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Multi-criteria decision-making methods: A promising tool for crime and criminal justice system analysis

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Abstract

Criminality is considered a social hazard that threatens sustainable development, and hence an effective linkage between Sustainable Development Goals (SDGs) and the Crime and Criminal Justice System (CCJS) is essential. Decision-making problems in real-life situations associated with CCJS are highly complex and unorganized to be addressed by examining a single criterion for evolving an optimum informed decision. The subject matter of analyzing progress in SDGs using an indicator-based approach and conducting a sustainability assessment by deploying Multi-Criteria Decision-Making (MCDM) methods have evinced the keen interest from decision-makers over a period of time. Despite the fact that concerted efforts were taken in the development and application of MCDM methods in various fields of science, engineering, management, social sciences, only limited attempts have been made to methodically depict the theoretical foundations and progress of MCDM methods and their applications in the field of CCJS analysis. This paper attempt to bridge this gap by performing a systematic critical literature review of MCDM methods, their applicability in the field of CCJS analysis, including its potential coupled with CCJS indicator-based metrics, decision support system, and other scientific approaches as a promising tool for the CCJS analysis for achieving SDGs.

Keywords: MCDM, Crime and Criminal justice system, UN SDGs, Sustainability and Crime indicators, DSS.

1. Introduction and Study Background

Crime in a matured society is often viewed as a social menace that potentially causes a detrimental impact on the economic development of a nation and the social environment and is a major threat to inclusive and sustainable development and is set to have a negative impact on the larger objectives of achieving seventeen United Nations Sustainable Development Goals (UN SDGs) (**Du Plessis, 1999**). A key democratic institution essentially encompasses a credible, accountable, effective, transparent, and fair justice system, and these form a critical component of a fair, just, equitable and inclusive society and are considered as a prerequisite for achieving seventeen UN SDGs. The approach of integrating the Crime and Criminal Justice System (CCJS) as a dimension of sustainability is a recent phenomenon, and it is imperative to create an effective linkage between UN SDGs and CCJS to address challenging problems of a criminal offense, inherent domain-related issues, and fear of crime spread in an urban, rural and industrial ecosystem. The complexity and multitude of factors in such an ecosystem challenge ability of law enforcement authorities and policymakers to construct robust models to help the Decision-Making Process (DMP) in CCJS analysis. Developing countries and economies in transition are particularly under stress on the increasing rate of crime, new forms of crime due to the emergence of new technologies coupled with poor socio-economic and environmental conditions **(Brunsdon & Corcoran, 2006; G. Oatley & Ewart, 2011)**.

Compounded with dynamic and probabilistic nature, CCJS analysis is often complex as there are many interacting parts, apart from having interfaces with other systems. Conceptualizing, designing, and implementing a robust model of CCJS analysis is a challenging task. DMP in real-life situations associated with CCJS is highly complex and unorganized to be addressed by examining a single criterion for evolving an optimum informed decision. Reliable, dependable, and accurate data may not be possible through manual processes, and such an approach does not favor the process of understanding trends, prediction, and DMP **(Loureiro, Mendonça, Moreira, & Sachsida, 2009).** Increasing crime rates, the emergence of new forms of crime, the complexity involved in the investigation warrant deployment of scientific tools and methods. The approach of clustering crimes through data mining technologies, Decision Support Systems (DSS) modeling, social network analysis, Geographical Information System (GIS), establishing a correlation among crime and offender profile, establishing criminal linkages and networks, finding a match between crimes, developing potential accused, and prediction of criminal occurrences are expected to play a significant role in complementing human inference in the CCJS analysis, and such complex situation creates one of the most challenging DMP **(G. C. Oatley & Ewart, 2003; G. Oatley & Ewart, 2011)**.

A defined set of multiple objectives, which are often conflicting in nature, is to be handled by a Decision-Maker (DM) in many real-world situations. Typically, an analyst in a Multi-Criteria (MC) method tends to develop numerous criteria by deploying multiple perspectives. Multi-Criteria Decision Analysis (MCDA) techniques, in recent years, are found to have exponential usage in solving complex real-world problems. A review of the literature reveals that several researchers have utilized Multi-Criteria Decision Making (MCDM) methods and applications for solving problems in the area of energy, infrastructure, sustainability, transport, management, and other fields of engineering, management **(B. Suresh, Erinjery Joseph James, & Jegathambal, 2016a).** Sustainability Assessment (SA) in a holistic manner, factoring different dimensions is a challenging and multi-faceted process. The subject matter of analyzing progress in seventeen UN SDGs using an indicator-based approach and conducting an SA by deploying MCDM methods have evinced the keen interest from DM over a period of time. SA concept needs to address different dimensions of sustainability, but conventionally it is viewed as an environmental or economic issue. Hence, in the SA process, apart from evolving holistic and comprehensive Economic, Environment, and Social Indicators (EESI) **(B. Suresh, 2017, 2018; B. Suresh, Erinjery Joseph James, & Jegathambal, 2016b)**; it is also essential to incorporate and integrate Crime and Criminal Justice System Indicators (CCJSI) in the analysis.

Despite the fact that concerted efforts were taken in the development and application of MCDM methods in various fields of science, engineering, management, social sciences, only limited attempts have been made to methodically depict the theoretical foundations and progress of MCDM methods and their applications in the field of CCJS analysis. Based on literature reviews on MCDM conducted made various researchers **(Arvind Jayant & Janpriy Sharma, 2018; B. Suresh et al., 2016a; Pereira Basilio, Pereira, & Gomes Costa, 2017; Zavadskas, Turskis, Kildienė, & Kildiene, 2014)**; it is evident that only a few articles and publications belonged to MCDM methods in relation to CCJS analysis and there were no many specific citations on applications of MCDM methods in the field of CCJS analysis that which this paper is intended to address.

B. Suresh et al. (2016a) performed a critical literature review of common MCDM methods, including their applicability for infrastructure planning and SA of infrastructure projects. Therefore, this prompted to conduct a systematic critical literature review of MCDM methods and present theoretical foundations and progress of MCDM methods in the context of CCJS analysis.

The main aim of the present article is to map significant research activities performed in the field of MCDM techniques, both traditional and emerging approaches, and to group them to identify perceived gaps in the literature and enhance opportunities for deployment in CCJS analysis. The ability of MCDA and MCDM methods to address the peculiarities of DMP in CCJS analysis is also discussed. Further, the paper highlights the potential of MCDM methods coupled with indicator-based metrics, DSS, and other scientific approaches as a promising tool in the CCJS analysis for achieving UN SDGs.

2. Theoretical Foundations of MCDA and MCDM Methods with a Focus on CCJS Applications

Theoretical foundations of MCDA and MCDM methods with a focus on CCJS applications are detailed in **Table. 1**.

Table. 1 Theoretical foundations of MCDA and MCDM methods with a focus on CCJS applications

S.No	Approach	Author	Description
1	Purpose	**(Pohekar & Ramachandran, 2004)**	Belonging to an operations research model, MCDM methods deal with DMP in an environment having a number of Decision Criteria (DC).
2	Purpose	(**Nepomuceno, Daraio, & Costa, 2020)**	MCDM methods can be viewed as a powerful tool for structured ranking of multiple alternatives factoring DC weighted with an evaluation conducted by one or many DM.
3	Purpose	**(Belton & Stewart, 2002)**	MCDM methods are a group of approaches facilitating explicitly for MC, thereby enabling ranking, selecting, analyzing, and/or comparing different alternatives. DMs can be individuals or groups, and applications can be technologies, products, projects, solutions, and policies.
4	Process	**(Cinelli, Coles, & Kirwan, 2014; Odu, 2019)**	In MCDM methods involving criteria weighting, it is pertinent to focus on objectivity factors of criteria weights and methodically determine these weights as they can have a significant level of influence on the final outcome and ranking alternatives.
5	Process	**(Nijkamp, Rietveld, & Voogd, 1990; Zeleny, 1984)**	MCDM DMP is nonlinear, iterative, and complex, and DMP characterized by multiple complex objectives can be dealt with and analyzed by MCDM methods because of its structured framework.
6	Process	**(Mardani et al., 2015)**	MCDM methods are structured to identify a preferred alternative, group, or classifying alternatives in a set of categories and/or in subjective preference order, performing ranking of alternatives.
7	Process	(**Pereira Basilio et al., 2017)**	Resources being finite in nature, a central part of MCDA lies in the judicious balancing between alternatives and competing interests in real-life situations in the process of resource allocation.

S.No	Approach	Author	Description
8	Process	**(Cinelli et al., 2014)**	Inherent features of MCDM methods include encouraging the engagement of participants in a DMP, providing precise better clarity on the intrinsic features of a DMP, enabling compromise and collective decisions, and providing a conducive platform for the understandable perception of models and analysts in a realistic scenario.
9	Process	**(Rogeberg et al., 2018)**	MCDA models are often evolved and best developed in well-structured and facilitated workshops with subject experts, creating a conducive open platform for exposing claims and judicial decisions to handle multiple views and providing an internal "peer-review" and a structured process for resolving variances in consideration.

Table. 1 (continued)

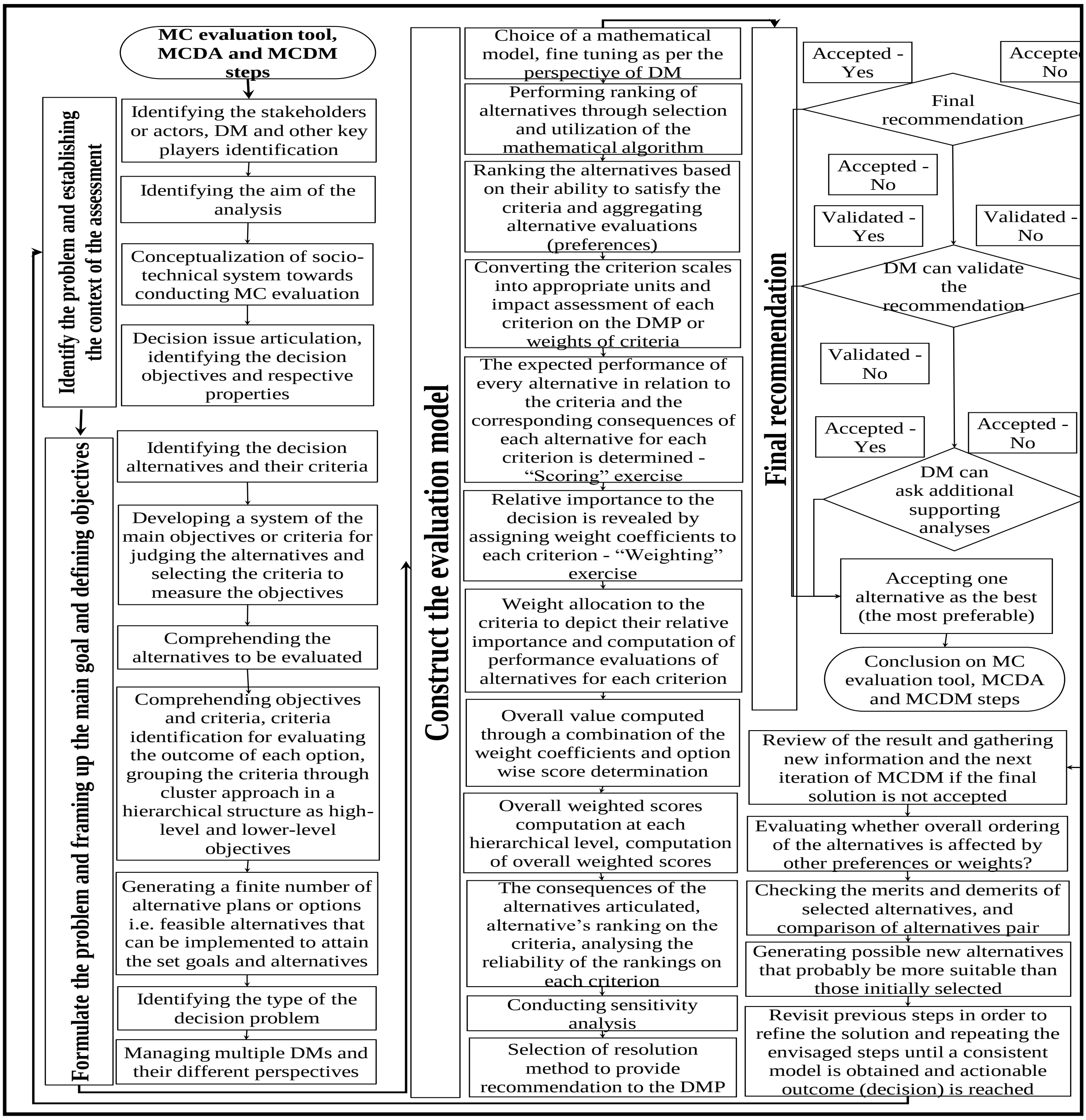
S.No	Approach	Author	Description
10	Process	**(B. Suresh, 2017, 2018; B. Suresh, Erinjery Joseph James, & Jegathambal, 2016b; B. Suresh et al., 2016a; Gasparatos & Scolobig, 2012)**	SA can be well performed using MCDM methods, through deployment of context-specific indicators, effective and appropriate set of tools, by considering different dimensions of sustainability spheres, perspectives, stakeholders, and EESI considerations.
11	Process	**(Zavadskas & Turskis, 2010; Zavadskas et al., 2014)**	DMP can be solved by descriptive analysis/behavior, decision research, or normative and prescriptive analysis.
12	Usage	**(Ananda & Herath, 2009)**	MCDM methods are suited to effectively deal with uncertainties, risks, and complex value issues, and long-term time horizons.
13	Usage	**(B. Suresh, 2017, 2018; B. Suresh et al., 2016a, 2016b; Cinelli et al., 2014)**	MCDM methods have the potential to perform SA of large, complex urban, rural, industrial ecosystems, factoring EESI.
14	Usage	**(Klapka & Piňos, 2002)**	Coupled with DSS, MCDM methods can facilitate multidisciplinary management of factors, requiring optimization for the achievement of the objective under consideration and evaluation.
15	CCJS application	**(Mu, Chung, & Reed, 2017)**	MCDA can be an effective tool not only to improve policies and procedures in police work but also in the holistic CCJS analysis.
16	CCJS application	**(Goala & Dutta, 2018; Goala, Limboo, Saikia, & Dutta, 2020)**	The application of MCDM methods is seen as a powerful tool in dealing with uncertainties in criminal investigation methodologies.
17	CCJS application	**(Hazwani, Shahizan, & Md Hafiz, 2012)**	The crime problem is associated with criteria for determining potential crime areas, and MCDM methods can effectively address this issue.
18	CCJS application	**(Goala & Dutta, 2018)**	MCDA is useful in Crime Linkage Analysis (CLA), enabling for what level a pair of crimes share a common offender or offenders.
19	CCJS application	**(Manning, Smith, & Homel, 2013)**	Viewed as an effective tool for evaluating many crime prevention policy options, MCDM methods have cascading effects across multiple domains and arriving at a preferred option factoring, past research's objective evidence, which can be meaningfully combined with stakeholder judgments.
20	CCJS application	**(Advisory Council on the Misuse of Drugs, 2010)**	Despite the fact that the MCDA model remains largely subjective and rather than providing definitive answers, it offers a credible

S.No	Approach	Author	Description
			framework on the harms associated with substances and assists the DMP in developing advice to ministers on the harms of drugs.
21	CCJS application	**(Pereira Basilio et al., 2017)**	MCDM method is still little explored in the field of public security and police procedural and administrative functions.

3. Main Categories of MCDM Methods

Despite the development of a wide range of basic and simple to complex MCDM methods, it is imperative to recognize that all the MCDM methods adopt the same DMP as detailed in **Figure. 1** developed by various scholars.

Figure. 1 The generalized flowchart and basic stages of MCDA and MCDM evaluation tools **(Hajkowicz et al., 2000; Papadopoulos & Konidari, 2011; Zavadskas & Turskis, 2010; Zavadskas et al., 2014).**



Several categories of MCDM methods are found in the literature, based on the type and nature of input data **(Triantaphyllou, Shu, Sanchez, & Ray, 1998)**, the nature of the alternatives to be assessed **(Janssen, 1992)**, the initial assumptions, availability of data perspective **(Sabaei, Erkoyuncu, & Roy, 2015)**, data processing **(Sabaei et al., 2015)**, the type of method deployed for the analysis, by a number of answers **(Korhonen, Moskowitz, & Wallenius, 1992; Sabaei et al., 2015**) and the output result **(Papadopoulos & Konidari, 2011)**. Also, several ways are possible to classify MCDM methods **(Figueira, Greco, & Ehrgott, 2005; Hwang & Yoon, 1981; Larichev O.I., 2000)**. Various authors have performed an in-depth review of MCDM methods **(Figueira et al., 2005; Greco, Matarazzo, & Slowinski, 2001; Mohammadshahi, 2013; Velasquez & Hester, 2013)**. There are different ways of selecting of appropriate MCDM method, and one such approach involves consideration of input requirements in terms of data and parameters of the methods, modeling effort and outcomes, and their granularity **(Guitouni & Martel, 1998)**. Another approach could be defining key parameters and using elicitation methods. The subject matter of taxonomy of MCDM methods, the necessity to compare MCDM methods, systematic methodology to select the relevant MCDM method for a context specific DMP are documented in the literature **(Guitouni & Martel, 1998; MacCrimmon, 1968)**.

Table. 2 discusses a generalized approach to the classification of MCDM methods. However, there is no unique and single well-defined MCDM method that can be deployed on a step-by-step basis from the start of a DMP to completion. Often MCDM methods are subjected to a particular criticism that different end results are witnessed for the same situation and for the same problem, primarily arising out of the differences among different techniques **(Zavadskas & Turskis, 2010)**.

Table. 2 Generalized approach on the classification of MCDM methods

S.No	Approach/author and classification
1	**Approach/Author**: **(Roy & Vincke, 1981; Vassilev, Genova, & Vassileva, 2005)**. **Classification**: • Various types of decision problems, namely choice, ranking, sorting, description, elimination, design problem, and elicitation problem.

2	**Approach/Author**: According to distinct approach and based on a computation of alternatives **(Agrawal, Kohli, & Gupta, 1991; Belton & Stewart, 2002; Bigaret, Hodgett, Meyer, Mironova, & Olteanu, 2017; Bouyssou, 1994; Hwang & Yoon, 1981; Korhonen et al., 1992; Larichev O.I., 2000; Velasquez & Hester, 2013; Zavadskas et al., 2014).**
	Classification:
	• The main methods are Multiple Attribute Decision Making (MADM) and Multiple Objective Decision Making (MODM).
	• Category I: MADM:
	  o Intertwined with rational choice theory on the premise that people act rationally within specifically given constraints, and individuals, while selecting best for them, must foresee the results of alternative courses of action.
	  o Suitability of MADM:
	    ▪ Evaluation facet;
	    ▪ A pre-defined set of alternatives;
	    ▪ A limited number of free determined alternatives;
	    ▪ Several conflicting criteria; and
	    ▪ Discrete preference information.
	  o School of thought:

	▪ Value-based theories: DM’s preferences for a given set of alternatives are depicted in a numerical manner in the form of a utility function; every alternative will have a global score, complete ranking, and full aggregation approach. • Multiple Attribute Utility Theory (MAUT) ▪ Outranking school of thoughts: Compare the preference relations among alternatives, pairwise comparisons of alternatives lead to preference or outranking degree, a pairwise comparison may lead to partial ranking.

Table. 2 (continued)

S.No	Approach/author and classification
	▪ ELimination Et Choix Traduisant la REalité (ELimination Et Choice Translating REality (ELECTRE), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and VlseKriterijuskaOptimizacija I KomoromisnoResenje (VIKOR). o Difference between the subcategories of MADM methods and choice: ▪ The way of comparing the alternatives; ▪ The type of information required from DM; ▪ The outranking methods are preferred if the evaluation is qualitative or if the DM is imprecise about their preferences in the model; and ▪ If compensatory behavior of the DM and trade-offs need to be modeled, then value-based methods are more suitable. • Category II: MODM: o Essentially addresses the design process; ▪ To design or arrive at the best/optimal alternative; ▪ Considering a group of well-defined design constraints; ▪ Quantifiable set of objectives; and ▪ Alternatives are non-predetermined and infinite in nature (continuous). o Suitability of MODM: ▪ Design or planning facet; ▪ Aimed at getting optimal solution; ▪ For problems wherein a set of alternatives are not pre-defined; ▪ Simultaneous achievement of a set of conflicting objectives; and ▪ A set of well-defined constraints. o Deployment of methods of mathematical programming: ▪ To address optimization problems; ▪ Trade-off problem: • Transformed into a weighed single objective: o Trade-off information; and o Or use of Pareto solution. ▪ Scale problem: • Issue of dimensionality and increased computational cost; o Managed using algorithms, i.e., genetic algorithm, genetic programming, and evolution strategies. o Common MODM methods: ▪ Goal Programming (GP), compromise solution, Data Envelopment Analysis (DEA), De novo programming, TOPSIS for MODM, and Multiple Criteria Multiple Constraints levels (MC^2).
3	**Approach/Author**: Three families of approaches **(Bouyssou, 1994; Vincke, 1992)**. **Classification**: • Group I: American school or school of MAUT; • Group II: French school or European school or methods of outranking and synthesis; and • Group III: Interactive methods or multi-objective mathematical programming models.

4	**Approach/Author**: **(Belton & Stewart, 2002; Ishizaka & Nemery, 2013)**. **Classification**: • Group I: Optimization or value measurement methods or full aggregation methods: ▪ To reflect importance, weight is assigned to each criterion; ▪ Calculation of numerical score for each alternative; and ▪ The highest score prevails. o Analytic Hierarchy Process (AHP).

Table. 2 (continued)

S.No	Approach/author and classification
	• Group II: Outranking methods: Ranking of the alternatives by comparing each pair of alternatives for each criterion: o ELECTRE, Preference Ranking Organization METHod for Enrichment of Evaluations (PROMETHEE). • Group III: Goal, or objective or aspiration or reference level methods: Identification of how far each alternative is from the ideal goal or aspiration: o TOPSIS.
5	**Approach/Author**: Based on determining criteria for weights **(Odu, 2019)**. **Classification**: • Subjective methods: Most respect given to subjective preferences of DM in criteria relevance evaluation: o AHP, including its improved forms, aggregation with some other MCDM methods, namely fuzzy logic, Best Worst Method (BWM), conjoint analysis, Delphi method **(Odu, 2019; Saaty, 1987).** • Objective methods: Assigning weight coefficient in mathematical model based on analysis of given data, discarding attitude of DM or experts: o Entropy, Criteria Importance Through Inter-criteria Correlation (CRITIC), DEA, correlation analysis, regression analysis, factor analysis, etc. **(Odu, 2019).**
6	**Approach/Author**: **(Vassilev et al., 2005; Vincke, 1992)**. **Classification**: • Group I: On the assumption that there does not exist limited comparability among the alternatives: o MAUT, value trade-off method, UTilites Additives (UTA) method, Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH) method, AHP weighting methods **(Keeney, Raiffa, & Rajala, 1979; Saaty, 1987)**. • Group II: Outranking methods on the assumption that there exists limited comparability among alternatives: o ELECTRE, PROMETHEE methods, Treatment of the Alternatives according to The Importance of Criteria (TACTIC) methods **(Brans, Mareschal, & Vincke, 1984; Roy, 1991; Vansnick, 1986).** • Group III: Motivated through optimization and are oriented to solve problems: ▪ A large number of alternatives; and ▪ A small number of criteria: o Visual Interactive Method for Discrete Alternatives (VIMDA) method, Aspiration-level Interactive (AIM) Method, InterQuad method, Light Beam Search (LBS) method, Reference Neighborhood Interactive Method (RNIM) **(Jaszkiewicz & Słowiński, 1997; Korhonen et al., 1992; Lotfi, Stewart, & Zionts, 1992; Narula, Vassilev, Genova, & Vassileva, 2004; Sun & Steuer, 1996).**
7	**Approach/Author**: Based on the nature of alternatives to be evaluated **(Janssen, 1992)**. **Classification**: • Continuous and discrete methods **(Hajkowicz et al., 2000)**.
8	**Approach/Author**: Continuous methods. **Classification**: • The aim is to determine an optimal quantity, and in a DMP, this can vary infinitely:

	o Aspiration-based models, GP, and linear programming **(Ananda & Herath, 2009)**.

Table. 2 (continued)

S.No	Approach/author and classification
9	**Approach/Author**: Discrete method. **Classification**: • The primary task is to perform a rational selection among a limited number of alternatives and to assess and rank a limited number of alternatives; • Alternatives are judged and ranked in a system having a finite number of alternatives, a set of objectives and criteria, based on how good they fulfill the objectives and criteria **(Hajkowicz et al., 2000)**; • Two categorizations are available, namely weighting and ranking methods (Nijkamp et al., 1990). Further, they can be sub-categorized into qualitative, quantitative, and mixed methods. Qualitative methods use only ordinal performance measures, whereas, in mixed qualitative and quantitative methods, different decision rules are applied based on the type of data available. In quantitative methods, all data are expressed in cardinal or ratio measurements **(Hajkowicz et al., 2000)**; and • Described by a set of criteria, with criteria values determined as cardinal or ordinal information exactly or fuzzy, determined at intervals, discrete alternatives are dealt with in MCDM methods.
10	**Approach/Author**: **(Basilio, Pereira, & Costa, 2019; Pereira Basilio et al., 2017; Roy, 1991)**. **Classification**: • Category I: Single synthesis criterion - Focused on consolidating performance attained by each alternative into a single criterion for facilitating a decision: o MAUT; o SMART; o MACBETH; and o AHP. • Category II: Methods of over-classification - Considering DM decision-making preferences in comparing two alternatives: o ELECTRE: and o PROMETHEE. • Category III: Interactive methods - Employ computational tools to accomplish calculations succeeded by interactions with DM to limit viable alternatives before proceeding with the next step: o VIMDA method **(Korhonen et al., 1992),** AIM method **(Lotfi et al., 1992)**, InterQuad method **(Sun & Steuer, 1996),** LBS method **(Jaszkiewicz & Słowiński, 1997),** RNIM method **(Narula et al., 2004)**.
11	**Approach/Author**: Type of information **(Larichev O.I., 2000; Zavadskas & Turskis, 2010)**. **Classification**: • Category I: Based on quantitative measurements like Multi-Criteria Utility Theory (MCUT): o TOPSIS **(Hwang & Yoon, 1981)**; o Simple Additive Weighting (SAW) **(MacCrimmon, 1968)**; o Linear Programming Techniques for Multi-dimensional Analysis of Preference (LINMAP) **(Srinivasan & Shocker, 1973)**; o Multi-Objective Optimization by Ratio Analysis Method (MOORA) **(Brauers & Zavadskas, 2006)**; o Complex Proportional Assessment (COPRAS) **(Zavadskas & Turskis, 2010; Zavadskas et al., 2014)**, Complex Proportional ASsessment method with Grey interval numbers (COPRAS-G) **(Zavadskas et al., 2014)**. • Category II: Based on qualitative initial measurements: o AHP **(Saaty, 1987)**; and o Fuzzy set theory methods **(Zimmermann, 2000)**.

Table. 2 (continued)

S.No	Approach/author and classification
	• Category III: Comparative preference methods modeled on pairwise comparison of alternatives: o Modifications of ELECTRE **(Roy, 1990)**; o PROMETHEE **(Brans et al., 1984)**; o TACTIC **(Vansnick, 1986)**, o Organization, Rangement Et Synthese De Donnes Relationnelles (ORESTE) **(Roubens, 1982)**. • Category IV: Methods based on qualitative measurements; ▪ Not converted to quantitative variables. o Methods of verbal decision-making analysis **(Berkeley, Humphreys, Larichev, & Moshkovich, 1991; Larichev O.I., 2000)** and in DMP situations involving high levels of uncertainty, the qualitative data are deployed.
12	**Approach/Author**: Type of data usage **(Greening & Bernow, 2004)**. **Classification**: • Classified as deterministic, stochastic, and fuzzy, including combinations of them factoring in some of their important features.
13	**Approach/Author**: **(Hajkowicz et al., 2000)**. **Classification**: • Group I: MC value functions or MAUT: o MAUT demands scoring function or specified weight and utility for every DC by one DM **(Keeney et al., 1979)**. • Group II: Outranking approaches to analyze whether if a particular alternative outperforms another alternative: o PROMETHEE **(Brans et al., 1984)** and ELECTRE **(Roy, 1991)**. • Group III: Distance to ideal point methods: o Compromise Programming (CP) **(Zeleny, 1984)** and TOPSIS **(Hwang & Yoon, 1981)**. • Group IV: Pairwise comparisons. o A popular method is AHP **(Saaty, 1987)**. • Group V: Fuzzy set analysis: o When a source of uncertainty arises out of an absence of sharply defined criteria rather than the presence of randomness, fuzzy set methods are deployed **(Zimmermann, 2000)**. • Group VI: Tailor methods: o A tailored method conventionally extends or adapts a fundamental methodology to a particular situation or application.
14	**Approach/Author**: Modelled on a number of answers **(Korhonen et al., 1992)**. **Classification**: • Group I: Innumerable when admissible answers are infinite; and • Group II: Numerable when admissible answers are finite.
15	**Approach/Author**: Type of decision model **(Carlsson & Fuller, 1996; Polatidis, Haralambopoulos, Munda, & Vreeker, 2006)** **Classification**: • Major family I: Outranking approach: o ELECTRE family **(Roy, 1990, 1991)**, PROMETHEE I and II methods **(Brans et al., 1984)**, and REGIME Method Analysis **(Nijkamp et al., 1990)**; • Major family II: Value or utility function-based approach or theory: o MAUT (Keeney et al., 1979); Simple Multi-Attribute Rate Technique (SMART) **(D. von Winterfeldt, W. Edwards D. Von Winterfeldt, 1986)**; AHP is a special method in this family (Saaty, 1987); and most elementary MC, SAW or Weighted Sum Method (WSM). • Major family III: Interactive - programming methods **(Bouyssou, 1994; Vincke, 1992)**: o The largest group is interactive Multiple Objective Linear Programming (MOLP); and

Table. 2 (continued)

S.No	Approach/author and classification
	• Major family IV: New approach based on group decision and negotiation theory: o Other methods such as Novel Approach to Imprecise Assessment and Decision Environment (NAIADE) **(Munda, 1995),** Flag Model **(Nijkamp et al., 1990)**, Stochastic Multi objective Acceptability Analysis (SMAA) **(Lahdelma, Hokkanen, & Salminen, 1998)**.
16	**Approach/Author**: **(Zopounidis & Doumpos, 2002)**. **Classification**: • Group I: Multi-objective / GP; • Group II: MAUT methods (AHP, MAUT, MACBETH, etc.); • Group III: Outranking methods (ELECTRE, PROMETHEE, ORESTE, etc.); • Group IV: Preference disaggregation methods UTA, UTilités Additives DIScriminantes (UTADIS), Multi-group Hierarchical Discrimination Method (MHDIS); and • Group V: Rough set theory methods.
17	**Approach/Author**: **(Greco et al., 2001).** **Classification**: • Utility function: Encompasses methods integrating information in a singular distinct parameter (also termed as performance aggregation based approach model) **(Keeney et al., 1979)**; • Outranking relation: Encompasses methods on the basis of comparison between pairs of options for ascertaining whether "alternative a can be considered at least as good as alternative b" (also termed as preference aggregation based approach model) **(Roy, 1991)**; and • Sets of decision rules: Emerges from a domain of artificial intelligence, and it permits acquiring a preference model through deploying classification or comparison of decision examples **(Greco et al., 2001)**.
18	**Approach/Author**: **(Guitouni & Martel, 1998)**. **Classification**: • Elementary methods: WSM, Lexicographic method, Conjunctive method, Disjunctive method, Maximin method; • Single synthesizing criterion methods: TOPSIS, Multi-Attribute Value Theory (MAVT), UTA, SMART, MAUT, AHP, EVAluation of MIXed Data (EVAMIX), Fuzzy weighted sum, Fuzzy Maximin; • Outranking methods: ELECTRE, PROMETHEE, Méthode d'ELimination et de CHoix Incluant les relation d'Ordre (MELCHIOR); ORESTE; REGIME; and • Mixed methods: QUALitative FLEXible (QUALIFLEX), Fuzzy conjunctive/disjunctive method.
19	**Approach/Author**: By type of problem **(Roy, 1990)**. **Classification**: • Problem formulation resulting in the best alternative; • Grouping well-defined alternatives and classes; • Addressing a problem resulting in a full classification of alternatives in order of preference; and • Describing how each alternative meets all criteria simultaneously.

4. The Ability of MCDA and MCDM Methods to Address the Peculiarities of the DMP in the CCJS Application

The subject of MC analysis has evinced the interest of researchers in the field of crime prevention, road safety, interpersonal violence, military safety, territorial insertion of victims, maritime safety, drug misuse, and drug harms, etc. **Table. 3** provides an overview of the ability of popularly deployed MCDA and MCDM methods to address the peculiarities of the DMP in the field of CCJS application. However, the literature on coverage of MCDM methods on CCJS application is limited, and that too without a predominance of a specific MCDM method. The perceived merit of the MCDM methods is their potential and versatility to address the CCJS analysis that is characterized by different and highly conflicting interests. Increasing complex problems of CCJS warrant holistic and comprehensive solutions, and the MCDM methods are often viewed as an effective and appropriate set of methods towards CCJS analysis. MCDM methods can play an important and pivotal role in enhancing performance and outcome in many key areas of the CCJS analysis.

Table. 3 Peculiarities and ability of MCDM methods to address challenges concerning CCJS and potential applications in CCJS

MAUT

○ **Peculiarities and ability of MCDM method:**
  ○ Ability to capture DM's perceptions of preferences in combined behavioral, situational, and forensic information in the context of Serious and High-Volume (SHV) crime analysis **(Albertetti, Cotofrei, Grossrieder, Ribaux, & Stoffel, 2013a, 2013b).**
○ **Application in the field of CCJS:**
  • CLA in SHV crimes **(Albertetti et al., 2013b).**

AHP

○ **Peculiarities and ability of MCDM method**:
  • Conventionally eyewitness identification activity is approached as a memory recapturing and recognition activity, and AHP, on the other hand, can empower it as a prioritization approach enabled through multiple pairwise comparisons and tabulates potential suspects, in pairs and not in sequence, by depicting evaluation of each potential suspect in the eyewitness process, in the context of perceived relative possibility whereby also providing a scope to re-examine assessment **(Mu et al., 2017);**
  • Several factors and constraints like demography, socio-economic, land and building use pattern, and transportation system need to be considered in the potential area crime identification process while identifying a location. AHP method can be effectively utilized to choose a particular location; method can identify these evaluation criteria, define intertwined effects on each other and evaluate their importance **(Buonanno & Montolio, 2008; Entorf & Spengler, 2000; Hazwani et al., 2012)**; and
  • Deployment of the AHP is mooted to determine the weights of criteria for assessing each crime factor.
○ **Application in the field of CCJS:**
  • Integration of the AHP method and GIS is a new trend in crime suitability analysis to identify potential crime **(Hazwani et al., 2012)**; and
  • Identifying potential crime tactical path-finding in situational crime prevention **(Bin Wan, Mohamad Nor, & Abdul Jalil, 2015).**

Fuzzy theory

○ **Peculiarities and ability of MCDM:**
  • A large number of similar criminal cases coupled with a lack of evidence pose challenges in the investigation of serial crimes. Resemblance measure expressing similarity between two intuitionistic fuzzy sets through fuzzy MCDM facilitates CLA **(Goala & Dutta, 2018)**;
  • Fuzzy mathematics facilitates analysis in crime prevention, prediction in serial crime, and linkage **(Goala & Dutta, 2016)**;
  • SHV crime analysis requires combined analysis of behavioral, situational, and forensic information, and fuzzy MCDM method facilitates to model experts' experience and handles vagueness besides evaluation and combining similarities **(Albertetti et al., 2013b)**; and
  • Pattern recognition is perceived as a fundamental challenge in crime mapping and analysis, and the fuzzy clustering approach can detect crime hot-spots or geographic areas of elevated criminal activity **(Grubesic, 2006).**
○ **Application in the field of CCJS:**
  • Fingerprint identification deploying a fuzzy neural network to detect similarity between two fingerprints and decide whether they belong to the same person **(Quek, Tan, & Sagar, 2001)**;

- Computerized CLA method for SHV crimes to combine situational, behavioral, and forensic information **(Albertetti et al., 2013b, 2013a).**
- Analysis of physical properties of bloodstain and properties of wounds for the reconstruction of the crime scene in gunshot analysis **(Goala & Dutta, 2016);**

Table. 3 (continued)

Fuzzy theory

- **Application in the field of CCJS:**
    - An intelligent system to detect and prevent crime by criminal profiling using fuzzy clustering technique **(Adeyiga & Bello, 2016);**
    - Utilized fuzzy MCDM to perform CLA by linking crimes pairwise from a collection of crimes **(Goala & Dutta, 2018)**;
    - Detection of crime hot-spot area in a city using fuzzy clustering **(Grubesic, 2006);** and
    - Determination of crime pattern and police duty positioning using fuzzy time series analysis **(Li, Kuo, & Tsai, 2010).**

ELECTRE

- **Peculiarities and ability of MCDM:**
    - Performance of integrated public safety areas in police requires an order evaluated based on strategic indicators of crime, requiring the ELECTRE MCDM **(Basilio et al., 2019)**.
- **Application in the field of CCJS:**
    - Compensatory effects of classification criteria in integrated public safety areas fulfilling set goals for the crime indicator **(Basilio et al., 2019)**.

PROMETHEE

- **Peculiarities and ability of MCDM:**
    - The stochastic nature of criminal behavior poses a problem in the non-parametric evaluation of police technical and scale efficiency. Combining a conditional non-parametric approach while considering a crime as an external factor and non-compensatory ranking based on PROMETHEE analysis can facilitate multi-dimensional efficiency and effectiveness comparison **(Nepomuceno et al., 2020)**.
- **Application in the field of CCJS:**
    - A geostatistical approach to study and analyze the distribution of criminal activities in urban parks with respect to their proximity to city centers **(Nazmfar, Alavi, Feizizadeh, & Mostafavi, 2020)**; and
    - Performed multi-dimensional efficiency and effectiveness comparison of Brazil's police departments **(Nepomuceno et al., 2020**).

SAW or WSM

- **Peculiarities and ability of MCDM:**
    - Deployed in problem structuring, analysis, and DSS for overall assessments and balancing of interests in the context of the law **(Lindell, 2017a, 2017b)**.
- **Application in the field of CCJS:**
    - Analysis of the harms of a range of drugs from the UK context **(Nutt, King, & Phillips, 2010)**.

ARAS

- **Peculiarities and ability of MCDM:**
    - Assessing Key Performances Indicators (KPIs) of police performance is complex in nature due to a host of factors and varies significantly according to hierarchy. ARAS MCDM method facilitates computation of KPIs evolved through choosing a set of evaluation criteria **(Paul, Agarwal, & Chakraborty, 2016)**.
- **Application in the field of CCJS:**
    - Keeping minimized criminal activities as KPI, analyzed and ranked Indian states **(Paul et al., 2016)**.

TOPSIS

- **Peculiarities and ability of MCDM:**
    - Detecting human cadavers of clandestine graves is complex, and the TOPSIS DSS algorithm based on weightage for criteria is an effective tool in analyzing probability for a crime site and risk for lipid Biomolecular analysis of soil **(Mohamad Noor, Ahmad Nubli, Mohemad, & Bakar, 2018)**.
- **Application in the field of CCJS:**

• Performance of traffic police centers was assessed by deploying order preference by similarity to an ideal solution based on preference ratio and efficient fuzzy distance measurement **(Sadi-Nezhad & Damghani, 2010)**;

Table. 3 (continued)

TOPSIS
○ **Application in the field of CCJS:** • Evolved structured, improved entropy TOPSIS methodology to conduct road safety risk assessment utilizing composite road safety risk index **(Chen, Wang, & Deng, 2015)**; and • Forensic investigation studies through the TOPSIS method facilitate detecting human cadavers of clandestine graves **(Mohamad Noor et al., 2018)**.
VIKOR
○ **Peculiarities and ability of MCDM:** ○ Linguistic variables can be applied to solve uncertainties and subjectivities in an expert DMP **(Talib, 2020).** ○ **Application in the field of CCJS:** ○ Proposal to reform criminal code, Ecuador, with greater proportionality of the penalty, harm committed based on a neutrosophic approach **(Paronyan, Carballido, & Matos, 2020)**.
SMART MCDM
○ **Peculiarities and ability of MCDM:** • In the context of public safety, it can analyze from the perspective of the strategic issue, city prioritizing areas, degree of occurrences of criminality to increase, and police occurrences **(Gurgel & Mota, 2013)**. ○ **Application in the field of CCJS:** • Prioritized areas based on spatial criminology using social and demographic criteria **(Gurgel & Mota, 2013)**.

5. Hybrid Models and Latest MCDM Trends

Structural models like DEcision MAking Trial and Evaluation Laboratory (DEMATEL), Interpretive Structural Modelling (ISM) addresses interrelation, including the type of relationship between the criteria. Often, DM and analyst combine one of the structural methods with one of the MCDM methods when the criteria are not independent, and cause-effect or causal relationship or other kinds of association between criteria needs to be modeled. The modular and hybrid MCDM methods development is often viewed as a significant initiative and are evolved on well-known previously developed methods, such as SAW, TOPSIS, AHP, Analytic Network Process (ANP), DEMATEL, DEA, VIKOR, PROMETHEE, ELECTRE, including their modification, by utilizing the theoretical principles of fuzzy and grey number. Seamless integration of MCDM methods with effective systems such as GIS, intelligence, and expert systems, etc., is triggered by the development of advanced DSS models to support DMP with high capabilities. Further, newly conceptualized MCDM methods, like Generalized Regression with Intensities of Preference (GRIP) **(Manish Gupta B. Chandra M.P. Gupta, 2014)**, Weighted Aggregated Sum Product ASsessment (WASPAS) **(Thakkar, 2021)**, ARAS, COPRAS, MOORA, Step-wise Weight Assessment Ratio Analysis (SWARA), and Multiple-Objective Optimization on the basis of Ratio Analysis plus full MULTIplicative form (MULTIMOORA) are viewed as a powerful tool. **Table. 4** discusses the typical application of hybrid models and the latest MCDM trends in CCJS analysis. CCJS analysis may also incorporate a range of statistical methods **(Sundaram.B, Sundaram, Priya, & Gayathri, 2020)**. There is also a need to evolve hybrid models to address the major challenges in CCJS analysis, and one such model could be Intelligent Decision Support Systems (IDSS) to integrate data mining, MCDM methods with a scope for the knowledge-based systems to interact in a dynamic manner **(Bhargava, Power, & Sun, 2007; Cheung, Leung, & Tam, 2005; Manish Gupta B. Chandra M.P. Gupta, 2014).** These hybrid models effectively address the multipurpose of establishing an automatic DMP or problem-resolution process, thereby replacing intensive human activities and assist the DM in a complex DMP **(Manish Gupta B. Chandra M.P. Gupta, 2014; Shim et al., 2002).**

Table. 4 A Typical Application of Hybrid Models and the Latest MCDM Trends in CCJS Analysis

S.No	Application area	Author	Description and case studies
1	Identification of potential crime area	**(Su, Qian, & Jianjun, 2008; Wang, Wu, & Yu, 2011)**	• Several contextual factors and conflicting situations like socio-economic conditions, demographic profile, land and building use pattern, societal issue, the imbalanced distribution of resources, transportation network, etc., can lead to a crime; and • The challenge to be addressed in this context is the identification of potential crime areas, which requires a well-structured DMP for weighing the criteria, evaluating the alternatives, and ranking.
2	Identification of potential crime	**(Hazwani et al., 2012)**	• A new trend in crime suitability analysis for identification of the potential crime by integration of the AHP method and GIS.
3	Crime prevention and crime analysis	**(A L & Rose, 2016; Hazwani et al., 2012; Ihsan, Sugandi, Affriani, & Himayah, 2019)**	• Mapping analysis and geographical databases, i.e., GIS, can be an important tool to help the police in the field of crime analysis and crime prevention, and a vulnerability analysis performed through a combination of GIS analysis and MCDA could analyze and predict the potential of crime act.
4	Spatial aspects	**(Rogerson & Sun, 2001)**	• A hybrid approach of integrating AHP and GIS is essential, while GIS can be utilized to address the spatial aspect of the problem, whereas the criteria weightages and alternatives ranking can be done through the AHP method.
5	Youth violence	**(Dev & Singh, 2017)**	• MC Futuristic Fuzzy Decision Hierarchy approach, a combination of Fuzzy Logic and AHP, enables investigation and prioritization of the risk factors that trigger youth violence.
6	Violence analysis	**(Gurgel & Mota, 2013)**	• A combination of modified SMART MCDM method, namely SMARTS and a Monte Carlo Simulation, thus enabling zone ranking on the basis of demographic and socioeconomic aspects that are likely to have an impact on violence.

Measuring the performance in terms of EESI and CCJSI facilitates SA of urban, rural, and industrial communities' ecosystem and being a challenging and complex process, SA warrants a comprehensive evaluation of the varied settings and situations under which these ecosystems perform and operate **(B. Suresh, 2018)**. The highly demanding and complex problems of CCJS necessitate a holistic approach and solutions, and MCDM methods coupled with the DSS model are viewed as an effective and appropriate assessment tool for SA factoring EESI and CCJSI and analyzing progress on seventeen UN SDGs.

6. Conclusion

One of the challenging tasks to be addressed in contemporary society is to combat the increasing crime rate. The problem is further compounded with the changing contours of the nature of the crime. The perceived merit of the MCDM methods is their potential and versatility to address the CCJS analysis that is characterized by different and highly conflicting interests. Increasing complex problems of CCJS warrant holistic and comprehensive solutions, and the MCDM methods are often viewed as an effective and appropriate set of methods towards CCJS analysis and SA utilizing EESI and CCJSI, primarily due to the flexibility and the scope for facilitating the dialogue and interaction between various actors. The development of hybrid and modular MCDM methods in the context of CCJS analysis is considered a significant initiative. MCDM methods can play an important and pivotal role in enhancing performance and outcome in criminal investigation, detection of criminals, the functioning of police organization, and other key areas of the CCJS analysis. The paper reveals that the deployment of MCDM in CCJS analysis is still little explored and conducting research in the comprehensive development of CCJSI for SDGs and application of MCDM methods for SA utilizing CCJSI is essential. The application of MCDM methods reveals its scope of large-scale implementation as a promising tool in complex CCJS analysis.

The contribution of this paper can be viewed from different perspectives. The theoretical background of MCDM is expected to provide a sound rationale for a selection of appropriate MCDM methods. A well-structured MCDM method could result in a reduction of government expenditure on the CCJS analysis, besides substantial reduction across CCJSI in quantitative terms and imbibing a positive change in the attitude of DM, thereby achieving progress towards UN SDGs. The intrinsic value of the present work is its ability to create awareness of the MCDM method that provides the DM of the CCJS analysis and other stakeholders an alternative approach and mechanism to enhance the scientific advancement of CCJS analysis. The paper also stimulates the deployment of hybrid options to include CCJSI and DSS models in monitoring the progress of UN SDGs for a holistic approach to SA. With the potential to benefit all stakeholders, the traditional approach to CCJS analysis, along with the application of appropriate MCDM methods and new interdisciplinary research, can lay a strong foundation for robust models. The paper is expected to benefit society by well conceptualized and configured CCJS analysis, thereby building a safe and sustainable urban, rural, and industrial ecosystem.

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