each stage are presented in Table 2.

Table 2 – Preliminary results.

Databases	Obtained results (n)	1st r*	2st r
SD	783	**563**	**47**

*r = round of the application of criteria.

Source: Authors (2022).

Trends in Multi-criteria Analysis Methods for Urban Sustainability

Research carried out by Yang and Zhang (2021) on the creation of sustainable urban drainage systems (SUDS) and the assessment of urban sustainability by Liang et al. (2022) serve as examples of the varied applications in this field. Notably, the years 2021 and 2022 have seen the highest number of publications addressing the use of indicators to evaluate sustainability in urban areas and the implementation of MCDM methods. It is important to highlight that indicators play a crucial role in evaluating urban sustainability. Fundamental principles such as relevance, accessibility, reliability, timeliness, and ease of interpretation need to be followed (Li et al., 2019; Yi et al., 2021).

Diverse MCDM methods have been developed, each possessing unique characteristics, resources, computational complexity, and scope. Table 4 offers an overview of the chosen articles, the employed methods, their variations, authors, and summarized applications.

In the intricate realm of multi-criteria analysis methods, the Analytic Hierarchy Process (AHP) stands out. Developed by Thomas Saaty, this method aims to organize objectives, attributes, criteria, issues, and stakeholders, presenting a comprehensive perspective of the complexities inherent in decision-making processes (Saaty, 1990). According to Saaty (1988), paired comparisons hold significance in the AHP methodology. Using a relative scale from 1 to 9, the preference of one criterion over another is assessed, leading to the creation of a comparison matrix - a crucial step in the process. Subsequently, it is vital to evaluate the consistency of expert judgments. If the value is below 0.1, the consistency is deemed satisfactory. However, a value exceeding 0.1 suggests inconsistency, indicating that AHP might not be appropriate (Saaty, 1991). In this article's context, multiple studies have emphasized the applicability of AHP.

Kusakci et al. (2022) presented a study offering significant insights by integrating indicators across economic, social, environmental, and institutional dimensions to formulate a Sustainable Cities Index (SCI) for different metropolises in Turkey, considering its rapid urbanization. They proposed an innovative methodology combining Type-2 Fuzzy Analytical Hierarchy Process (IT2F-AHP) and Complex Proportional Assessment of Alternatives (COPRAS). Another study, grounded in field research, GIS analysis, and an AHP entropy method, identified the environmental and social benefits of 38 Urban Wetlands Parks (UWPs) in Wuhan, China. The researchers constructed geographically weighted regression (GWR) models and three coupling coordination models to examine park attributes and built environmental factors affecting UWP spaces, given their varied environmental and social advantages (Ye and Quiu, 2021).

For Rahan et al. (2022), transit-oriented development (TOD) is recognized for enhancing the quality of life (QoL) of urban residents and promoting social sustainability. This holds particularly true when TOD ensures optimal and convenient spatial access to urban facilities. Their approach utilized cluster analysis of built environmental (BE) factors to quantify an integrated index of spatial accessibility and uncover the connection between BE indicators and spatial accessibility of urban facilities.

In a distinct study, factors influencing the spatial resilience of secondary cities in Ethiopia amid urban uncertainties were identified. Household perceptions from Kombolcha residents were gathered for this purpose. Empirical data were collected through questionnaires and key interviews, which were later analyzed using SPSS and the Analytic Hierarchy Process. The outcomes unveiled a connection between land use zoning changes and the rise of informal settlements (Maru et al., 2021). Rapid urbanization was attributed to the deterioration of environmental quality in urban settlements. To assess this environmental quality, an Environmental Quality Index (EQI) for the District of Ernakulam, India, was developed. EQI values were visually represented in a map divided into five categories: "very poor, poor, moderate, good, and very good" (Krishnan and Firoz, 2021). In addition, this approach offers a systematic method to tackle uncertainties in decision-making by quantifying criteria and options related to objectives, as indicated by Kamdar et al. (2019), Adenle et al. (2021), Awad and Jung (2022), Aidinidou et al. (2023).

Another notable MCDM method is TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), introduced by Hwang and Yoon in 1981. Designed to handle challenges in multi-criteria decision-making, the authors highlighted its ability to calculate alternative ratings without requiring attribute transformations. The dominance analysis involves comparing the first two alternatives; if one dominates the other, the dominated alternative is discarded (Hwang and Yoon, 1981). The method's appeal lies in its simplicity and the foundational notion that the optimal solution is close to the positive ideal solution and far from the negative ideal one (Yoon and Wang, 1995).

Regarding the application of TOPSIS, a notable study focuses on urban health across eight districts of Qom, using a descriptive analytic method. The TOPSIS method and SPSS were employed to elucidate variables, complemented by relevant models (Mahdi et al., 2016). This approach aids in assigning weights to sustainability indices, thereby enhancing the importance of individual groupings. Challenges faced after strategy evaluation for designated attributes and their clusters are addressed (Yang and Zhang, 2021; Silva et al., 2022; Valencia et al., 2022). Another innovation, the Combined Compromise Solution (CoCoSo) method, provides results across various scenarios through normalization techniques derived from combined commitment solutions, as seen in selected studies (Ersoy, 2021; Mokarrari and Torabi, 2021; Pamucar et al., 2021; Dwivedi and Sharma, 2022).

Yazdani et al. (2018) introduced a novel method that combines a compromise decision-making algorithm with aggregation strategies, enhancing result flexibility. An aggregated multiplication rule was utilized to finalize alternative rankings. Termed the Combined Compromise Solution or CoCoSo method, its variations suit diverse objectives. Through its normalization techniques, the method produces outcomes across diverse scenarios arising from combined commitment solutions. Its applicability spans themes like Quality of Life in a GIS environment, either as standalone or integrated, as observed in studies by Ersoy (2021), Mokarrari and Torabi (2021), Pamucar et al. (2021), Dwivedi and Sharma (2022).

Continuing our exploration of MCDM methods, Jafar Rezai introduced a novel approach to address contemporary challenges in the MCDM domain. This method offers a structured framework for comparisons, requiring between 2n-3 to n elements for pairwise data. To ensure the reliability of these comparisons, a consistency ratio was integrated into this new method, termed the Best Worst Method (BWM) (Rezaei, 2015). Researchers like Ye and Quiu (2021) utilized BWM (alongside another MCDM method) in a GIS environment, unveiling the environmental and social benefits of UWPs in Wuhan, China. These benefits were attributed to the utilization of coupling coordination models. BWM, designed to transcend the limitations of existing methods, demonstrates improved stability, logical outcomes, and reduced need for pairwise comparisons. This is evident in studies by Omidipoor et al. (2019), Rahimi et al. (2020), Salvador et al. (2022), Badi et al. (2023).

In 2012, Zavadskas et al. (2012) proposed a fusion of multi-criteria analysis methods, specifically the Weighted Sum Model (WSM) and the Weighted Product Model (WPM). This amalgamation significantly improved ranking accuracy over individual methods. This hybrid approach was named the Weighted Aggregated Sum Product Assessment (WASPAS). A subsequent study in 2014 underscored WASPAS's versatility and precision, particularly when optimizing the weighted aggregate function (Zavadskas et al., 2014). Moreover, WASPAS adeptly handles cost and benefit criteria through linear normalization, as demonstrated in studies by Aydin et al. (2022), Mokarrari and Torabi (2021).

Notable Multi-criteria Analysis Methods and Their Applications

In the late 1980s, the multi-criteria analysis landscape witnessed the emergence of the Preference Ranking Method for Enrichment Evaluation (PROMETHEE). Notable characteristics of this method are stability, simplicity, and clear parameter management. Brans and Vincke (1985) emphasized the necessity for decision-makers to assign weights to each evaluation criterion, reflecting their significance. Six distinct preference representation methods were introduced, offering flexibility in applying criteria. Rooted in overclassification value relationships and criterion-specific weights, this method found application in studies like those by Mokarrari and Torabi (2021), Yang and Zhang (2021).

The late 1990s introduced the VIKOR (VIsekriterijumsko KOmpromisno Rangiranje) method. This stepwise approach focuses on ranking alternatives and pinpointing the compromise solution closest to the ideal (Opricovic, 1998). It aims to enhance problem-solving in complex multi-criteria systems by establishing a compromise ranking list and solution, considering initial data weights (Opricovic and Tzeng, 2004). The efficacy of this method in tackling intricate challenges, particularly in forming compromise classifications and solutions, is evident in studies by Nesticò et al. (2022) and Zhou et al. (2020).

Following our exploration of existing multi-criteria methods, another noteworthy approach emerged, resulting in the creation of a program named 'Elimination and Choice Translating Reality' or ELECTRE. This method formulates a resultant relation that facilitates the elimination of specific subsets, thereby narrowing the choice problem to complementary subsets. It delves into the dynamics of ‘agreement’ and ‘disagreement’ indicators (Roy, 1968). A distinctive feature of the ELECTRE method and its variations is the use of outranking, which includes concepts like superclassification, prevalence, subordination, and notably, domination. In this context, if a generic alternative 'a' dominates another generic alternative 'b', the alternatives that are ‘outperformed’ by others are considered dominated (Roy and Bertier, 1971). The method's adaptability is apparent in its ability to handle both qualitative and quantitative criteria, diverse scales and significance levels, and both favorable and opposing perspectives regarding objectives. Its impact on the decision-making process is demonstrated in studies by Yang and Zhang (2021) and Nesticò et al. (2022).

Belton and Stewart (2002) introduced the term Multiattribute Value Theory (MAVT). Implementing this approach involves several steps: defining and normalizing criteria weights, establishing a value scale for each criterion to assess the alternative's value, and synthesizing information while conducting sensitivity and robustness analyses for model validation. The authors highlight the critical role of decision-maker involvement, deemed the methodology´s key contribution. For specific studies, including those by Bottero et al. (2021) and Fancello and Tsoukiàs (2021), MAVT emerged as the preferred method. It enables the expression of the value function provided by the decision-maker for multiple associated criteria and/or objectives. This reflects the relative importance of the evaluated attributes, influencing the context under investigation.

Furthermore, within the scope of this scoping review, some articles were singly cited, leading to their categorization under a "others" column, as illustrated in Table 3 below.

Table 3 – MCDM methods and studies, year and applicatons

MCDM Method	Year/Case study/ Application
AHP /Fuzzy AHP /Mives /IT2F-AHP 'Analytic Hierarchy Process'	2023/ Flood risk management sustainable [Aidinidou et al., 2023]; 2022/ TOD sustainability [Keet et al., 2022]; 2022/ Strategies for sustainable cities [Kusakci, et al., 2022]; 2022/ Sustainable urban regeneration [Awad and Jung, 2022]; 2022/ measure the outdoor environment performance of four existing neighbourhoods [Zhao et al., 2022]; 2022/Urban mobility and sustainability [Silva et al., 2022]; 2022/ select the best location for mobility hub to be established at the Anatolian side of Istanbul [Aydin et al., 2022]; 2022/ identification of cities and the pollutants which are used as indicators for air quality [Raheja et al., 2022]; 2022/ Urban water resources [Noori et al., 2022]; 2022/ Location of green space areas [Nesticò et al., 2022]; 2021/sustainable urban drainage system development (SUDS)[Yang and zhang, 2021]; 2021/model to find the most suitable green roof to reduce air pollution in cities [Motlagh et al., 2021]; 2021/ critical review of role of GIS and MCDM tools in EIP site selection [Nuhu et al., 2021]; 2020/ Sustainable disposal technologies [Zhou et al., 2020]; 2020/ Indicators integrating [Yannis et al., 2020]; 2020/ statistical analysis on preliminary results and implemented a relative AHP model [D'Alpaos and Andreolli, 2020]; 2020/ sustainable livability touristic districts [Mushtaba et al., 2020]; 2019/ urban resilience and compare it with urban smartness [Zhu et al., 2019].
TOPSIS/ Entropy TOPSIS/ Fuzzy Topsis 'Techniques for order Preference by Similarity to Ideal Solutions'	2022/ Urban water resources [Noori et al., 2022]; 2022/Urban mobility and sustainability [Silva et al., 2022]; 2022/ Indicators integrating [Valencia et al., 2022]; 2022/ Location of green space areas [Nesticò et al.,2022]; 2021/the concept of "smart city" and its pillars/[Mokarrari and Torabi, 2021]; 2021/ the applicability of the SDG index system to the Mega-city regions and reflect the overall sustainable development [Xu et al., 2021]; 2021/development of the indicators' panels to assist analysis and decision making [Paz, et al., 2021]; 2021/sustainable urban drainage system development (SUDS) [Yang and Zhang, 2021]; 2021/ Sustainable development [Luczak and Just, 2021]; 2020/ Smartcities, technology [Ozkaya and Erdin, 2020]; 2019/perform a quantitative evaluation of the energy economic and environmental performance [Vavreka and Chovancová, 2019]; 2019/ urban resilience and compare it with urban smartness [Zhu et al., 2019].
Cocoso / Dumbi Cocoso	2022/ Performance of the SDG's [Dwivedi and Sharma, 2022]; 2021/ urban mobility setting [Pamucar et al., 2021]; 2021/the concept of "smart city" and its pillars/[Mokarrari and Torabi, 2021].
BWM /Fuzzy BWM /Bayesian BWM 'Best Worst Method'	2022/ framework to evaluate several decision-influencing criteria for locating an OWF [Salvador et al., 2022]; 2020/ Landfill site selection [Rahimi, et al., 2020]; 2019/ Renovation of urban blight areas [Omidipoor et al., 2019].
Waspas /The Weighted Aggregates Sum Product Assessment	2022/ select the best location for mobility hub to be established at the Anatolian side of Istanbul [Aydin et al., 2022]; 2021/the concept of "smart city" and its pillars/[Mokarrari and Torabi, 2021].
PROMETHEE/ Promethee II 'Preference Ranking Organization Method for Enrichment Evaluation'	2021/sustainable urban drainage system development (SUDS) [Yang and Zhang, 2021]; 2021/the concept of "smart city" and its pillars/[Mokarrari and Torabi, 2021].
VIKOR 'VIsekriterijumsko KOmpromisno Rangiranje'	2022/ Location of green space areas [Nesticò et al., 2022]; 2020/ Sustainable disposal technologies [Zhou et al., 2020].
ELECTRE 'Elimination and Choice Translating Reality'	2022/ Location of green space areas [Nesticò et al., 2022]; 2021/sustainable urban drainage system development (SUDS) [Yang and Zhang, 2021].
MAVT 'Multi-attribute value theory'	2021/ people's value of urban and environmental opportunities [Fancello and tsoukiàs, 2021]; 2021/ Sustainable cities [Bottero et al., 2021];
Others	Method mentioned solely once

Source: Authors (2022).

Multi-criteria Analysis Methods and Extracted Indicators

The AHP method and its variations were referenced 18 times across the reviewed papers, while the TOPSIS method and its variations appeared 12 times. Similarly, the BWM and CoCoSo methods were each referenced three times among the selected articles. Regarding other methods detailed in the table, WASPAS, PROMETHEE, VIKOR, ELECTRE, and MAVT and their respective variations were each mentioned in two articles. The row labeled 'other' pertains to methods that surfaced only once during the review. As previously noted, the AHP method, either standalone or in conjunction with other multi-criteria analysis methods (MCDM), was featured in 18 of the chosen articles. While there's no consensus deeming it the optimal method for every scenario, its ability to deconstruct intricate problems and hierarchically organize them via paired comparison is commendable (Saaty, 2008). Its compatibility with the GIS environment, as shown in studies by Mustaha et al. (2020), Nesticò et al. (2022), and Silva et al. (2022), supports its widespread adoption, despite limitations similar to those of other methods.

Among the 47 examined articles, we extracted indicators used to gauge qualitative and quantitative aspects influencing the urban environmental quality experienced by residents. The 'CODE' column houses dimension-related acronyms or abbreviations, such as "Ev" for Environmental, "In" for Infrastructure, and "S" for Social. Sequentially, numbers in this column are arranged in ascending order (e.g., 01, 02...), based on their table placement. Of the 70 extracted indicators, 24 are related to the Environmental dimension, 29 to Infrastructure, and 17 to the Social dimension. Table 4 subsequently presents these indicators, their designations, and the studies/authors that utilized them.

Table 4 – Indicators, identification codes and studies were applied.

CODE	Environmental	Articles
Ev01	Air Quality/Pollutants	*Vavrek and Chovancovà (2019)*; D'Alpaos and Andreolli (2020); Bottero et al. (2021); Mokarrari and Torabi (2021); Narayanan et al. (2021); Pamucar et al. (2021); Pamucar et al. (2022); Raheja et al. (2022); Silva et al. (2022); Zhao et al. (2022).
Ev02	Particulatte matter (PM 2.5; PM 10)	*Xu et al. (2021)*; Raheja el al. (2022).
Ev03	Sulphur Dioxide (SO^2)	Raheja et al. (2022).
Ev04	Nitrogen Dioxide (NO^2)	Raheja et al. (2022).
EV05	Ozone (O^3)	Raheja et al. (2022).

Ev06	Carbon Monoxide (CO)	Raheja et al. (2022).
Ev07	Carbon Dioxide (CO²)	*Nikoloudis et al. (2020)*; Motlagh et al. (2021); Paz et al. (2021); *Pamucar et al. (2022)*; Valencia et al. (2022).
Ev08	Emissions level (GHG)	Vavrek and Chovancovà (2019).
Ev09	Water	D'Alpaos and Andreolli (2020).
Ev10	Ratio of treated water (%)	Chen et al. (2022).
Ev11	Water quality	Zhu et al. (2019); Mustaha et al. (2022).
Ev12	Water comsumption	Xu et al. (2021).
Ev13	Waste water discharge	Xu et al. (2021).
Ev14	Per capita water resource	Yi et al. (2019).
Ev15	Land use (scale 1:1000000)	*D'Alpaos and Andreolli (2020)*; Pamucar et al. (2021); Awad and Jung (2022); Mustaha et al. (2022); Noomi et al. (2022); Aidinidou et al. (2023).
Ev16	Vegetation (scale 1:1000000)	Noomi et al. (2022).
Ev17	Soil type (1:12000000)	Noomi et al. (2022).
Ev18	Temperature (annual long term average)	*Mustaha et al. (2022)*; Noomi et al. (2022).
Ev19	Proximity to legal/protected urban areas	*Rahimi et al. (2020)*; Kusackci et al. (2022); Salvador et al. (2022); Silva et al. (2022).
Ev20	Waste management	*D'Alpaos and Andreolli (2020)*; Motlagh et al. (2021); Narayanan et al. (2021); Paz et al. (2021); Xu et al. (2021); Kusackci et al. (2022); Salvador et al. (2022).
Ev21	Noise Pollution	*Mustaha et al. (2022)*; Silva et al. (2022).
Ev22	Energy Consumption	*Mokarrari and Torabi (2021)*; Silva et al. (2022).
Ev23	Fossil fuel consumption	*Pamucar et al. (2022)*; Silva et al. (2022).
Ev24	Renewable Energy	Pamucar et al. (2021).

CODE	**Infrastructure/Physical**	
In01	Green urban spaces	*Zhu et al. (2019)*; Morrakari and Torabi (2021); Xu et al. (2021); Ghasemi et al. (2022); Nesticò et al. (2022)
In02	Extension	Nesticò et al. (2022)
In03	Acessibility	Nesticò et al. (2022)
In04	Green areas	*D'Alpaos and Andreolli (2020)*; Ke et al. (2021); Narayanan et al. (2021); Awad and Jung (2022); Chen et al. (2022); Ghasemi et al. (2022); Mustaha et al. (2022); Nesticò et al. (2022)
In05	Parks	Ghasemi et al. (2022)

In06	Per capita green areas	*Yi et al. (2019)*; Xu et al. (2021); Yi et al. (2021); Chen et al. (2022); Liang et al. (2022)
In07	Vertical green and green roof	Ke et al. (2021)
In08	Ratio of Green coverage of built-up areas	*Yi et al. (2021)*; Liang et al. (2022)
In09	Built environment	D'Alpaos and Andreolli (2020)
In10	Pathaways Network	Ghasemi et al. (2022)
In11	**Transportation**	Ghasemi et al. (2022)
In12	Proximity to important facilities	Ghasemi et al. (2022)
In13	Congestion and traffic levels	Silva et al. (2022)
In14	Coverage/Capacity of Public Transportation Service	*Zhu et al. (2019)*; Narayanan et al. (2021); Silva et al. (2022)
In15	Public transportation per capita	Chen et al. (2022)
In16	Accident rates	Pamucar et al. (2021)
In17	Road use efficency	Pamucar et al. (2021)
In18	Ports	Salvador et al. (2022)
In19	Quality of Public Transportation	*Mokarrari and Torabi (2021)*; Silva et al. (2022)
In20	Subway Stations	Ghasemi et al. (2022)
In21	Use of Sustainable Vehicles	Silva et al. (2022)
In22	Medical care capacity	Zhu et al. (2019)
In23	Distance from industrial areas	Rahimi et al. (2020)
In24	Number of houses	Xu et al. (2021)
In25	Healthcare facilities (nº of hospitals)	*Yi et al. (2019)*; Narayanan et al. (2021); Paz et al. (2021); Yi et al. (2021); Kusackci et al. (2022); Aidinidou et al. (2023)
In26	Healthcare services	*Nikoloudis et al. (2020)*; Mokarrari and Torabi (2021); Mustaha et al. (2022)
In27	Educational services (nº Schools)	*Nikoloudis et al. (2020)*; Narayanan et al. (2021); Ayadin and Erdin, 2022; Ghasemi et al. (2022); Mustaha et al. (2022)
In28	Equality education	Zhu et al. (2019)
CODE	**Social**	
S01	**Population**	Bottero et al. (2021)
S02	Urban population	Noomi et al. (2022)
S03	Urban population density	*Chen et al. (2022)*; Kusackci et al. (2022); Salvador et al. (2022); Aidinidou et al. (2023)
S04	Urbanization rate	*Yi et al. (2019)*; Rahimi et al. (2020); Xu et al. (2021); Aidinidou et al. (2023)
S05	Employment rate	*Bottero et al. (2021)*; Narayanan et al. (2021); Ayadin et al. (2022); Liang et al. (2022)

S06	Per capita GDP	*Zhu et al. (2019)*; Yi et al. (2019); Rahimi et al. (2020); Yi et al. (2021); Kusackci et al. (2022); Liang et al. (2022)
S07	GDP per employed person rate	Ozkaya and Erdin (2020)
S08	Unempolyment rate	*Zhu et al. (2019)*; Rahimi et al. (2020); Yi et al. (2021); Valencia et al. (2022)
S09	GDP grow rate	*Chen et al. (2022)*; Liang et al. (2022)
S10	Age	Ayadin et al. (2022)
S11	Municipal Human Development Index	Rahimi et al. (2020)
S12	Natural growth rate of population	Liang et al. (2022)
S13	Crime ratio index	*Pamucar et al. (2021)*; Valencia et al. (2022)
S14	Public security	*Ke et al. (2021)*; Mokarrari and Torabi (2021); Narayanan et al. (2021); Valencia et al. (2022)
S15	Accessibility for vulnerable users	*Pamucar et al. (2022)*; Silva et al. (2022)
S16	Innovation Index Score	Ozkaya and Erdin (2020)
S17	Per capita households deposits	Liang et al. (2022)

Source: Authors (2023). *

The aforementioned indicators are presented in a general manner. It remains uncertain whether all of these indicators will have applicable data in the context of Brazilian cities.

CONCLUSION

Addressing the challenge of sustainable urban development requires meticulous attention and effective management. Striking a balance between economic progress, social fairness, and environmental well-being is pivotal for achieving success in this endeavor. To align with our research objectives, we meticulously refined our search terms based on an initial literature review, thereby guiding our selection of relevant keywords

Our findings reaffirm that scoping reviews are valuable methodological tools among the various approaches used to synthesize evidence from scientific literature. Our investigation of the Sustainable Development (SD) database, utilizing search terms such as “quality of life assessment,” “environmental impacts,” “urban,” and “MCDM methods,” yielded promising results.

These findings encompassed both the quantity of scholarly articles and insights into leading countries within this domain, in accordance with our chosen research approach. The MCDM methods most frequently mentioned were the Analytic Hierarchy

Process (AHP) and its variants, cited in 18 studies, closely followed by the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and its variations, mentioned in 12 studies.

Additionally, other methodologies, including Best Worst Method (BWM) and CoCoso, were featured in three selected articles. Notably, China and Iran emerged as leaders in publication volume, contributing a combined total of 17 articles, followed by Turkey and India with six each, and Italy and the United States with two apiece

Among the 69 extracted indicators, categorized into their respective dimensions, these indicators have found applications in diverse biogeographical and contextual settings. When coupled with multi-criteria analysis methods in a Geographic Information System (GIS) environment, they enrich our understanding of urban environmental dynamics. The arrangement of land use in urban areas significantly impacts environmental quality, influencing factors like green space availability, preservation of natural habitats, and the state of air and water quality. Thus, comprehensive land use analysis is a cornerstone for comprehending the environmental implications of urban development and promoting sustainable urban planning.

As we conclude this scoping review, we acknowledge that while we have achieved our primary objectives, new and relevant keywords may emerge in future research endeavors. This constant evolution ensures that our understanding of sustainable urban development continues to grow and adapt.

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