

Multicriteria Decision-Making in Public Security: A Systematic Review

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Abstract: The Multiple Criteria Decision-Making/Analysis (MCDM/A) methods have been widely used in several management contexts. In public security, their use enhances managerial decision-making by considering the decision-maker's preference structure and providing a multidimensional view of problems. However, methodological support for their applications in this field lacks clarity, including selecting appropriate methods, addressing pertinent problematics, and identifying alternatives and criteria. To address this gap, this article conducts a Systematic Literature Review (SLR) to diagnose the state of the art and identify the main directions of the research in multicriteria models applied to public security management. The research methodology involves five main research questions, and the extraction and analysis of data from 51 articles selected through a structured filtering process. The analysis includes identifying the number of publications and citations, as well as listing the MCDM/A approaches and issues employed. Furthermore, the criteria used and the number of criteria considered are discussed, as well as the method employed. Finally, the identification of the main research directions in MCDM/A models applied to public security is presented. The findings suggest that prioritization and classification are common problematics, social criteria are frequently considered, and the AHP method is widely used, often employing fuzzy sets and hybrid models.

Keywords: multicriteria models; decision making; public security; systematic literature review

MSC: 90B50



Citation: Costa, J.; Silva, M. Multicriteria Decision-Making in Public Security: A Systematic Review. *Mathematics* **2024**, *12*, 1754. <https://doi.org/10.3390/math12111754>

Academic Editor: Junyi Chai

Received: 27 April 2024

Revised: 31 May 2024

Accepted: 2 June 2024

Published: 5 June 2024



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1. Introduction

Governmental entities face the daily challenge of ensuring public security by exploring potential factors. In this context, the UNODC Global Homicide Report [1] reveals that, in 2022, the global homicide rate was 5.8 per 100,000 inhabitants, an alarming figure that represents twice the number of deaths occurring in armed conflicts. These statistics reflect the loss of thousands of lives, with devastating consequences for individuals, families, and communities. Furthermore, the accelerated urbanization process presents even more challenges, resulting in an increasingly steep demand for quality of life in areas such as health and security. The latest United Nations [2] projections indicate that the global population could reach approximately 8.5 billion in 2030, 9.7 billion in 2050, and 10.4 billion in 2100.

The management of public service operations with the active definition and constant review of actions, or public policies, is an important means of sustaining the safety of citizens. However, this management is a complex task and, in the field of public security, the effectiveness of the security promotion process depends on identifying ways to ensure effective decisions. In this sense, it is important that the management of public security is based on scientific approaches that can provide subsidies for decision-making [3,4].

Given the complexity involved in managing practices for crime mitigation and control, the efficient allocation of resources is one of the most critical decisions. In this context, multicriteria decision-making methods are considered crucial in supporting the decision-maker in the good allocation of such finite resources among competing alternatives [5–7]. Managers of police units constantly face the challenge of making decisions that impact police behavior, the effectiveness of crime suppression structures, and resource allocation among the different units. Therefore, Multi-Criteria Decision Analysis (MCDA) may serve as a useful mathematical tool to assist them in decisions that take into account a variety of objectives simultaneously [8].

Organizations, in general, need to deal with multiple objectives constantly, and the decision-making process needs to include them in decision guiding. However, this is not a simple procedure due to situations in which the objectives of a decision may be conflicting [9,10]. Thus, the decision-support methodologies aim to assist in this process, which involves the study and development of models that can help the decision-maker to make a decision considering the performance of other actors, such as analysts, stakeholders, experts, among others.

These models are developed to take into account the various, often contradictory, objectives that need to be considered. Therefore, methodologies are essential in this decision-making process in complex situations, such as public security management. It is possible to state that, mainly due to the wide variety of problems in which MCDM/A approaches can be used, there has been significant development in this type of decision-making in recent decades [11].

Recent studies have strongly pointed out the need for decision support in law enforcement agencies and public security control, as in de Colla and Santos [12], Camacho-Collados and Liberatore [13], de Figueiredo and Mota [14]. The decision-making process in this area can be better controlled through the use and implementation of structured procedures, involving direct/indirect contributions from stakeholders in this process and considering discussions about the trade-offs that such decisions are subject to, such as between financial objectives and social justice. In the study by Agarwal et al. [15], for instance, the PROMETHEE-GAIA method is used to classify the performance of the police in Indian states, comparing and identifying the state(s) that require(s) urgent attention and reform. In the study by Mota, de Figueiredo and Pereira [16], the objective is to identify areas considered vulnerable to homicides in a certain region of Brazil; for this purpose, a model developed in the framework of a Geographic Information System (GIS), based on MCDA, was presented, represented by the acronym GIS-MCDA. In both studies, it can be said that several perspectives need to be considered in order to obtain a formal and realistic representation of the problem at hand.

The relevance of using these models in relation to problems involving social issues has motivated literature reviews related to several contexts, such as that of the application of MCDA in the healthcare field [17–22], in the support for solid waste management and sustainable development [23–27], and even in contexts involving multidimensional flood management [28] and inclusive housing development [29].

To date, however, the scientific community still lacks a comprehensive and systematic review method that can diagnose the state of the art of multicriteria models applied in public security management. This scarcity of studies is due to the fact that most of the available research does not provide a systematic and in-depth analysis of the applications of these models in the context of public security. This gap in the literature is particularly troubling given the fundamental importance of public security management in ensuring the universal right to life and personal security. Indeed, effective security management is one of the primary responsibilities of the state, as it directly affects the quality of life and sense of well-being of the population.

In this sense, it is fundamental to investigate the application of multicriteria models in the area in question to provide subsidies for the development of strategies for the management of this sector. A comprehensive and systematic review can identify the main

trends and research directions, thereby contributing to the advancement of knowledge and the improvement of management practices in this critical area. Hence, a systematic study could diagnose the state of the art, identifying applications, benefits, and limitations. Systematic reviews are highlighted as important sources of information because they allow studies to be conducted in a transparent, systematic, and reproducible manner, contributing to the advancement of research.

This study aims to fill a gap in the literature by investigating the use of multi criteria decision-making methods (MCDM/A) in supporting decision-making in the field of public security. It includes the analysis of articles seeking to understand how MCDM/A approaches have been used in this context. By doing so, it seeks to establish the current state of research in the area, to identify gaps and pertinent issues, and to assist new researchers in choosing appropriate strategies and models for the development of their research. Therefore, the research problem concerns the mapping and analysis of the use of multicriteria decision-making methods in public security management, aiming to support researchers in the development of new mathematical models that assist in the efficient allocation of resources and in making complex decisions in this field.

The study aims to address five key questions, essential for understanding the application of MCDM/A models in public security management. Firstly, it investigates how MCDM/A models have evolved in terms of the number of articles and citations (1), aiming to assess whether the development of mathematical decision support models has been a focus of recent research in the context under consideration. Secondly, it identifies which MCDM/A issues are most applied (2), with the objective of determining if there is a prevalence of certain approaches regarding the sets of alternatives considered. Thirdly, it analyzes how many and which criteria are considered in decisions (3), providing guidance to future researchers on the complexity of the quantitative and/or qualitative criteria involved. Fourthly, it examines which MCDM/A methods have been most utilized (4), seeking to identify potential gaps in the literature, such as the use of fuzzy sets. Lastly, it highlights which trends can be observed (5), offering insights and guidance for readers interested in the application of mathematical methods in decision-making. These questions are fundamental to promoting a comprehensive and detailed understanding of the use of MCDM/A in public security, contributing to the advancement of research and the improvement of decision-making practices in the field.

The paper is divided into five main sections. Section 1 presents the introduction and justification for the study. In Section 2, the theoretical background necessary to understand the MCDM/A concepts is described. Section 3 presents the methodological framework of the systematic literature review, including article inclusion and exclusion criteria, search strategy, and study selection. In Section 4, the results of the analysis of the selected articles are presented and discussed. Finally, Section 5 presents the conclusions of the study, the main findings and identified gaps, as well as suggestions for future research.

2. MCDM/A Methods

Unlike classical optimization problems, multiple-criteria decision-making problems deal with more than one objective simultaneously. In addition, these objectives often conflict with each other, which brings the study closer to reality and allows for broad applications in practical problems [9,30–32].

Multicriteria decision-support models are tools that help in evaluating alternatives in situations where there are multiple criteria that need to be considered. They intend to make the decision-making process easier by highlighting the priorities and trade-offs among criteria. The MCDM/A approach is based on the principle that decisions are made based on multiple objectives with different levels of importance. Therefore, MCDM/A aims to evaluate alternatives under multiple aspects, considering the satisfaction of multiple objectives. In addition, MCDM/A allows the representation of uncertainties and the consideration of different perspectives of decision-makers [33–35].

Considered a subfield of operations research, this approach has a strong mathematical foundation in its methods, which are used to support complex decisions involving subjectivity. For the most part, these methods include determining relevant criteria and alternatives, assigning weights or importance levels to each criterion relative to the objective, and defining thresholds and other preferences [36]. The structure of a problem of this type is characterized by the establishment of certain conditions, such as the existence of at least two alternatives from which the decision-maker must choose. The intended outcome of this choice can be determined based on different problematics. Among the most common are: the choice problematic, which aims to clarify the decision by selecting a subset from the action space; the classification problematic, which aims to allocate each action to a class; the ranking problematic, which seeks to organize actions in a sequence; and the portfolio problematic, which aims to select a subset from a set of alternatives [6,31].

MCDM/A methods are widely used in various sectors, such as urban planning, natural resource management, strategic planning, engineering, environmental management, and others. In the field of security, various studies in the literature demonstrate decision-making in complex scenarios with multiple criteria. In the study by Basilio et al. [37], for example, the researchers proposed a multicriteria method that combines the ENTROPY and CRITIC methods with the PROMETHEE method to support the ranking of policing strategies aimed at reducing crime. The authors emphasize that this method enables managers to make decisions with less uncertainty. Tutak and Brodny [38] employed the TOPSIS method to analyze crime and determine the state of security in Polish cities, aiming to propose strategies for enhancing security aligned with the multidimensional concept of smart cities. In the study conducted by de Assis et al. [39], the WASPAS method was employed to analyze and prioritize alternatives for helicopters most suitable for police aerial activity in the state of Rio de Janeiro, Brazil.

While the literature presents a wide range of approaches, it is crucial to acknowledge that there is no method considered ideal for application in all contexts or decision problems. Different techniques may yield varying decision suggestions [40]. However, examining the methods and contexts in which mathematical models are employed can provide valuable guidance for analysts.

Some of the most common methods include Analytic Hierarchy Process (AHP), Elimination et Choix Traduisant la REalité (ELECTRE), and the Preference Ranking Organization METHod for Enrichment Evaluations (PROMETHEE). Among the Multicriteria Decision Making/Analysis methods, three common categories can be distinguished: Unique Criterion of Synthesis Methods, Outranking Methods, and Interactive Methods. Unique Criterion of Synthesis Methods aim to obtain an overall score that summarizes all the considered criteria. Multi-Attribute Value Theory (MAVT) and Multi-Attribute Utility Theory (MAUT) are examples of this type of method. Outranking Methods do not use a single score for synthesis, and some of them may arrive at final recommendations without scores assigned to alternatives. The ELECTRE and PROMETHEE families of methods are the main examples of this group. Finally, interactive methods can be applied to discrete or continuous problems, mostly used in multi-objective linear programming (MOLPs) and goal programming problems [41–44].

In contemporary literature, several advancements in multicriteria approaches are underscored, such as the application of fuzzy set theory (FST) [45]. This theory represents uncertainty in human beliefs, allowing for its effective application in conjunction with MCDM/A methodologies to yield more sensitive, tangible, and precise results. As emphasized by Mishra et al. [46], real-world circumstances often introduce uncertainty and information distortion, thereby justifying the need to develop a fuzzy environment.

Over the decades, multicriteria approaches have undergone significant diversification and enrichment. However, the literature highlights several common flaws, including inadequate configuration, excessive and unbalanced criteria for different objectives, insufficient stakeholder participation, oversimplification, and the presence of bias [47,48]. Some studies highlight that the selection of an appropriate method is crucial due to discrepancies in

the performance of different techniques used [49]. Consequently, some researchers have dedicated themselves to conducting studies aimed at analyzing and synthesizing articles that involve this type of approach in specific areas, such as health [22], sustainability [29,36], water resource management [50] and supply chain management [51]. However, up to the present moment of this study, no work has been found in the literature that focuses on evaluating general issues and methodological aspects of the applications of this mathematical approach in the field of public safety.

3. SLR Structure

The purpose of an SLR is to identify relevant primary articles, allowing for the analysis and synthesis of all available research relevant to a given research question, area, or phenomenon of interest [52,53].

In this sense, this paper conducts a comprehensive review to identify applications of Multiple-Criteria Decision-Making (MCDM) models in the context of public security, with the main objective of providing guidance and support for readers interested in this area. To achieve this, a methodology was applied, consisting of the steps presented in Figure 1, based on the guidelines proposed by Kitchenham et al. [54], Pizard et al. [55], and the systematic review guide proposed by Okoli [56], taking as objectives:

- To establish the current state of research on the use of MCDM/A models in public security. This objective aims to provide a comprehensive and up-to-date overview of the state-of-the-art concerning the utilization of MCDM/A models in the area of public security. In doing so, researchers can gain a deeper understanding of extant approaches, emerging trends, and knowledge gaps, thereby enabling a critical assessment of the current progress in this domain;
- To identify gaps in the use of MCDM/A models in public security. This objective focuses on identifying specific areas within the field of public security where MCDM/A models have not yet been adequately explored or applied. Identifying such gaps is crucial for guiding future research and developments, contributing to filling these knowledge spaces and expanding the utilization of these models in new contexts or problems within this area;
- To support researchers in directing new research activities in this area. This objective aims to provide valuable guidance and insights to researchers interested in initiating or advancing work related to the use of these mathematical models within the specific context. By understanding the existing research gaps and the primary challenges faced, researchers can effectively direct their efforts, focusing on areas of greater relevance and potential impact;
- To identify the main issues related to MCDM/A models in public security. This objective aims to highlight and comprehend the most relevant and challenging issues regarding the use of MCDM/A models in public security. This may encompass concerns such as integrating multiple decision criteria, considering uncertainties, and adequately representing decision makers' preferences. By identifying and understanding these issues, researchers can focus their efforts on addressing specific challenges and developing innovative solutions to enhance the effectiveness and applicability of the models.

By addressing these points, this study paves the way for the development of innovative solutions that enhance the effectiveness and applicability of MCDM models in public security, significantly contributing to the advancement of the field.

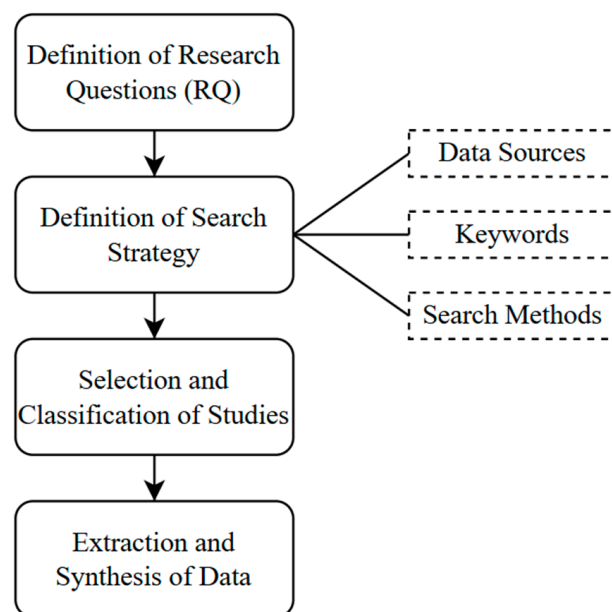


Figure 1. Stages of SLR.

3.1. Research Questions

Decision-making in the public security area is a complex task that involves several aspects, from resource limitations to political and cultural influence [57]. Furthermore, crime is a multifactorial phenomenon, and the control of its spread is of utmost urgency. Based in this context, the structuring and resolution of decision problems with the use of supporting techniques increasingly originates from the concerns of policy-makers, analysts, and other stakeholders with an interest in obtaining assistance in the planning and management of activities [58]. To design the SLR, following the stages in Figure 1, five main research questions were defined in the context of public security, as shown in Table 1.

Table 1. Research questions.

Research Questions (RQ) in the Context of Public Security	
RQ 1.	How have MCDM/A models evolved in terms of the number of articles and citations?
RQ 2.	Which MCDM/A problematics are most often applied in public security?
RQ 3.	How many and which criteria have been considered in the decisions?
RQ 4.	Which MCDM/A methods have been most used?
RQ 5.	What trends can be highlighted?

The aforementioned issues have considerable impact. By exploring the trends (RQ5) in publications and citations (RQ1), one can gauge the perceived relevance of research in MCDM, highlighting crucial perspectives, such as the consideration of multiple objectives [59]. Additionally, all these issues encompass fundamental aspects of multicriteria analysis.

In the study by Gallo et al. [60], the authors observe that these methodologies can be adapted to the specific conditions and needs of each case, irrespective of the decision context. The addressed research questions can thus guide the participants involved in the decision-making process, tackling the identified problematics (RQ2), the criteria considered (RQ3), and the methods employed (RQ4) in the studies.

Addressing the challenges of public security demands the consideration of complexities and the pursuit of tailored solutions. In this regard, recognizing the problematics addressed will enable the reader to identify the desired comparative positions of alternatives [31].

Regarding the identification of criteria and methods, readers will be able to obtain guidance to tackle similar challenges in public security. It is important to mention that the

choice of method is associated with various characteristics of the decision problem to be addressed, including the rationality of the decision-maker [58,61].

Based on these research questions, an overview of the characteristics and evolution of MCDM/A models in the addressed context is provided, as well as the identification of existing gaps in the current literature, presenting opportunities for further investigations and studies. In addition, the SLR points out some important challenges for future research.

3.2. Search Strategy

The initial search for primary studies took place in January of the year 2023, using the Web of Science (Core Collection—Clarivate Analytics), compiled by the Institute for Scientific Information (ISI), in articles published up to 31 December 2022, in English. The Web of Science (WoS) can be defined as an online citation indexing service capable of supporting the production of high-quality research, covering various areas of knowledge. It is worth noting that, in order to control the quality of the works, the research was limited to journals. Furthermore, it is noteworthy to mention that the search was updated in May 2024 to incorporate more recent studies, thus ensuring the temporal comprehensiveness of the analysis, encompassing studies published up to 2023.

Through a brainstorming process, the authors defined two sets of keywords (Table 2) related to the theme of this study. The first set of keywords refers to the context of public security (with 25 keywords), and the second set relates to MCDM/A approaches (21 keywords). Additionally, with one keyword from the first group and another from the second, the strings from the two groups were combined using the Boolean operator “AND”, generating a set of 525 keyword combinations to be used in the search for the articles.

Table 2. Keywords.

“Public Security”; Crime; “Public Safety”; Violence; “Social Security”; “Security Public Policies”; “Society Security”; “Urban Security”; “Urban Safety”; “Social Safety”; “Society Safety”; Criminality; Criminal; “National Safety”; “National Security”; “State Security”; “State Safety”; “Homeland Security”; “Homeland Defense”; “Security of Country”; “General Security”; “Citizen Security”; “Citizen Safety”; “Safety Measure”; “National Peace”.	“Multi-attribute”; “Multiple-Attribute”; “Bi-criteri”; Multiattribute; “Multi-criteri”; “Multiple-criteri”; Multicriteri; “Many-Objective”; “Multiple-dimensio”; Multidimensio; “Multi-objective”; “Multiple-objective”; MCDM; MCDA; MAUT; MAVT; PROMETHEE; ELECTRE; AHP; SMARTS; TOPSIS.
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3.3. Selection and Classification

From the combination of keywords, the field label known as “TS-Topic” was used, and initially, 4475 results were obtained from the main collection of WoS. As previously notes, articles published until 2023 were considered. In order to analyze articles of greater academic relevance, conference articles, books, and other publication categories were removed, resulting in a total of 3108 articles. Review articles were also excluded. To ensure the coherence with the research area in question, steps were taken to refine the selected articles.

Initially, from the identification of keywords such as “multiple dimensions”, it was possible to identify a potential heterogeneity of areas and articles that would not be related to MCDM/A in public security. Thus, full readings were performed on the selected articles, eliminating those considered outside the research scope. Subsequently, full readings of selected articles were conducted, resulting in further refined analysis and the elimination of those that were not suitable for the research area. These stages were crucial to ensure the credibility and coherence of the analysis performed.

The data extracted from the articles were: title of the article, author(s), country of origin of the research (the country of the first author was considered for articles in which the country in which the research was applied was not identified), journal of publication, year of publication, number of citations and the questions that are related more specifically to the MCDM/A models (problematic used, criteria considered, method used and the

specific context in which the decision was supported). To effectively identify studies to be included in the review, a set of inclusion and exclusion criteria were defined, summarized in Table 3.

Table 3. Inclusion and exclusion criteria.

Inclusion Criteria (General)	Exclusion Criteria (General)
-Published in English	-Published in another language
-Published before 2024	-Published in 2024
Title and abstract	Title and abstract
-It is a Public Safety decision supported by the MCDM/A	-It is not a Public Safety decision supported by the MCDM/A
Full text	-Does not present abstract
-Provides the necessary information for the analysis of general data and methodological steps	Full text
-Text available	-Does not clearly structure the decision problem (alternatives, criteria, problematic)
	-Text unavailable
	-Does not specify the method used

Additionally, four quality questions were defined to objectively evaluate the selected studies in the review (as shown in Table 4). The authors evaluated each of the preselected articles, and through discussion defined which articles met the research questions and should be included in the study.

Table 4. Quality questions.

Number	Quality Question
1	Did the study present the components of the proposed review?
2	Did the study show consistent results?
3	Did the study describe the problem it addressed?
4	Are the analyses and interpretations of the data consistent with the chosen methodology?

As shown in Figure 2, a summary of the study can be derived by considering the five refinement stages.

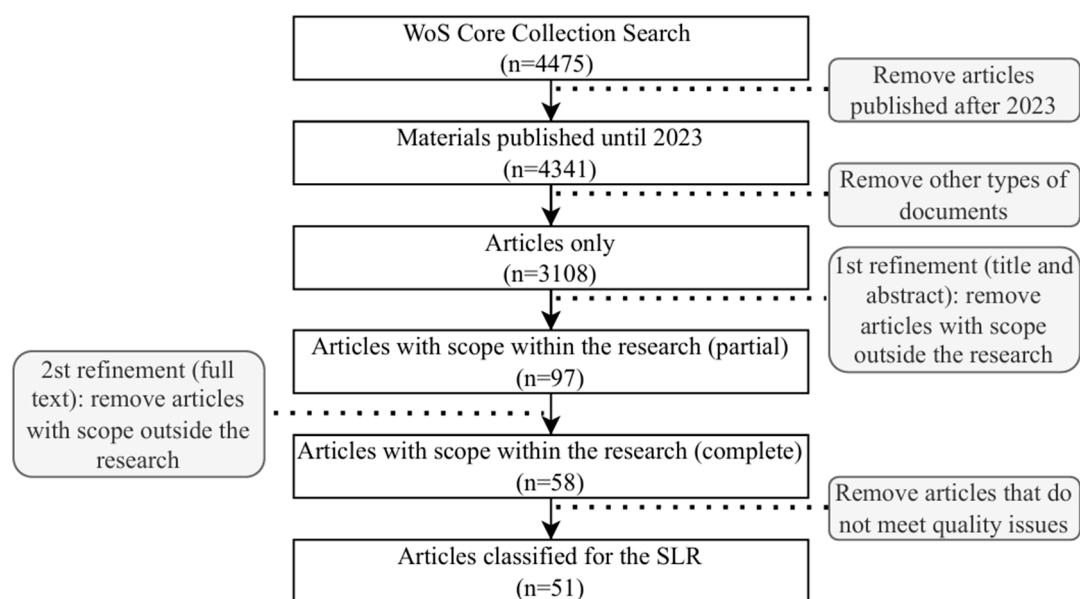


Figure 2. Stages of the filtering process.

4. Results and Discussions

In order to provide guidance for future studies on the subject addressed, the research questions previously addressed will be discussed in the subsequent topics. A set of 51 articles, selected through a systematic review process, were examined and will assist in identifying future directions.

4.1. Evolution of MCDM/A Models in Public Security in Number of Articles and Citations

Based on the analysis of the literature, it is possible to observe an evolution in the number of studies involving the application of MCDM/A techniques in decision-making in complex and uncertain situations in public security. The use of these techniques can contribute to the development of efficient and effective strategies in this field.

The graph shown in Figure 3 demonstrates a significant increase in the number of articles published in 2013, with a noticeable peak in 2018. There was a small decrease between 2019 and 2020, followed by a new increase in 2021, 2022 and 2023. This growth trend in scientific production in the area in question may indicate greater attention given to the topic and a growing interest in improving public security strategies with the aid of MCDM/A techniques.

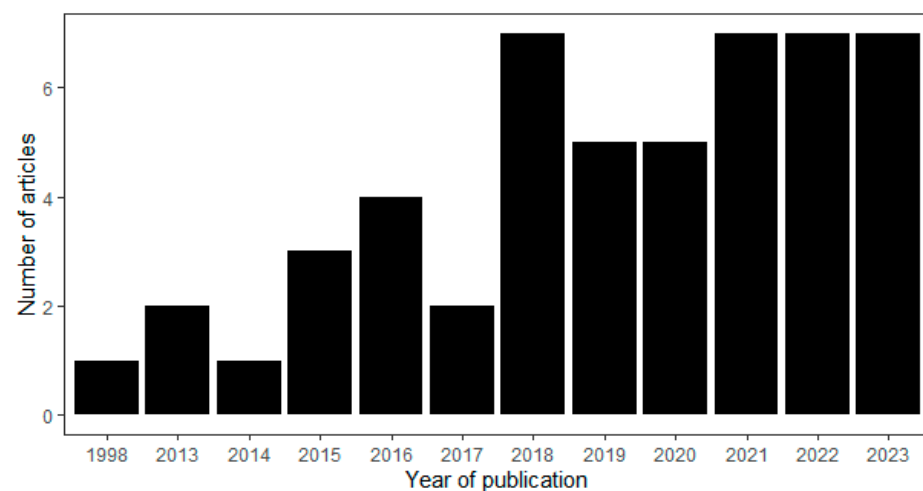


Figure 3. Number of articles.

In addition to analyzing the number of published articles, it is crucial to consider the number of citations received by the papers over time. The number of citations is an indicator of the impact and relevance of studies within the scientific community, reflecting the influence they had on subsequent research. Therefore, the analysis of the number of citations can provide valuable information about the advancement and consolidation of the research area in question. Thus, it is possible to assess whether the increase in the number of articles is related to an increase in the quality and relevance of the studies, or whether it is just an increase in the volume of publications.

Observing the bar graph in Figure 4, it is possible to perceive an exponential growth in the number of citations over the years, with a significant increase in recent years. In the early years of the series, from 1998 to 2002, the number of citations was approximately zero. Then there was a small increase in the number of citations in 2003, which continued in 2005, 2006 and 2007. In 2013, the number of citations increased further, peaking at 25 in 2018, before hitting an even higher peak of 117 in 2021. In summary, the presented data indicate an exponential growth in the number of citations over the years. This increase can be attributed to several factors, including the overall increase in research production in the area.

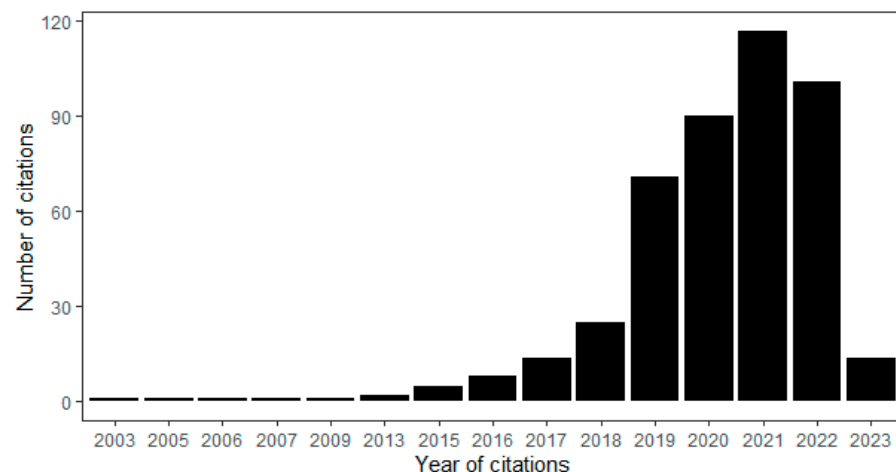


Figure 4. Number of citations.

This collection of articles (51), according to the Web of Science Core Collection database, was cited by 452 articles from 2003 to 2023. Additionally, it can be observed that the h index of the collection is 11, meaning that the group possesses 11 articles that were cited at least 11 times. According to Waltman and Van Eck [62], the h-index is a measure that can be used to evaluate the quality and influence of a group of documents or articles. It is particularly useful when one wishes to assess the impact of a group of documents in a specific research area because it takes into consideration both the number of citations and the distribution of those citations.

Regarding the journals in which the 51 articles were published, 44 different journals were identified. Among them, the *Journal of Modelling in Management* stands out, with a total of four publications. In addition, the journals *Mathematical Problems in Engineering*, *International Journal of Information Technology & Decision Making*, *Omega*, and *Sustainable Cities and Society* each had two publications. The others registered only one publication each. Table 5 presents all 44 journals.

Furthermore, regarding the number of articles published by country, it can be seen in Figure 5 that Brazil leads the list with 16 articles, followed by India and China, with 6 and 5 articles, respectively. Iran, the United States, and Spain also have a significant presence, with five, four and three articles, respectively. Australia, Portugal, and Turkey have a moderate number of articles, with two each. In addition, Japan, Lithuania, Mexico, Poland, Saudi Arabia and United Arab Emirates are represented with only one article each. These data provide an overview of scientific activity in different countries and can be useful for analyzing academic production and scientific collaboration among nations.

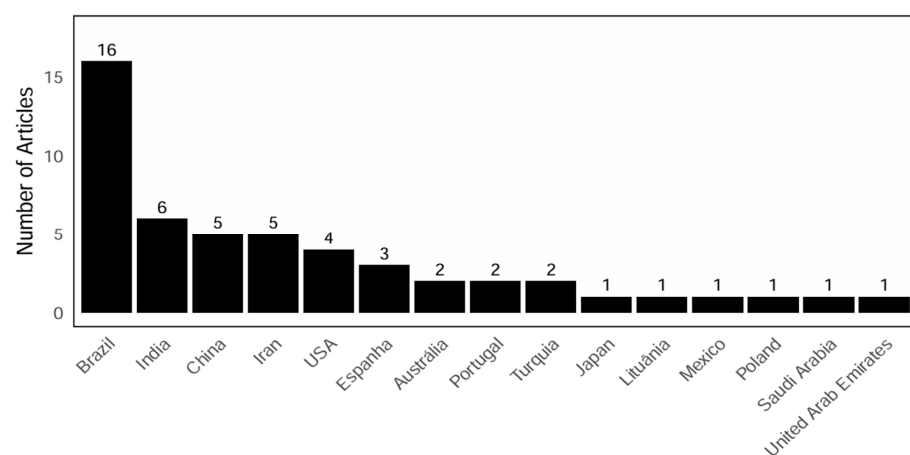


Figure 5. Number of article per country.

Table 5. Journals.

Journals	
Omega	Journal of Modelling in Management
Sustainable Cities and Society	Landscape and Urban Planning
Journal of Public Policy	International Journal of Intelligent Systems
Neurocomputing	Symmetry-basel
International J. of Information Tec. & Decision Making	Journal of Nursing Management
Decision Support Systems	Journal of Urban Planning and Development
European Journal of Operational Research	Information Sciences
Mathematical Problems in Engineering	Sustainability
International Journal of Drug Policy	Operational Research
American Journal of Criminal Justice	GeoJournal
International Journal of Production Economics	Decision Science Letters
Computers & Industrial Engineering	Cuestiones Politicas
Journal of Taibah University for Science	Environmental Research and Public Health
Journal of Multi-criteria decision analysis	International Journal of Geo-Information
Technological Forecasting and Social Change	Automation in Construction
International J. of Information T. and Systems Approach	Discrete Dynamics in Nature and Society
Transportation Research Part D: Trans. and Environment	Buildings
Expert Systems with Applications	Environment, Development and Sustainability
Journal of the Operational Research Society	IIE Transactions
Axioms	Smart Cities
IEEE Access	Plos One
Mathematics	Information Sciences

4.2. Decision Problematics Applied in MCDM/A Models in Public Security

MCDM/A models are based on the idea that decisions are made based on multiple criteria or objectives, and that different options can be evaluated in relation to these criteria. However, the way in which options are evaluated and the relationships between different criteria can vary, resulting in different types of decision problematics. For example, some decision problematics may involve choosing among several options, while others may require ranking the options on a priority scale. Similarly, some problematic may involve classifying options into different categories, while others may require selecting a set of options that complement each other.

The importance of the type of decision problematic in MCDM/A models is related to how options are evaluated and the consequences of these evaluations for decision-making. Therefore, understanding the different decision problematics and choosing the most appropriate approach for each situation is critical to ensuring that the decisions made are effective and strategic.

According to the data presented in Table 6, it is possible to verify that ranking is the most common problematic in MCDM/A models applied to public security, representing 58.82% of the analyzed articles. This suggests that the ability to establish a priority order among different action options is crucial for effective decision-making in public security situations. Classification is also a prominent problematic, representing 29.41% of the analyzed articles. This suggests that the ability to group different options into categories can be useful in helping to understand the different aspects of the public security problem.

Table 6. Decision problematics.

Problematic	N° of Articles	% of 51
Choice	5	9.8
Ranking	30	58.82
Classification	15	29.41
Portfolio	1	1.96

The choice represents only 9.8% of the analyzed articles, suggesting that the majority of studies consider it more important to establish a priority order or classify different options than simply choosing a single option. Finally, the portfolio problematic represents only 1.96% of the analyzed articles. This suggests that the ability to select a set of options that complement each other and form a more effective solution is not common in MCDM/A models applied in public security. In summary, prioritization and classification are the most common problematics in MCDM/A models applied in public security, while choice and portfolio are less common. This highlights the importance of prioritizing and grouping different options to make more effective decisions in situations of public security.

4.3. Criteria Considered in Decision-Making

Identifying criteria is a crucial step in the decision-making process. When making a decision, it is important to take into consideration several relevant factors, which are called criteria. These criteria can vary depending on the situation at hand and the decision-maker's preferences and objectives. Identifying suitable criteria helps in evaluating available options and making the best possible decision. However, it is not always easy to identify them, especially for decisions that are complex or have many options. Therefore, it is important to dedicate time and effort to recognize and carefully evaluate them.

In this review, it was observed that there is a large variation in the number of criteria used, with an average of approximately 8.29 and a standard deviation of approximately 5.99. Furthermore, it was observed that the median is six and since the numbers four, five and six appear frequently in the list, this indicates a concentration of cases around these values. It should be noted that approximately 75% of the evaluated articles presented a quantity of criteria equal to or less than 10.

Due to the diversity of criteria used in public security, they were grouped to facilitate identification and evaluation. Seven groups of criteria were established, namely, types of damages, types of crimes, financial, social, infrastructure, performance, and others. As shown in the bar chart presented in Figure 6, the three most considered categories of criteria from the 51 analyzed articles were types of crimes, performance and social.

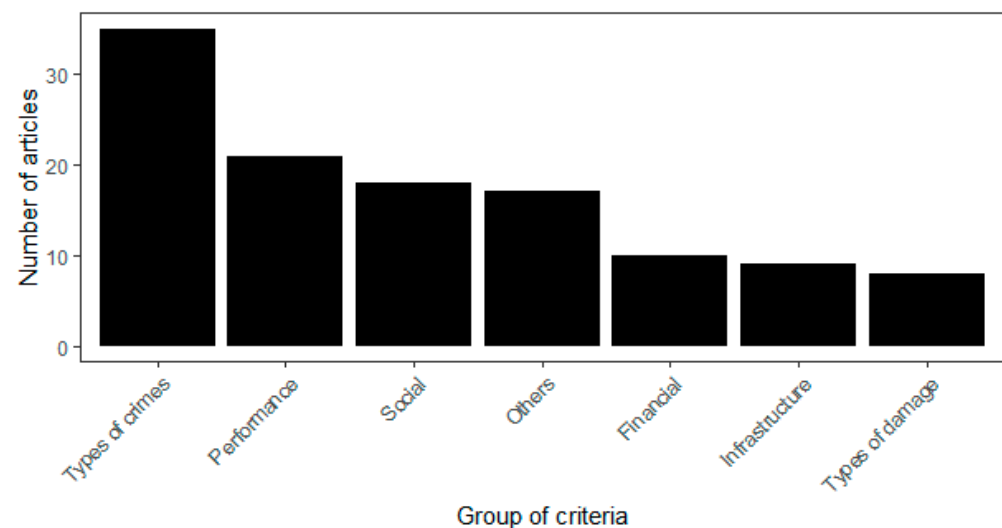


Figure 6. Types of criteria.

In a study conducted by De Figueiredo and Mota [14], for example, some of the social criteria considered were the level of education and the percentage of literate people. In the work of Nepomuceno et al. [63], some examples of criteria categorized as “performance” include relative directional efficiency in violent crimes and relative directional efficiency in street robberies. In the study by Camacho-Collados et al. [64], the criterion of “patrolling demand” was categorized as others.

It is relevant to point out that many studies have considered the analysis of two or more areas of criteria concurrently. In particular, De Figueiredo and Mota [65] considered the inclusion of criteria such as income, Gini index, infrastructure, education, and population density per km². This approach implies the use of more than one category of criteria, including infrastructure, financial, and social areas.

4.4. The Most Used MCDM/A Methods in Public Security Decision-Making

The choice of the most suitable MCDM/A method for a specific decision problem depends on the characteristics of the problem, decision-makers' preferences, and data availability. It is important to consider the rationality of the decision-maker, the organizational context, as well as the decision-maker's preference structure. The selection of an appropriate method can help in ensuring that decisions made are consistent, transparent, and based on careful and systematic analysis [7].

In the literature, various options of methods capable of modeling decision problems in public security can be observed, ranging from the PROMETHEE and ELECTRE family of methods to TOPSIS, AHP, SMART, DRSA, additive ratio evaluation, and others.

The compilation of the methods used in this group of articles is presented in Table 7.

Table 7. Most used MCDM/A methods.

Method	References	Total
Hybrid	[13,14,37,63,64,66–82]	22
Weighted aggregation	[67,83,84]	3
AHP	[66,68,70,73,75,78,80,81,85–94]	18
DHP	[95]	1
ANP	[72,74]	2
ELECTRE	[5,71,96–98]	5
MACBETH	[77,99]	2
TOPSIS	[38,70,76,79–81]	6
WASPAS	[39,100]	2
PROMETHEE	[15,37,63,74,101]	5
DRSA	[14,60,65]	3
GP—Goal Programming	[64]	1
ARA	[73,82]	2
Fuzzy	[8,72,73,81–83,86,92,102]	9
Optimization	[14]	1
Heuristic	[13,64,67,69,103]	5
Other	[8,13,63,69,76,78,79,82,90,102–104]	12

For example, it is possible to verify that the authors Iwasaki and Tone [85] used the Analytic Hierarchy Process (AHP) method in their article. Similarly, authors Candan and Toklu [82] employed a hybrid method involving Additive Ratio Assessment (ARAS) along with Simple Multi-Attribute Rating Technique (SMART) and fuzzy technique (SMART-Fuzzy). In this context, ARAS was used as an additional method, which highlights the diversity of methods employed to address the multiple dimensions and criteria involved in decision making.

The AHP method was the most applied, representing about 43.14% of applications, i.e., 22 of the 51 analyzed articles. The application of this method was performed in different ways: using a fuzzy set approach [73,86,92] to allow for the consideration of uncertainties and partially unknown facts in the model; in conjunction with hybrid models [70,73,78,80,81]; and involving other forms of application of the method, such as the Dynamic Hierarchy Process—DHP, which is an advanced version of AHP considering temporal changes [95].

4.5. Trends in Research

As evidenced throughout the text, multicriteria decision-making models have been widely used in public security management, aiming to support the choice of more appropri-

ate public policies, the design of patrol areas, and the classification of regions with a higher propensity for crime occurrence, among other relevant types of decisions in this context. It is possible to observe a growing interest in and application of these models, which stand out as useful tools to improve the effectiveness of actions.

The adoption of hybrid approaches has emerged as a prominent trend, as it is noted that 22 of the articles included the combination of two or more methods. In addition, all articles published in 2022, with the exception of the study by Mahdavi Zargar, Moazami, and Azimzadeh [94], employed the hybridization strategy. However, it is important to note that more classical methods employed in isolation still prevail. As already mentioned, the AHP figures among the most frequently used classical methods; however, it is important to emphasize that, even though this is a widely employed method, several criticisms have already been made of it, via the points highlighted by Belton and Goodwin [105], these being as follows:

- Restriction in the comparisons to a scale of 1 to 9. The scale proposed by Saaty is arbitrary, which can generate inconsistencies in the elicitation process, and this necessarily imposes inconsistencies in the answers;
- The correspondence between semantic and numerical scales. The choice of values for the numerical scale was made arbitrarily. In this case, taking as an example, several authors argue that 5 is too high a number to indicate strong preference;
- Lack of operational significance of answers to questions that raise the relative importance of criteria. The fact that these questions do not relate to the scales on which the criteria are measured, or the alternatives that are evaluated, means the introduction of the “order reversal” effect or the “reversal of the order of alternatives”. Therefore, since this information is not related to the scales on which the criteria are measured, or to the alternatives that are evaluated, the relative position of the alternatives can be changed, depending on the introduction or removal of alternatives;
- The assumption of an underlying ratio measure in relation to the criteria. This concerns the consideration of the criteria weights only as a degree of importance.

Besides these, we should note the exhaustive process for the decision-maker (it requires many pairwise comparisons), the use of up to seven alternatives (limitation), the fact that it is highly sensitive to the quantity of criteria and alternatives, related to the amount of information required by the decision-maker, and the subjective and arbitrary Saaty scale, which can generate inconsistencies.

In the context of the use of imprecision approaches, low adoption was observed. Among the imprecision techniques used in only 9 of the 51 articles, the fuzzy approach was the only one mentioned. This approach seeks to improve decision-making in complex and uncertain environments, allowing us to model human thinking and to deal with uncertain or imprecise information, as is common in public security cases. The concept of uncertainty is used to describe information that is imprecise, vague, or incomplete.

Depending on the circumstances, data on criminal occurrences can be incomplete, compromising the adequate analysis of crime trends in a particular region. Moreover, other situations, such as calculating the cost of a particular type of crime or quantifying losses resulting from criminal acts, can also be sources of uncertainty in this context. Tian et al. [106] pointed out that most multicriteria decision-making problems need to be evaluated with many interactive and qualitative indices, which can it be challenging for existing methods to handle effectively. Therefore, techniques such as grey and fuzzy approaches have been widely accepted. In light of this, it can be stated that the use of fuzzy techniques represents an opportunity for research and applications in the field.

In relation to the decision-making process, of the 51 articles analyzed, 52.94% relied on a group of specialists to formulate the problem and build the multicriteria decision model. Given the complexity related to the theme of public security, it is expected that this situation be analyzed under a multidimensional perspective and with varied perceptions of the problem. Nevertheless, 47.06% took into consideration only the preferences of one decision-maker during the decision-making process, although in the research of Das et al. [103] and

Nepomuceno et al. [63], different stakeholders helped in the construction of criteria and the identification of alternatives.

Another observation concerns the identification and structuring of objectives, which helps in providing a broad vision to ground better decisions, using the effort and time expended, with regard to decision-making, in the best possible way. After conducting an individual analysis of each of the 51 articles, it can be inferred that only 5 of them made use of Problem Structuring Methods (PSM), these being Marques et al. [99] and Oliveira et al. [91] with the use of cognitive mapping, as well as Trevisan et al. [77] and López et al. [97], with the employment of VFT, and de Assis et al. [39], who used Soft System Methodology. Thus, considering all the articles analyzed, only 9.8% used PSM in designing, understanding, describing, and identifying the important factors of decision models. Therefore, as this is a very low percentage, it is stated that this is a research gap in the public security area, characterized as a great opportunity for application, which can substantially support the resolution of the initial stage in decision problems, showing the importance and applicability of such methods. In this context, we indicate the use of some of the main PSMs in the literature, namely, Value Focused Thinking (VFT), Strategic Option Development and Analysis (SODA) and Soft Systems Methodology (SSM). Finally, it is recommended to apply a multimethodological approach, combining the use of one or more PSM with multicriteria decision-making.

In the literature, several types of decisions have been supported by a multicriteria model. In order to facilitate the identification of trends in decision-making areas, six distinct categories were established: patrol, investigation, interventions, specific crimes, identification of strategic areas, and system evaluation. In addition, a category called “other” was created to encompass decision problems that do not fit into the categories aforementioned. Table 8 presents the articles, classified according to the corresponding decision category. It is worth noting that among the mentioned categories, system evaluation stands out as the most recent. Of the five articles in this category, one was published in 2021, two in 2022, and the other two in 2023.

Table 8. Types of decision.

Type of Decision	N° of Articles	References
Patrolling	8	[13,39,64,67,69,78,79,93]
Investigation	8	[8,70,85,86,90,102,103]
Interventions	11	[5,66,71,73,77,87,89,95,97,101,104]
Specific crimes	4	[68,88,94,98]
Identification of strategic areas	9	[14,16,65,75,83,91,92,99,100]
Systems evaluation	5	[15,37,38,80,82]
Other	6	[63,72,76,81,84,96]

The advancement of information technology and the ability to deal with a large repository of data (structured and unstructured) have supported security management activities. Geographic Information Systems (GIS) are an example of an efficient technological tool in supporting management. The relevance of the GIS application in the review is perceived in some applications, such as in Mota, de Figueiredo and Pereira [16], where an MCDM-GIS model is used to support the exploration of factors that may lead to vulnerability to homicides, highlighting areas lacking public policies, and in the study of Camacho Collados and Liberatore [13], in which the authors use a multicriteria method supported by GIS to design predictive patrolling areas.

Last but not least, it is worth noting that there are still few papers that make use of MCDM/A in public security decisions, showing a scarcity, especially when compared to other areas such as risk management, financial modeling, maintenance, and reliability. This disparity suggests a significant opportunity to increase the number of publications in this specific field. For example, De Almeida et al. [61] found 263 articles that use multicriteria or multi-objective models in the context of risk management. Furthermore, in a systematic

review conducted by De Almeida-Filho et al. [7], 657 articles were identified that employ multicriteria models in financial modeling problems.

These numbers demonstrate the existence of a solid research base in these mentioned areas, while the application of the MCDM/A approach to public security is still in the early stages of implementation. Therefore, there is a clear opportunity to broaden the scope of publications and further explore the potential of this approach in public security-related decision-making.

5. Conclusions

This study features a comprehensive analysis of the MCDM/A methods used in public security management, covering different research areas and fields of application. A total of 51 articles were considered, which highlighted the importance of MCDM/A approaches in the context at hand. Over the period from 2013 to 2023, i.e., the last 10 years, an increase in the annual publication rate of MCDM/A models on the topic can be observed, reflecting its growing relevance in the field. This prominence is also reflected in the increased annual citation rate of articles on the subject.

The five research questions addressed were answered based on the main aspects of MCDM/A methods applied to public security management. Besides the evolution of models in terms of the numbers of articles and citations, the most considered issues were presented, identifying the ranking issue as a highlight, as well as aspects such as the number and group of criteria considered in decisions and methods used. However, an inherent difficulty in the systematic review process was the search, screening, and analysis process, due to the heterogeneity of the issues addressed in the context of public security management. This demands careful attention in the rigorous selection of articles.

Regarding the limitations of this study, it is noteworthy that the analysis predominantly focused on studies published in English, which may have neglected important contributions from research published in other languages. Additionally, conference papers, book chapters, notes, and other materials not published as journal articles were omitted, which may have resulted in an incomplete view of the findings presented. The study was also restricted to the Web of Science database. Therefore, it is suggested that future research include other databases to broaden the scope and accuracy of the research questions addressed.

The suggestions for research directions presented at the end of this study offer a series of relevant contributions to improve the perspective of obtaining managerial decisions that can effectively contribute to the fight against crime. It is crucial that, when considering any of the proposed directions, the decision-maker's preference structures are considered, and a multidimensional view of the problem is adopted to ensure that the decisions made are appropriate and meet the specific requirements of different situations. It is also important to emphasize the need for group decision-making, highlighting the process of identifying all stakeholders involved in the decision-making process. Careful consideration of each stakeholder's perspectives and interests contributes to a comprehensive understanding and more informed decision-making in the public security arena. This participatory and inclusive approach promotes the cooperation, transparency, and legitimacy of decisions, resulting in more effective and sustainable management in this complex area.

The proposed suggestions offer a broad spectrum of research possibilities for MCDM/A models, ranging from the combination of different decision-making methods to the application of new multicriteria analysis techniques, considering aspects such as the uncertainty and imprecision of the data involved.

Additionally, the suggestions emphasize the importance of considering the specificities of the public security context, such as the complexity and dynamism of the environment, as well as the specific needs of different agents involved in the decision-making process. By following these suggestions, significant progress can be made in research on MCDM/A models applied to public security management, contributing to the improvement of decision-making practices, the reduction in crime, and the improvement of the quality of life of the population. In conjunction with other research and intervention ini-

tatives, these suggestions can have a significant impact on public security, promoting the more efficient management of policies and resources aimed at this important and sensitive area of society.

The study offers numerous opportunities for a broad audience, encompassing both researchers in mathematics and related fields as well as professionals working in public security. Among the opportunities, the study highlights directions for the development of new mathematical models that address specific needs, considering the uncertainty, data imprecision, and environmental complexity. The study demonstrates how mathematics can have a significant practical impact, promoting more effective decision-making and contributing to a safer society.

Finally, it is important to highlight that there are still several areas for future research that can expand the knowledge base established in this work. A promising direction involves investigating hybrid approaches that combine MCDM/A with artificial intelligence, machine learning, or data envelopment analysis, to emphasize the robustness and adaptability of decision support systems with this combination of techniques.

Moreover, future research could explore the application of models to address emerging challenges in public security. Areas such as counter-terrorism, cybersecurity, and the management of social disturbances could benefit from the structured approach offered by MCDM/A.

Additionally, investigations into the incorporation of real-time data within MCDM/A frameworks could provide valuable insights for law enforcement agencies. This would enable a more proactive approach to threats and improve resource allocation during critical situations. By pursuing these research directions, scholars can contribute to the continuous development and refinement of MCDM/A as a valuable mathematical tool for decision-making in public security. Ultimately, this will result in a safer society for everyone.

Author Contributions: Conceptualization, J.C. and M.S.; methodology, J.C.; validation, M.S.; investigation, J.C.; resources, J.C.; writing—original draft preparation, J.C.; writing—review and editing, J.C.; supervision, M.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES).

Data Availability Statement: The original contributions presented in the study are included in the article, and further inquiries can be directed to the corresponding author/s.

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

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