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Review Article

REVIEW OF ALTERNATIVE RANKING METHODS IN MULTI-CRITERIA DECISION ANALYSIS BASED ON WASPAS AND COCOSO METHODOLOGIES

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Abstract: Along with crisp data, one of the most popular methods in decision-making under uncertainty is the multi-criteria decision-making (MCDM) method. Over time, the MCDM process has incorporated numerous decision-making methods. Among these methods, Weighted Aggregated Sum Product Assessment (WASPAS) and Combined Compromise Solution (CoCoSo) are lauded for their effectiveness in handling complex, uncertain decision situations. Using these methods, numerous researchers have discussed in their research papers how to solve various problems observed in different areas of real life. Based on multiple previous research findings, this review paper provides a thorough description of the above MCDM methods. It explains in detail their theoretical basis, mathematical framework, computational methods, pseudocode, their use in various real-world problems, etc. in uncertain environments. A comparative discussion between the two methods is given which focuses on the similarities, contrasts, strengths, and weaknesses between them. Further, two real-world applications of these two methods were added and results were discussed in a comparative manner. Additionally, this review discusses the applicability of these methods in real-world decision-making contexts and identifies avenues for future research in this dynamic field.

Keywords: Multi-criteria decision making (MCDM); WASPAS; CoCoSo; Uncertain environment.

MSC: 90B50, 90C29, 03E72.

1. INTRODUCTION

Every decision is part of the decision-making process, which is a complex mental activity aimed at solving problems and finding the best results by taking into account many different factors. This process can be logical or illogical and may rely on hidden or obvious assumptions influenced by factors like physiology, biology, culture, and society. Additionally, the level of authority and risk involved can add to the complexity of decision-making. Today, we can tackle complicated decision-making problems using mathematical formulas, statistical methods, economic theories, and computer technology to automatically calculate and predict solutions.

In today's complex and uncertain environments, Multi-criteria Decision Making (MCDM) stands out as a significant approach to making sound decisions. It changes how we make decisions by allowing us to consider many factors at the same time. This new approach helps us make more balanced and informed choices. Multi-criteria Decision Making (MCDM), has its roots in Benjamin Franklin's work on moral algebra [1]. His ideas provided the basis for a more organized consideration of several criteria in the decision-making process. This approach gives a more profound and more careful investigation than conventional decision-making strategies [2, 3, 4, 5], making it easier to consider all factors and make better choices.

The basic idea of MCDM is that when evaluating alternatives, several criteria or objectives need to be considered. For example, decision-makers may need to consider cost, proximity to suppliers, and environmental impact when selecting a new location for a shopping center. MCDM provides a systematic way to evaluate these criteria and make a decision that best meets the overall objectives. Another important aspect of the MCDM method is the weighting of the factor (or criteria). Different methods weight the criteria in different ways, providing information about their relative importance in the decision-making process. Some methods allow the decision maker to directly enter these weights, while others use mathematical techniques to extract the weights from the data.

Since the 1950s, researchers have attempted to improve the decision-making system through the development of multi-criteria decision-making (MCDM) strategies. These efforts aim to provide structured tools to help solve problems and prioritize different options. The development of MCDM techniques is a significant advancement, providing valuable resources to individuals and organizations looking to streamline their decision-making processes. With the use of mathematical models, researchers have designed systematic approaches that simplify the management of complex decision-making situations. Furthermore, by integrating uncertain environments into the decision-making framework, the objectivity, efficiency, and informativeness of decisions were further improved. These advances in decision science have profound implications that make it more robust and applicable to real-world situations.

Multi-Criteria Decision Making (MCDM) could be a valuable apparatus for solving regular issues. It makes a difference individuals make superior decisions by considering different variables at once. For example, when buying a car, MCDM can help us consider factors such as price, fuel consumption, safety, and comfort. Likewise, this can apply to choosing a vacation destination, choosing the best job offer, or even deciding what to have for dinner. By using MCDM, we can systematically compare different alternatives and make our decision-making process more organized, effective, and efficient. Simply put, MCDM (Multi-Criteria Decision Making) is used to support planning, decision-making, and organization when there are many complex factors to consider. This makes it possible to choose the optimal course of solution based on what the decision-maker wants.

In Multiple Criteria Decision Making (MCDM), there are several prominent methods. Popular MCDM techniques [6] include the Analytic Hierarchy Process (AHP), which organizes choices progressively and utilizes pairwise comparisons to prioritize criteria; the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [7], which assigns a ranking to several options according to how near the ideal answer they are; the Simple Additive Weighting (SAW) method, which aggregates weighted criteria scores; CRiteria Importance Through Inter-criteria Correlation (CRITIC) decides the objective weights of relative significance in MCDM issues; VIšekriterijumsko KOmpromisno Rangiranje (VIKOR), emphasizes the ranking and selection of alternatives with conflicting criteria; other notable methods include the Weighted Aggregated Sum Product Assessment (WASPAS) [8], which combines weighted sum and product models; the ÉLimination Et Choix Traduisant la REalité (ELECTRE) method, known for its higher ranking relationships for ranking alternatives, uses composite weights that combine both subjective and objective factors to determine concepts of concordance and discordance concepts; Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH), which uses qualitative judgments to assess the relative attractiveness of pairs of elements, then generates numerical scores and weights for each criterion; the COmbinative Distance-based ASsessment (CODAS), which evaluates choices utilizing Euclidean and Cab separations; the Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) model, where the decision maker allocates a priority function to each criterion to convert the difference in criterion value between two alternatives into a priority between 0 and 1 in the comparison in pairs and Combined Compromise Solution (CoCoSo), which helps to identify the most suitable option by combining ideas from compromise solutions. Additionally, over the years, numerous techniques for multi criteria decision-making (MCDM) have been created, each offering valuable insights and tools for managing decision-making scenarios.

In the world of techniques for multi criteria decision-making (MCDM), the two ranking methods, WASPAS and CoCoSo, are essential for making decisions in many situations where multiple factors need to be considered. The WASPAS method, or Weighted Aggregated Sum Product Assessment, introduced by Zavadskas, E. K. et al. [9], is a modern and effective way of making decisions when many factors are taken into consideration. This method combines two other methods: the weighted sum model (WSM) and the weighted product model (WPM). By using both, WASPAS improves decision-making accuracy. The WSM method simply adds the values, while the WPM method multiplies the values to account for how they interact with each other. By merging these two approaches, WASPAS improves decision-making accuracy. Due to its flexibility, WASPAS can be used in several fields, including finance [10], healthcare [11, 12, 13, 14, 15, 16], transportation [17, 18, 19], energy [20, 21, 22, 23], stock market [24] and engineering [25, 26, 27, 28].

On the other hand, the Combined Compromise Solution Strategy (CoCoSo) was developed by Yazdani et al. [29] in 2019 for Multi-Criteria Decision Making (MCDM). It merges simple additive weighting (SAW) with an exponentially weighted model. CoCoSo's initial steps are similar to those of the WASPAS method, both of which deal with complex decisions. This method is popular for quickly evaluating and choosing between options, especially in uncertain situations where finding compromise is important. CoCoSo can be applied in many fields such as healthcare [30], transportation [31], agriculture [32], construction [33], financial risk evaluation [34], stock management [35] and engineering [36] to make informed choices.

However, decision-making is often complicated by various factors of uncertainty, stemming from incomplete or inaccurate information, conflicting objectives, and the unpredictable nature of many real-world phenomena. To address these challenges, researchers have attempted to develop various multi-criteria decision-making (MCDM) methods with the concept of fuzzy sets [37]. This extension effectively manages uncertainty and supports decision-making in complex environments.

This review article talks about two important decision-making methods called WASPAS (Weighted Aggregated Sum Product Assessment) and CoCoSo (Combined Compromise Solution), outlined above. These methods are very effective in helping us make decisions when things are uncertain or complicated. It explains how these methods work, why they are useful and gives examples of how people use them in different situations. The structural framework of the MCDM methodology is presented in Figure 1.

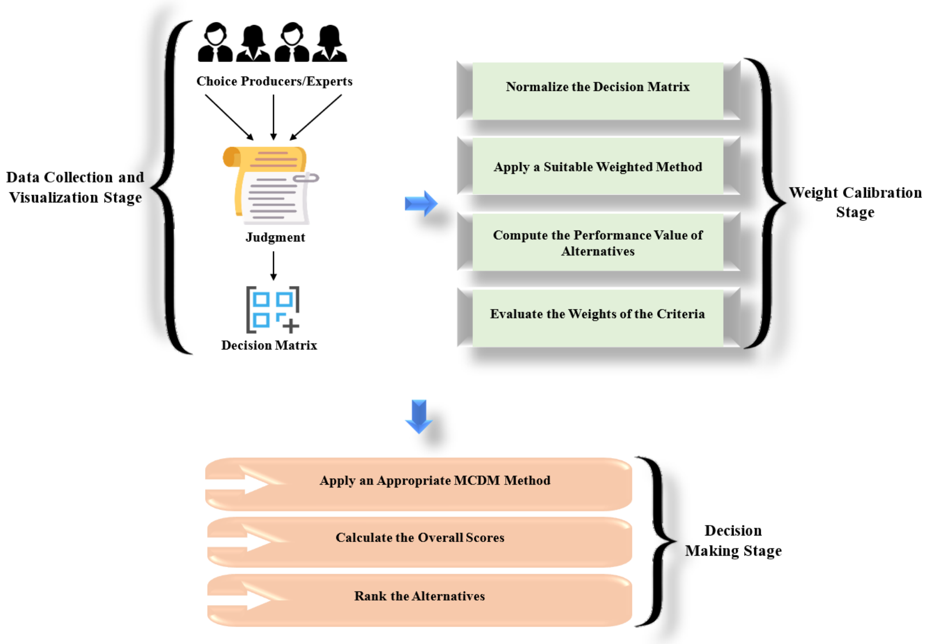

Figure 1: Hierarchical structure of MCDM method

1.1. Motivation of this study

The motivation section describes the review of the two Multi-Criteria Decision-Making (MCDM) techniques, namely, WASPAS and CoCoSo methods. The main focus of this study is to explain the importance of reviewing these techniques, their importance in MCDM and a comparative analysis between the two methods. Another purpose of this review is to make a clear, systematic comparison between WASPAS and CoCoSo methods and to investigate their theoretical underpinnings, potential synergies and practical applications. Additionally, another aim of this review is to identify research gaps and suggest future directions for the evaluation and utilization of MCDM methods in evolving domains like artificial intelligence, sustainability, supply chain and decision support systems. Lastly, this article aims to contribute to the growing body of information on MCDM techniques by providing a detailed analysis of WASPAS and CoCoSo methods, encouraging their wider use and applicability in both academic research and industrial decision-making contexts.

This study gives a comparative review of the MCDM based two optimization methodologies, namely WASPAS and CoCOSo methods. Then, the sensitivity and robustness of those methods are analysed by this study, where lack of research was found. Further, limited sources are found in the computational complexity of the proposed model, which is discussed elaborately in this study. Additionally, the integration of MCDM methods with uncertainty is discussed very well, which has the capacity for data handling. The decision based optimization of the MCDM techniques is explained in this research study.

1.2. Novelties of this Research

This section describes the novelties of this research in detail. This article talks about several contributions to the existing research on the MCDM methods, in particular focusing on WASPAS and CoCoSo methodologies. The main novelties of this study include:

1. Comprehensive comparison between two MCDM methods, namely, WASPAS and CoCoSo.
2. Analysis of their performance in various domains.
3. Evaluate the advantages and disadvantages of these methods.
4. Results analysis based on real-life applications.
5. Identified research gaps and future research directions.

1.3. Structure of this paper

This section describes the structure of this study. The introduction of this study is described in Section 1. Further, the historical evaluation of the MCDM methods is presented in Section 2. Then, Section 3 covered the MCDM in an uncertain environment. The mathematical representation of MCDM methodologies is presented in Section 4. Then, the comparative analysis between WASPAS and CoCoSo methodologies is analysed in Section 5. Additionally, the applications of MCDM methods are presented in Section 6. Lastly, the conclusion of this study is discussed in Section 7.

2. HISTORICAL EVOLUTION OF MCDM METHODS

The decision-making process is an important issue for the progress of society and the satisfaction of daily needs in real life. Multi-criteria decision-making (MCDM) [38, 39] was created in the mid 20th century to bring order and clarity to this complex decision-making process. After overcoming some challenges in the early stages, MCDM has evolved into a very complex mathematical system that incorporates human judgment.

In 1951, Kuhn and Tucker developed optimal conditions for solving nonlinear problems and elegantly considered problems with multiple objectives. In 1955, Charnes, Cooper, and Ferguson published a paper that introduced the concept of goal programming. Although the term goal programming was formally used by Charnes and Cooper in 1961. In 1959, Ron Howard and G.E. Kimball detailed the data in their study of sequential decision processes. The term decision analysis was probably coined by Howard in the mid 1960s. In the mid 1960s, in Europe, Bernard Roy and his colleagues developed the ELECTRE method for multicriteria decision analysis. K.R. MacCrimmon published an important article on Decision-making among multiattribute alternatives [40]. Contini and Zionts formulated a model in 1968 to discuss multiple criteria. They later worked on interactive decision support systems in the late 1970s. In 1972, Zeleny and Cochrane organized a major MCDM conference in Columbia, South Carolina. Steuer, Jim Dyer, and many other dignitaries participated in the conference. The proceedings of this conference were first and foremost and still contribute significantly to its various researches. Zionts continued his work with a special interest in the multicriteria problem, and in 1973, he met Sir Jyrki Wallenius of the European Institute for Advanced Studies in Management. Later they published jointly an important research paper on the multi-criteria decision-making problem [41]. In 1975, Roy founded the EURO working group "Multiple Criteria Decision Aiding". In 1976, Keeney and Raiffa published a valuable book that helped establish the multi-attribute value theory. Decision-making Trial and Evaluation Laboratory (DEMATEL) [42] and Data Envelopment Analysis (DEA) [43] methods were developed in 1976 and 1978, respectively. In 1979, Kinney, Raifa, and Rajala [44] developed rules for making decisions when there are many goals to consider. In the same year, Hwang and Masud [45] reviewed how multiple objective decision-making methods were developed and used in a short period. Więckowski, J. et al. [46] applied MCDM based optimization technique, namely the Comprehensive Sensitivity Analysis Method (COMSAM) method to select the Composite Material.

The 1980s and early 1990s saw an acceleration in the development of MCDM research, which continued to grow exponentially. T. Saaty developed the Analytical Hierarchy Process (AHP) [47] in 1980 as a method for setting priorities in multi-criteria decision-making. Hwang and Yoon in 1981 produced the technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [48], which is a well-liked tool for solving MCDM problems. The Preference Ranking Organisation Method for Enrichment Evaluation (PROMETHEE) [49] was created by J.P. Brans in 1982, which assists decision-makers in examining a range of options while taking into account different factors. In 1984 and 1988, T. Saaty published two significant research articles that addressed AHP [50, 51]. During this time, some important MCDM methods emerged such as MACBETH by Bana e Costa and Vansnick, EXPROM by Diakoulaki and Koumoutsos, TODIM by Gomes and Lima, COPRAS by E.K. Zavadskas and A. Kaklauskas, CRITIC by Diakoulaki, Mavrotas, and Papayannakis, etc. In 1996, T. Saaty developed the Analytic Network Process (ANP) [52] as a generalization of the AHP method. S. Opricovic introduced the VIšekriterijumsko KOmpromisno Rangiranje (VIKOR) method in 1998 for multi-attribute optimization of a complex system. A revised version of ANP was published in 2004 by T. L. Saaty [53].

Recently, MCDM has become more powerful in the decision-making process, linked to forces like artificial intelligence and big data. Machine learning algorithms are being used on large data sets and complex models, which are particularly helpful to decision-makers. Many new MCDM methods have emerged such as MOORA by Willem Karel M. Brauers and E. K. Zavadskas [54], ARAS by Zavadskas and Turskis [55], SWARA by Keršulienė, V. et al. [56], KEMIRA by Krylovas, A. et al. [57], EDAS by Ghorabaee, M. K. et al. [58], WASPAS by Zavadskas, E. K. et al. [9], CoCoSo by Yazdani et al. [29], etc. These methods are facilitating the work of decision-makers in various real-world complex decision-making problems.

2.1. Historical evolution of WASPAS methodology

The Weighted Aggregate Sum Product Assessment Method (WASPAS) [59] is an elegant and innovative technique used in multi-criteria decision-making (MCDM). The concept was initially introduced by Zavadskas, E. K., et al. [9] in 2012. This method combines features of both the Weighted Sum Model (WSM) [60] and the Weighted Product Model (WPM) [60] to improve decision-making accuracy. By combining these models, WASPAS effectively balances the simple additive calculation of WSM with the multiplicative interaction effects considered in WPM. This integration permits a more comprehensive assessment of options, driving to more dependable and exact choice results.

Ever since the WASPAS strategy was presented, it has experienced a noteworthy increment in ubiquity. Since its inception in 2012, many analysts have understood this strategy as a way to solve several real-world challenges. The attractive feature of this technique is it provides a structured and efficient way of formulating options, making it a very popular tool in many sectors. The research on the multi-criteria appraisal of forward alternatives was carried out in 2013 by Zavadskas, E. K. et al. [61]. They presented a case study on the classification of public and commercial building facades, demonstrating the application of their evaluation method in real-life situations. Bagočius et al. [62] suggested an integrated proposal for selecting deep-water ports in Klaipeda. The demonstration combines entropy and WASPAS strategies, advertising a strong system for tending to complex choice issues in port choice. Staniūna, M. et al. [63] talks about an eco-economic analysis of updating multi-family homes. They evaluated various upgrade scenarios using different MCDM methods such as COPRAS, WASPAS, and TOPSIS. šiožinytė and Antuchevičienė [64] tended to the challenges of daylighting and keeping up conventional coherence within the recreation of a vernacular building. AHP, COPRAS [65], TOPSIS, and WASPAS strategies are utilized here. Zolfani et al. [66] introduced a new MCDM model combining SWARA and WASPAS for shopping center location selection. Tehran serves as a case study, where the study identifies and evaluates potential locations for establishing shopping malls. Further, Mishra, A. R. et al. [67] applied intuitionistic fuzzy set to determine the prioritisation of Blockchain networks and its efficiency using SWARA, TOPSIS and VIKOR methods.

After 2013, the WASPAS method gained rapid popularity, marking a significant increase in its adoption and recognition in the academic and professional communities. This method is not only widely applied but also makes significant contributions in the context of fuzzy environments. Since its introduction, researchers have continued to explore and extend the WASPAS method, integrating it into more complex decision-making frameworks. They combined it with various multi-criteria decision-making (MCDM) methods, such as fuzzy logic and unbiased aggregation, to fruitfully handle uncertainty and ambiguity in decision information [68, 69, 70, 71, 72, 73]. This integration advances the power and suitability of the WASPAS technique, making it a profitable instrument for monitoring complex and ambiguous choice situations. Currently, the WASPAS [74] strategy has found different applications in different areas, including energy, construction, transport, engineering, healthcare, and IT divisions. Various analysts, like Verma et al. [20], Khan et al. [75], Chakraborty et al. [76], and Kahraman et al. [77], Andjelković et al. [19], Stanujkić and Karabašević [78], Deveci, M. et al. [79], Ghorabaee et al. [80], Tumsekcali et al. [17], Kaya et al. [81] have contributed their experiences to various sectors.

2.2. Historical evolution of CoCoSo technique

The combined compromise solution (CoCoSo) made by Yazdani, M. et al. [29] in 2019 is an imaginative approach to Multi-Criteria Decision Making (MCDM). The technique is built on the integration of two central MCDM techniques: Simple Additive Weighting (SAW) and the exponentially weighted item display. SAW could be a direct and broadly utilized strategy in MCDM, which calculates the weighted whole of criteria to rank choices. In differentiation, the exponentially weighted item demonstration joins the concept of exponential weighting, which alters the significance of each measure exponentially. By combining these two models, CoCoSo leverages the straightforwardness and clarity of SAW with the nuanced weighting capability of the exponentially weighted item demonstrated, driving more refined and adjusted choice results. Two real-life illustrations, a logistic provider selection problem and a green supplier selection issue, are displayed in [29]. A comparison of the suggested method with other MCDM processes is done and a sensitivity study is performed.

After the invention of the CoCoSo technique, a bunch of researchers have utilized the concept for various real-life problems, Selecting suppliers in construction management in Madrid by Yazdani et al. [82], Sustainable Supplier Selection by Zolfani et al. [83], choosing third-party logistics (3PL) service suppliers by Wen, Z et al. [84], Cold chain coordinations administration of pharmaceutical by Wen, Z et al. [85] and Stock handling to reduce storage charge by Erceg et al. [35].

Lai, H. et al. [86] created an enhanced version of the CoCoSo technique in 2020 by using maximum variation optimization and applying it to choose a cloud service provider. The initial discussion of various normalization strategies and their applicability to the CoCoSo method was done by Ersoy, N. [87] in 2021. It can be inferred from his study that the fixed algorithm for the CoCoSo method can use non-linear normalization, linear normalization, and improved exact method instead of Weitendorff linear normalization. In 2022, Turkis, Z. et al. [88] established an extension of the CoCoSo approach called CoCoSomGqNN. This extension is a combination of the CoCoSo technique with the $m-$generalized $q-$neutrosophic sets (mGqNNs). To get around the drawbacks of conventional QFD (Quality Function Deployment), Xu et al. [89] developed the innovative combined compromise solution (CoCoSo) approach on spherical fuzzy sets. Wang et al. [90] established a unique CoCoSo (Combined Compromise Solution) approach in 2023, based on the Frank operating principle and softmax function for $T-$spherical fuzzy sets. Recently, Liu, H. [91] made an extension of the CoCoSo method to intuitionistic fuzzy sets (IFSs).

The CoCoSo method has found a variety of applications in various fields, including healthcare, agriculture, stock market, construction, engineering, etc. in modern days and various researchers such as Chakraborty et al. [92], Alnoor et al. [93], Narang et al. [94], Karami et al. [95], Erdal et al. [96], Saputro et al. [97], Parthasarathy et al. [98] and more have contributed their important thinking in these areas.

3. MCDM IN UNCERTAIN ENVIRONMENT

In the decision-making process, Multi-Criteria Decision Making (MCDM) [99] is an essential tool for decision-making and evaluation. MCDM is particularly important in various uncertain, complex environments because various ambiguities and imperfections are observed in MCDM data and standards in uncertain situations. This uncertainty can arise from a variety of factors, including limited data, personal opinions, and the inherent unpredictability of decision-making. In the face of such uncertainty, conventional deterministic models cannot accurately reflect the intricate details and complexities of real-life situations. Consequently, decision-making under uncertain conditions requires the MCDM approach to successfully navigate and implement various strategies to deal with this uncertainty. To overcome this ambiguity and incompleteness, researchers have integrated fuzzy set theory, gray system theory, and various uncertainty modelling methods into the MCDM approach. Fuzzy set theory is a process of semantic inference that enables decision-makers to deal with ambiguity and incompleteness through the use of linguistic variables and membership functions, weighting criteria, and modelling uncertainty in the performance rating of alternatives.

Over time various extensions of fuzzy sets have been incorporated to better handle fuzziness and uncertainty such as intuitionistic fuzzy sets, hesitant fuzzy sets, neutrosophic sets, spherical fuzzy sets, etc. These advanced fuzzy sets are integrated into various MCDM techniques, including CoCoSo [100], AHP [101], TOPSIS [102], WASPAS and VIKOR [103]. As these fuzzy sets are combined with various MCDM methods, the decision-making framework becomes more elaborate and the process of representing uncertain, ambiguous, and incomplete information is simplified. This integration makes complex decision problems more flexible, adaptive, and realistic, thereby improving decision quality and robustness in uncertain environments. Recent advances in MCDM also explore hybrid models that combine two or more techniques to take advantage of their strengths and mitigate their weaknesses.

The use of MCDM in uncertain and ambiguous settings is seen in a wide range of fields, including healthcare, energy, finance, stock market, agriculture, construction, transportation, engineering, and supply chain. MCDM supports healthcare by improving diagnosis, treatment planning, and resource allocation by considering the uncertainty of patient status. In finance, the use of MCDM helps make informed investment choices, manage portfolios, and assess risk in the face of market volatility. MCDM supports sustainable development by addressing resource allocation and policy planning. In supply chain management, MCDM helps in supplier selection, risk management, and logistics despite demand uncertainty. Also, MCDM is effective in decision-making and evaluation in various other cases, especially in ambiguous and uncertain situations.

This section discusses the practical role of WASPAS [104] and CoCoSo [29] methods in decision-making processes in various ambiguous and uncertain practical areas. How different researchers have used the two methods in different fields, how the methods have been extended using different datasets, how the methods will be used in the future, and what the impact will be is presented.

3.1. Weighted Aggregated Sum Product Assessment (WASPAS) technique in uncertain environments

When there are many criteria (or factors) to consider; even if the criteria conflict with each other, the Multiple criteria decision-making (MCDM) methods help us to rank the different alternatives in that situation. One popular method is the Weighted Aggregated Sum Product Assessment (WASPAS) method, introduced by Zavadskas, E. K. et al. [9], which is often chosen over other methods because it serves a dual purpose: firstly, to evaluate the precision of the Weighted Sum Model (WSM) and Weighted Product Model (WPM) methods, and secondly, to introduce a mechanism for enhancing the ranking precision of alternatives. Currently, the WASPAS method gained increasing popularity among model designers or decision-makers and is widely used in various uncertain decision-making scenarios. The most valuable aspect of this approach is its adaptability and efficiency, which can provide a strong foundation for successfully making informed decisions in situations where ambiguity and vagueness are common. Through this approach, professionals can navigate complex, ambiguous systems with enhanced accuracy and performance, underscoring its importance as a reliable instrument in the context of ambiguous environments. Its adaptability has permitted it to be applied in many fields, including finance [10], healthcare [11, 12, 13, 14, 15, 16], construction, transportation [17, 18, 19] and engineering [25, 26, 27, 28], etc.

By using the WASPAS approach in the context of uncertainty, several researchers have significantly advanced their knowledge. Over time, their commitments have moved forward the information and applications within the teach. In the following literature, we elaborate on various applications of the WASPAS technique in different real-world domains.

The WASPAS method is useful for decision-making problems in the energy sector due to its ability to handle both qualitative and quantitative criteria and reliable findings. Nie et al. [70] addressed the Solar-Wind Power Station Location Problem through the utilization of an Extended Weighted Aggregated Sum Product Assessment (WASPAS) Technique employing Interval Neutrosophic Sets. A practical example is presented through a case study focusing on the selection of locations for solar wind power stations. Wang et al. [23] described an MCDM methodology to evaluate potential wave energy sites along the coast of Vietnam. This study utilized the fuzzy analytical hierarchy process (FAHP) in conjunction with the WASPAS method. Pamucar et al. [105] scrutinized the selection of a recovery centre for end-of-life automotive lithium-ion batteries through an integrated fuzzy WASPAS approach. Thanh and Lan [106] selected a combination of Hybrid SWOC-FAHP-WASPAS methodologies to conduct an in-depth analysis of the potential formation of solar energy for the long-term sustainability and development of Vietnam. Ilbahar, E. et al. [22] have applied the Pythagorean fuzzy WASPAS method to rank renewable energy sources with the input of multiple experts. The findings are compared with results generated through interval-valued intuitionistic fuzzy WASPAS, intuitionistic type-2 fuzzy WASPAS, and crisp WASPAS techniques. Among the various renewable energy options considered, biomass is identified as a way to meet the energy needs of the Central Anatolia Region in Turkey.

Supply chain management [107] is the cornerstone of every business and one of the major challenges of SCM is selecting the best suppliers. In such complex problems, the MCDM method comes into play. In the article conducted by Ghorabaee, M. K. et al. [108], a novel integrated strategy based on the Weighted Aggregated Sum Product Assessment (WASPAS) method is put forth to address multi-criteria group decision-making issues involving interval type-2 fuzzy sets (IT2FSs). To demonstrate the practicality of the proposed method in addressing real-world MCDM challenges, they utilize a green supplier selection problem as a case study. Keeping awareness of environmental issues, Gupta, S. et al. [109] analyzed a comprehensive framework for evaluating green suppliers. To make informed decisions in supplier selection, the proposed method blends the Fuzzy Analytic Hierarchy Process (AHP) along with three other techniques – MABAC, WASPAS, and TOPSIS. A Methodology for Selecting Resilient-Green Suppliers Using WASPAS, BWM, and TOPSIS with Intuitionistic Fuzzy Sets has been developed by Xiong, L. et al. [110]. Aggarwal, S. et al. [111] identified 29 humanitarian supply chain management barriers (HSCMBs) and developed 20 solutions to address these barriers. Fuzzy SWARA weighs HSCMBs, while Fuzzy WASPAS ranks solutions to address HSCMBs. Aytekin et al. [112] addressed the challenges associated with pharmaceutical supply chains and developed a new method called integrated entropy-WASPAS with Fermatean fuzzy sets to help with this.

MCDM is a significant aspect of dealing with the complex situation due to rapid technological evolution. Among the various MCDM methods, the WASPAS technique helps decision-makers systematically evaluate different alternatives based on multiple criteria. Mohagheghi and Mousavi [113] discussed the process of high-technology project and project portfolio selection in a fuzzy environment. Yel et al. [25] applied Fuzzy AHP, EDAS, and WASPAS in the selection of process methods for software projects. Maja, S [114] compared three decision-making methods (MULTIMOORA, WASPAS, and WISP) for choosing a software engineer. She wanted to see which method was best for picking the right person for a job at an IT company. Shanthi and Preethi [28] studied how Electrochemical Discharge Machining works using a method called bipolar fuzzy WASPAS. Gireesha, O. et al. [115] have accomplished an integrated Multi-Criteria Decision-Making approach for selecting cloud service providers. Here, the IVIFS-WASPAS approach is utilized to determine the significance of Quality of Service (QoS) attributes and to rank the Trustworthy Cloud Service Providers (TCSPs). To assess Public Cloud Computing Services, Alam, et al. [116] employed an Uncertainty-aware Integrated Fuzzy AHP-WASPAS Model.

Infrastructure is considered as the backbone of modern society. In various real-life problem-solving projects, different complex problems arise in the way of infrastructure development. WASPAS, a multiple-criteria decision-making (MCDM) approach, is an important tool to address these complexities, enabling the evaluation of alternatives based on multiple criteria such as cost, quality, environmental impact, and social benefits. Turskis, Z. et al. [117] employed a fuzzy WASPAS approach to identify critical information infrastructures for EU sustainable development. Salimian, S. et al. [118] employed an interval-valued intuitionistic fuzzy set (IVIFS) in their study to address ambiguity in infrastructure projects (IPs). They utilized the RPR, MABAC, and WASPAS methods, applying a real case study from the literature to validate the proposed model's performance.

Alimohammadlou and Khoshsepehr [119] investigated organizational sustainable development using an integrated approach that combines interval-valued intuitionistic fuzzy AHP and WASPAS. To ensure the robustness of the proposed method, sensitivity analyses are conducted. Tumsekcali et al. [17] undertook an extensive evaluation of public transportation services by developing a new version of the SERVQUAL model called P-SERVQUAL 4.0. This model was integrated into an Interval-valued Intuitionistic Fuzzy AHP-WASPAS framework for more detailed public transportation service assessment. Aktas and Kabak [26] demonstrated the application of an Interval Valued Pythagorean Fuzzy WASPAS Method for Drone Selection in Last Mile Delivery Operations, displaying its validity through a case study that evaluated four alternative drones based on five criteria. Koma et al. [18] explained that choosing airline routes is tricky because there are many factors to consider, like different routes and conflicting opinions.

In healthcare, decision-making often involves the evaluation of multiple criteria. A prominent MCDM method used in healthcare is the Weighted Aggregate Sum Product Assessment (WASPAS) method. Rani, P. et al. [11] conducted a study focusing on a crucial concern for patients - the process of choosing the proper physician. In their research, they introduced a comprehensive approach called the WASPAS method, which incorporates innovative information measures such as entropy and divergence measures, as well as operators within the context of Intuitionistic Fuzzy Topsis. Ghoushchi et al. [120] introduced a groundbreaking method known as the SWARA-WASPAS Framework, which utilizes the principles of the Spherical Fuzzy Set theory, to address the difficult challenge of choosing suitable landfill sites for medical waste disposal. Raj, A. and Rani, P. [12] have put forth a creative approach that involves combining the WASPAS method with Fermatean fuzzy sets (FFSs) to tackle the issue of determining the most suitable sites for healthcare waste (HCW) disposal. Chakraborty and Saha [13] created a model that integrates LR fuzzy AHP and fuzzy WASPAS to address the recycling of healthcare waste. To showcase the validity of their approach, they carried out a detailed case study involving multiple district hospitals located in Tripura, India. Menekşe and Akdağ [14] designed a strategy for transferring medical waste in healthcare facilities using a spherical fuzzy CRITIC-WASPAS method that can be implemented in both single and interval-valued spherical fuzzy settings. Rao et al. [15] framed a fuzzy WASPAS approach for selecting healthcare waste treatment technologies. Sıcakyüz, C [16] studied the quality of healthcare and wellness products by analyzing online customer reviews using a combination of fuzzy LMAW and Fermatean fuzzy WASPAS methods. Komal [121] compared various approaches to the disposal of medical waste using a technique known as the Archimedean t-norm and t-conorm. This approach provides useful outcomes even in uncertain situations by addressing scenarios in which we are unsure of the relative weights of each criterion.

Manufacturing is an important sector that transforms raw materials into finished products through various processes, tools, and machinery. It plays an important role in the economy by providing products for daily use. In their study, Ghorabaee et al. [80] examined a new approach to evaluating sustainable manufacturing strategies that involve integrating two different multi-criteria decision-making methods, namely WASPAS and SECA (Simultaneous Evaluation of Criteria and Alternatives). Boltürk and Gündoĝdu [122] investigated the Issues Faced by a Contract Manufacturing Company in the Personal Auto Sector Using the Spherical WASPAS Method. Sampathkumar, S. et al. [27] suggested a novel approach that combines the COPRAS and WASPAS techniques within an intuitionistic dense fuzzy set structure. This ingenious hybrid model was developed to select a manufacturing robot that is best fitted for a specific application. In their study on the Wire Arc Additive Manufacturing (WAAM) Technique, Trivedi et al. [123] explored a new approach by combining fuzzy CRITIC and fuzzy WASPAS methodologies. Selecting the appropriate storage technology is of utmost importance. The process of making this decision is multi-faceted and difficult.

Of all the MCDM techniques, the Weighted Aggregate Sum Product Assessment (WASPAS) technique has shown itself to be a successful approach in the construction sector. The WASPAS strategy helps decision-makers in the construction industry choose wisely when it comes to project selection, resource allocation, risk management, and performance evaluation. Turskis, Z. et al. [68] introduced a wide-ranging framework for evaluating the performance of multiple attributes using fuzzy logic, specifically targeting the selection of the optimal location for constructing a shopping center in Vilnius. In this article, they integrated the strengths of two methodologies, namely the Weighted Aggregated Sum-Product Assessment method with Fuzzy values (WASPAS-F) and the Analytical Hierarchy Process (AHP). Pavlov, N et al. [124] conducted a novel two-phase methodology to assist warehouse designers in navigating some complexity.

The location selection problem is an important decision-making process that involves identifying the most suitable geographical location for a particular purpose, such as establishing a new educational institution or building a restaurant, power plant, or hospital. When choosing a site, the WASPAS method encourages thoughtful and impartial decision-making. The article by Ayyildiz and Gumus [125] encompasses a novel approach that creatively integrates spherical fuzzy AHP with spherical WASPAS for selecting petrol station location problems. In this study, a practical case study is conducted for Istanbul. Aydin and Seker [126] created a system for making decisions using interval-valued intuitionistic fuzzy (IVIF) sets, which involved using the WASPAS and MULTIMOORA techniques to determine the best hub locations. Ayyildiz, E. et al. [127] identified the optimal locations for establishing camps for refugees residing in Istanbul using a Pythagorean fuzzy number-based integration of AHP and WASPAS approaches. Deveci, M. et al. [79] studied fuzzy multi-criteria decision-making techniques for aircraft type selection. They proposed an approach that integrates Entropy-based WASPAS and Interval type-2 hesitant fuzzy sets.

In addition to the areas listed above, the Weighted Aggregated Sum Product Assessment (WASPAS) technique has a significant impact on several additional sectors. Zavadskas, E. K. et al. [128] proposed an extended version of the Weighted Aggregated Sum Product Assessment (WASPAS) method, specifically designed for application in uncertain decision-making environments. Zavadskas, E. K. et al. [69] proposed a novel extension to the WASPAS method called WASPAS-SVNS. This extension enables explicit modelling and representation of uncertainty within the framework of the single-valued neutrosophic set. It is noteworthy that the roles of membership in falsity, indeterminacy, and truth are distinct from one another. Baušys and Juodagalvienė [129] discussed the selection of garage locations problem for residential houses using the WASPAS-SVNS method. Deveci, M. et al. [130] proposed a new method to solve the issue of selecting sites for potential car-sharing stations. This method combines the Weighted Aggregated Sum Product Assessment (WASPAS) based Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) with an interval type-2 fuzzy multi-criteria decision-making (MCDM) model. By using interval type-2 fuzzy sets (IT2FS), the model can effectively manage uncertainties related to membership and non-membership functions. Stanujkić and Karabašević [78] conducted an extension of the WASPAS method for decision-making problems involving intuitionistic fuzzy numbers. The efficacy and user-centric nature of the proposed approach are displayed through an example focusing on the assessment of a website. Pehlivan, N. Y. et al. [71] proposed an integrated fuzzy multicriteria decision-making (FMCDM) methodology that integrates the Fuzzy Analytic Hierarchy Process (FAHP), Weighted Aggregated Sum Product Assessment-Fuzzy (WASPAS-F), Evaluation based on Distance from Average Solution-Fuzzy (EDAS-F), and Additive Ratio Assessment-Fuzzy (ARAS-F) methods. Ilbahar and Kahraman [131] discussed an approach to measuring retail store performance using an interval-valued Pythagorean fuzzy WASPAS method. This research compares the results obtained from the traditional WASPAS method with those from the interval-valued intuitionistic WASPAS technique, showcasing how the proposed approach produces reliable and insightful findings. Mishra, A. R. et al. [132] developed a complete strategy based on the WASPAS method to address multi-criteria decision-making (MCDM) issues that integrate hesitant fuzzy data. Their approach relies on hesitant fuzzy operators, modifications to the conventional WASPAS technique, and a structured process to assign weights to criteria. Kahraman, C. et al. [72] utilized Pythagorean fuzzy sets to extend the WASPAS method. To illustrate the application of the proposed Pythagorean fuzzy WASPAS method, they consider a selection problem among communication firms. Davoudabadi, R. et al. [133] investigated an innovative approach to multi-attribute group decision-making in the context of interval-valued intuitionistic fuzzy uncertainty. Otay and Atik [134] evaluated oil station locations with multi-criteria analysis using Spherical AHP and WASPAS. During the COVID-19 pandemic, Nguyen et al. [135] eloquently described the Governmental Intervention Strategies using A Hybrid Spherical Fuzzy MCDM Approach. Lin et al. [136] implemented an integrated mathematical approach using fully fuzzy BWM and fuzzy WASPAS for risk assessment in a SOFC (Solid Oxide Fuel Cell). Eghbali-Zarch et al. [137] developed a novel decision-making model that integrates the Integrated Determination of Objective Criteria Weights (IDOCRIW) and WASPAS procedures in a fuzzy setting. This hybrid approach aims to improve decision-making processes in view of both objective criteria weights and weighted aggregated sum product assessments within a fuzzy environment. In their research study, Deveci, M. et al. [138] presented a decision-making model based on q-ROFSs, which integrates q-ROFEA and q-ROFHGM to prioritize safe e-scooter operation alternatives. Vaid et al. [139] applied the MCDM techniques VIKOR and WASPAS to prioritize various market alternatives. Their approach for selecting gensets is deemed convenient, practical, and efficient. Zolfani et al. [140] investigated a method that combines FUCOM and WASPAS techniques using Intuitionistic Fuzzy Dombi Aggregation Operators to evaluate special warehouse handling equipment. Kaya et al. [81] talked about how container ports can be sustainable using a method called WASPAS, which uses type-2 neutrosophic fuzzy numbers. Handayani, N. et al. [141] conducted a study to use MCDM and WASPAS in a decision support system for choosing online courses. They suggest using hybrid MCDM with Interval-valued Pythagorean Fuzzy AHP and WASPAS methods.

From the above discussion, it is evident that a large number of scholars are actively working on projects related to the WASPAS approach. Their commitment to resolving a wide range of challenging issues in the context of decision-making has greatly ensured. Their essential contribution has allowed for continued refinement and deployment of WASPAS, resulting in more precise and dependable solutions to complex issues across various areas.

These days, a lot of researchers are actively contributing their work based on the Weighted Aggregated Sum Product Assessment (WASPAS) methodology, especially in environments of uncertainty in a variety of fields, including healthcare, energy, education, finance, and engineering. These insightful studies, carried out by committed researchers, are essential for supporting decision-making in challenging circumstances. They offer frameworks, planning, and observation that improve our understanding of how to deal with uncertainty and make wise decisions. In Table 1, we have compiled a comprehensive list of recent research studies that utilize the WASPAS (Weighted Aggregated Sum Product Assessment) methodology across various fields. This table not only highlights the diversity of applications of the WASPAS technique but also provides insights into its practical implementations. By examining these studies, readers can gain a better understanding of how the WASPAS methodology is applied in real-world scenarios.

3.2. Combined Compromise Solution Strategy (CoCoSo) method strategy in uncertain environments

The Combined Compromise Solution Strategy (CoCoSo), created by Yazdani et al. [29] in 2019, is an innovative approach to Multi-Criteria Decision Making (MCDM). This method integrates simple additive weighting (SAW) principles with an exponentially weighted feature model, creating a sturdy framework for decision-making. The CoCoSo approach is essentially an improved adaptation of the WASPAS technique, which centers on developing a progression decision-making form with multiple factors and choices (or alternatives). The initial steps of the CoCoSo approach closely follow those of the WASPAS approach, as both address complex decision-making challenges. This handle includes a system of guided steps to successfully evaluate and compare different choices and components. CoCoSo has gained prominence as an elegant approach to quickly evaluate and select from different alternatives, especially in situations where finding compromises is important, such as in uncertain situations.

Since its presentation, CoCoSo has been connected over different inquiries about areas, illustrating its flexibility and adequacy in multi-criteria decision-making. In environmental management, it classifies sustainable energy sources by balancing cost, efficiency, and environmental impact. In the transport sector, it evaluates transport routes and modes taking into account cost, time, and sustainability. Additionally, in healthcare, it prioritizes treatments based on effectiveness, cost, and patient outcomes. Numerous analysts have essentially progressed information utilizing the WASPAS strategy in uncertain situations. Their commitments have improved the field's understanding and applications over time.

Logistics centers or distribution hubs are an important part of the supply chain [157]. It stores, manages, and distributes goods efficiently. Positioned to optimize transporta-

Table 1: Current works on WASPAS technique in uncertain environment and their details

Authors Name	**Year**	**Methods**	**Application Area**
Ionaşçu et al. [10]	2024	SAW, WPM, WASPAS	Primary Sector Selection for Economic Activity
Andjelković et al. [19]	2024	DEA, SWARA, WASPAS	Road Section Efficiency Analysis
Verma et al. [20]	2024	CRITIC, WASPAS	Investment in renewable energy projects
Dhumras et al. [21]	2024	AHP, WASPAS	Energy sector
Işık et al. [24]	2024	DEMATEL, CRITIC, EDAS, TOPSIS, WASPAS	Stock market performance ratios
Khan et al. [75]	2024	WASPAS	Evaluation of software reliability
Chakraborty et al. [76]	2024	WASPAS, CODAS, CoCoSo	Healthcare supplier selection
Kahraman et al. [77]	2024	AHP, TOPSIS, WASPAS	No application
Khan, A. A. et al. [142]	2024	CRITIC, WASPAS	Sustainable urban development evaluation
Anjum, M. et al. [143]	2024	CRITIC, WASPAS	Assessing Cooperative ITS Scenarios
Thilagavathy et al. [144]	2024	WASPAS	No application
Eisa et al. [145]	2024	WASPAS	Plant Location Selection
Dehshiri et al. [146]	2024	BWM, WASPAS	Renewable energy project evaluation
Dağıstanlı et al. [147]	2024	GIS, WASPAS	Ammunition depot location selection
Momena et al. [148]	2024	Entropy, WASPAS, CoCoSo	Edge computing model setup in an educational institute
Tümsekçalı et al. [149]	2024	BWM, WASPAS	Public transportation system
Ali et al. [150]	2024	WASPAS, MCGDM	patients' prioritization problem
Ayvaz, B. et al. [151]	2024	AHP, WASPAS	Aquaculture sector
Abdelhafeez et al. [152]	2024	WASPAS	Livestock location selection
Hoang et al. [153]	2024	AHP, WASPAS	Assessing ESG performance
Goyal et al. [154]	2024	WASPAS	Waste treatment technology selection
Tayşir et al. [155]	2024	SWARA, WASPAS	Removing barriers to social entrepreneurship
Jeon et al. [156]	2024	FUCOM, WASPAS	Dumpsite remediation problem

tion, it receives products from manufacturers, manages inventory [158] using advanced systems, and ensures on-time delivery to retailers or consumers. Ulutaş, A. et al. [159] exhibited a process for distribution hub (or logistics center) choice utilizing fuzzy SWARA and CoCoSo strategies. To demonstrate practical application, they select the Sivas territory in Turkey. For cold chain distribution hub center (or logistics center) determination, Liao, H. et al. [160] presented a Pythagorean fuzzy CoCoSo strategy that integrated the total prospect hypothesis and combined weights. Kieu et al. [161] created an algorithm using SF-AHP and CoCoSo to select a distribution hub location. They applied it to a sweet potato case study in Vietnam's Mekong Delta. Korucuk et al. [162] described how logistics companies can develop smart network strategies. They used an integrated picture fuzzy LBWA-CoCoSo framework to show the effectiveness of these strategies. Pamucar and Görçün [163] suggested a framework to choose which seaport to use for containers. They used an integrated technique called the LBWA-CoCoSo'B fuzzy technique in their scheme.

Financial risk assessment is essential to identify, analyze, and evaluate potential threats to a company's financial health. Effective risk assessment helps businesses implement strategic mitigation measures, ensure financial stability, and promote sustainable growth. The CoCoSo methodology in MCDM facilitates a smoother and more efficient risk assessment process. Peng and Huang [34] used the fuzzy multi-criteria decision-making (MCDM) method, using CoCoSo and CRITIC methods to evaluate financial risk. In this paper, a new watermark-corrected q-score function is introduced for comparison, calculating objective weights using CRITIC and presenting the combined weights reflecting subjective and objective. Metawa and Mourad [164] developed an MCDM model using a Neutrosophic set. They evaluated financial risk management performance from multiple experts' perspectives with the COCOSO method to rank possible responses. Xia et al. [165] built a system to measure risks in agricultural supply chain finance (ASCF).

CoCoSo technique in decision-making has many applications in transport system management. It helps to select the best options for aspects such as traffic control, route planning, and vehicle maintenance, thereby improving the operation of the transport system. Ulutaş et al. [166] studied three fuzzy methods (PIPRECIA, PSI and CoCoSo) for selecting transportation companies. Their goal was to find the best way to select these companies for their research. Ecer et al. [167] created a method using IVFNN-Delphi-LOPCOW-CoCoSo to study the extent to which small transportation solutions, such as scooters, bicycles, or shared cars, help the city maintain sustainability. They considered how these solutions affect the environment, the economy, and society. Švadlenka et al. [31] illustrated a fuzzy decision process for probabilistic last-mile transportation using the CoCoSo technique. A real-life case study evaluating potential last-mile delivery modes within Pardubice, an administrative center in one of the 14 regions of the Czech Republic, is presented. Gorcun et al.[168] used a new method called fuzzy hybrid MCDM to solve the problem of picking the right tanker vehicles. This approach helps in making better decisions by considering various factors and uncertainties.

The healthcare industry is essential for human health and longevity, encompassing a range of services from preventive care to diagnosis, treatment, and rehabilitation. In this landscape, the CoCoSo technique emerges as a pivotal player, enhancing patient outcomes and streamlining the pharmaceutical supply chain across multifaceted decision-making contexts. Its flexibility works in many healthcare situations, helping to allocate resources better and make operations more effective, which improves the quality of care. Ortíz-Barrios et al. [169] introduced a fuzzy multi-criteria hybrid decision-making model to evaluate emergency services (ES) and recommend improvements. They used IF-AHP to prioritize criteria, IF-DEMATEL to assess interdependencies, and CoCoSo to rank EDs and identify areas for improvement. Peng, X. et al. [170] constructed an innovative approach for intelligent healthcare management evaluation by integrating CoCoSo and CRITIC methodologies into a novel interval-valued fuzzy soft decision-making method. Zhang and Tian [171] built a new method to evaluate medical and public health services using fuzzy numbers. They extended an existing method, CoCoSo, for working with fuzzy numbers and applied it to evaluate these services. Ortiz-Barrios et al. [172] conducted a comprehensive evaluation of clinical laboratory performance in the context of the Covid-19 pandemic.

The CoCoSo model is widely used in the energy sector to optimize resource allocation, evaluate renewable energy projects, and improve efficiency. It helps make decisions on energy policy, investment, and management by integrating multiple criteria and providing comprehensive assessments. Thanh, N. V. [173] proposed a fuzzy MCDM model to select a solid-waste-to-energy plant location in Vietnam. FAHP analyzes evaluation elements' weights, and CoCoSo ranks the candidates. Dehshiri and Amiri [174] assessed IoT (Internet of Things) risks in renewable energy using a hybrid fuzzy decision approach. They used Fuzzy SWARA to determine the criteria importance and recommended Fuzzy CoCoSo to evaluate IoT integration risks in renewable energy systems. Rani et al. [175] developed a new method for selecting renewable energy sources. It uses SWARA to find criteria weights and the improved CoCoSo method to select the best option, all within a single-valued neutrophil set (SVNS) framework. Alao et al. [176] conducted a study to select suitable prime movers for the profitable operation of a Combined Heat and Power (CHP) system, utilizing the Fuzzy-Entropy and CoCoSo techniques. The COVID-19 pandemic is hampering energy development in developing countries, especially in off-grid areas. The research paper conducted by Ali et al. [177] proposes a novel approach using multiple decision-making methods(Delphi, BWM, and CoCoSo) to address these issues based on a case study in Bangladesh. Rajalakshmi and Mary [178] devised a selection plan for a solar plant based on the Normal Wiggly Hesitant Bipolar-Valued Fuzzy Set.

In today's world, the stock market is a complex and constantly evolving system. It is influenced by many factors such as economic signals, world events, and new technologies. To understand and make decisions in this environment, people use multi-criteria decision-making (MCDM) techniques. These techniques help investors, analysts, and policymakers deal with the challenges of the stock market. Narang et al. [94] have designed a new method for making decisions about which stocks to include in a portfolio. They combined fuzzy CoCoSo with the Heronian averaging operator. Peng and Luo [179] created a model to help warn about bubbles in China's stock market. They used a method called CoCoSo and included picture fuzzy information. Erceg et al. [35] presented a modern demonstration named ABC-FUCOM-Interval Rough CoCoSo Demonstrate to justify the costs incurred in making the stock management system easy to operate.

Multiple criteria decision-making (MCDM) is important in infrastructure and construction projects because it helps in selecting the most suitable option from among many alternatives. By considering factors such as cost, schedule, quality and environmental impact, MCDM techniques help project managers and stakeholders make informed choices. Karami et al. [95] suggested a new way to choose contractors for construction projects using two uncertain methods: IVF-SWARA and IVF-CoCoSo. The study by Banihashemi and Khalilzadeh [180] explores the best ways to carry out construction projects to reduce costs, delays and environmental damage by assessing their environmental impact. In this research, they used the BWM-CoCoSo model. Abdelkader et al. [181] created a model to help make decisions about partnerships between governments and private companies on transportation projects. This model takes into account many different factors to ensure the success of these partnerships. The research conducted by Zhang et al. [182] uses a new way to handle uncertain opinions called hesitant fuzzy linguistic term sets. They proposed a new method that mixes the Best Worst Method (BWM) and Combined Compromise Solution (CoCoSo) for making decisions based on these opinions.

In agriculture, decision-making can be difficult because there are many things to consider, like how crops grow, where to use resources, and making things sustainable. The CoCoSo method contributes to this by considering various factors such as land, water, money and the environment. It helps farmers and others choose the best practices, making farms more productive and sustainable. Fernández-Portillo et al. [100] studied how to encourage more farmers to use organic farming. They used two methods, BWM and Fuzzy CoCoSo, to help make decisions about the best strategies to achieve this. Kieu et al. [161] developed a method using SF-AHP and CoCoSo to select the best location for a distribution center. They tested this in an agricultural supply chain to see how well it worked.

Supply chain management (SCM) is a pillar of the business world. SCM optimizes the flow of goods and information from suppliers to customers. Multi-criteria decision-making (MCDM) methods like CoCoSo help improve SCM by evaluating multiple factors, supporting better decision-making, supplier selection, and logistics management for higher efficiency in an uncertain atmosphere. Ortíz-Barrios et al. [183] proposed a method for managing sustainability in digital manufacturing supply chain systems in the food industry. They integrated the IF-AHP, IF-DEMATEL, and CoCoSo methods to create this new method. Han and Rani [184] surveyed the challenges of receiving blockchain in maintainable supply chain administration for the manufacturing sector utilizing an innovative Pythagorean fuzzy-CRITIC-CoCoSo strategy. Ecer and Pamucar [185] presented a new FMCDM model combining two methods, F-BWM (fuzzy best worst method) and CoCoSo'B (fuzzy CoCoSo with Bonferroni), for sustainability supplier selection (SSS). Wen et al. [84] adapted the CoCoSo method into a vague and hesitant linguistic framework to address the multi-expert MCDM problem of 3PL (third-party logistics) service provider selection. Zhang and Song [186] Zhang and Song introduced a new method for analyzing risks in blockchain-based sustainable supply chain management. Wei et al. [187] used a method called CoCoSo along with FFS to evaluate green suppliers. This method helps a group make decisions together by considering many different factors. Lahane and Kant [188] recognized a circular supply chain (CSC) usage enabler. An observational case examination is conducted in an Indian manufacturing industry and the proposed system is analyzed through a hybrid PF-AHP and PF-CoCoSo approach. Mishra et al. [189] have developed a method for selecting the most environmentally friendly option, called Sustainable 3PRLP (S3PRLP). They combined the CoCoSo method with a new measure using a hesitant fuzzy set (HFS) to make it easier to select the appropriate alternative.

Apart from the sectors mentioned above, the contribution of the Combined Compromise Solution (CoCoSo) methodology can be seen in various other sectors. Peng, X. et al. [190] connected CoCoSo and CRITIC-based Pythagorean fuzzy MCDM techniques, consolidating a score work within a 5G industrial setting. Peng and Smarandache [191] used the neutrosophic soft CoCoSo technique to evaluate the safety of China's rare earth industry. Choosing the best material supplier for home improvement is important for investors and buyers. Zhang et al. [192] presented a new method with linguistic term sets to minimize human error and improve group assessment. Maghsoodi et al. [193] proposed a new target-based MADM method, combining BWM, CoCoSo, and MULTI-MOORA in an interval-valued structure. Nguyen et al. [101] used a new method combining Pythagorean fuzzy AHP and CoCoSo with artificial intelligence technologies. Qiyas et al. [194] developed a decision support system using the CoCoSo method with picture fuzzy information. Lai et al. [195] displayed a special method called Hesitant Fermatean Fuzzy CoCoSo for Group Decision-Making in Blockchain Platform Evaluation. Xu et al.

[89] proposed a new QFD approach using spherical fuzzy sets (SFSs) and the CoCoSo method to improve traditional QFD. Tripathi et al. [196] researched a new way to make decisions using intuitionistic fuzzy parametric divergence measures and score function-based CoCoSo method. Erdal et al. [96] applied fuzzy entropy and fuzzy CoCoSo to assess Anti-Tank Guided Missiles, combining technical and simulation data. Oyinlola and Kamil [197] worked together to choose the best gateway for the Internet of Things. They used a method that combines Fuzzy-BWM, Fuzzy-LBWA, and fuzzy-CoCoSo-LD models. Tavana et al. [198] evaluated eco-friendly packaging options using a new method called Interval Type-2 Fuzzy best-Word to find the best compromise solution.

Currently, various researchers have utilized the excellence of the CoCoSo method to facilitate the decision-making process in important areas such as education, health, construction, economy, infrastructure, etc. CoCoSo has also achieved considerable success in various complex, uncertain issues. Table 2 below highlights the real-life problem-solving issues of the CoCoSo method under different uncertain situations.

Table 2: Current works on CoCoSo technique in uncertain environment and their details

Authors Name	Year	Methods	Application Area
Chakraborty et al. [92]	2024	DEA, WASPAS, CODAS, CoCoSo	Healthcare supplier selection problem
Alnoor et al. [93]	2024	PIPRECIA, CoCoSo	Agriculture sector
Saputro et al. [97]	2024	AHP, CoCoSo, SWARA, FMEA, DEA	Green supplier selection
Parthasarathy et al. [98]	2024	Entropy, CILOS, CoCoSo	Battery recycling method
Haseli et al. [199]	2024	BCM, CoCoSo	Urban transportation system
Wang et al. [200]	2024	DEMATEL, CoCoSo	Design features of mobile medical application
Chatterjee et al. [201]	2024	CoCoSo	Drilling experiment
Rad et al. [202]	2024	FBWM, COCOSO	Supplier selection
Ahmad et al. [203]	2024	CoCoSo	Oil and gas supply chain
Zheng et al. [204]	2024	CoCoSo	Sepsis diagnosis
Kumar et al. [205]	2024	CoCoSo	Biomass crop selection
Joshi, M. [206]	2024	AHP, CoCoSo	Motor insurance policy selection
Dhruba et al. [207]	2024	LOPCOW, CoCoSo	Vendor selection for health centre
Sampathkumar et al. [208]	2024	PSI, COCOSO, PIV, MARCOS	Robot deployment
Nabeeh et al. [209]	2024	CoCoSo	Medical best bearing ring selection

4. MATHEMATICAL REPRESENTATION OF MCDM METHODOLOGIES

Mathematical representation of various models is considered an important factor in the multi-criteria decision-making process. Decision problems are formalized in mathematical representations of models, where multiple conflicting criteria must be evaluated to determine the best alternative. Typically, an MCDM problem is structured as a decision matrix where alternatives are listed in different rows and criteria are listed in different columns. Each cell of the decision matrix indicates how closely a particular alternative is related to a criterion. Various mathematical formulas are used to weight the criteria and calculate the overall score. In this section, the mathematical representation of the WASPAS and CoCoSo techniques is described step by step, and the various mathematical formulas used to calculate the weights and different scores are formulated.

4.1. Representation of WASPAS method

The Weighted Aggregate Sum Product Assessment Method (WASPAS) was first created by Zavadskas, E. K., et al. [9] in 2012. After its invention, it has been applied in various fields like construction, healthcare, engineering, transportation, energy, etc. Consider a scenario where there are f factors, each with a conceivable choice. In this setting, there are e choice producers (or experts) who give their favoured choices in linguistic terms. Based on the specific requirements of the presentation, a suitable fuzzy number is selected to replace these language phrases. Graphical structure of the WASPAS method depicted in Figure 2. The details of the WASPAS method are described below:

A. Creation of decision matrices $((\tilde{\mathscr{H}}^c)_k)$:
The decision matrix is formed by $k-$th choice producers (or experts) according to their linguistic information, where $k = 1, 2, \ldots, e$. According to linguistics transformation, each choice producer's assessment can be transformed into a specific fuzzy number (which is chosen based on the specific requirements of the model). The $k-$th decision matrix can be represented as follows:

$$(\tilde{\mathscr{H}}^c)_k = \begin{bmatrix} (\tilde{\mathscr{F}}_{11})_k & (\tilde{\mathscr{F}}_{12})_k & \cdots & (\tilde{\mathscr{F}}_{1f})_k \\ (\tilde{\mathscr{F}}_{21})_k & (\tilde{\mathscr{F}}_{22})_k & \cdots & (\tilde{\mathscr{F}}_{2f})_k \\ \vdots & \vdots & \ddots & \vdots \\ (\tilde{\mathscr{F}}_{a1})_k & (\tilde{\mathscr{F}}_{a2})_k & \cdots & (\tilde{\mathscr{F}}_{af})_k \end{bmatrix} \tag{1}$$

i.e.,

$$(\tilde{\mathscr{H}}^c)_k = [(\tilde{\mathscr{F}}_{\gamma\psi})_k]_{a\times f} \tag{2}$$

where $k = 1, 2, \ldots, e$ and $(\tilde{\mathscr{H}}^c)_k$ is a matrix of $a \times f$ order . Each element of the decision matrices is a specific fuzzy number (which will be considered for the model).

B. Combine (or aggregate) the decision matrices $(\tilde{\mathscr{H}}^c)$:
At this stage, we combine the above e number of decision matrices given by the choice producers (or experts) into a single matrix utilizing the following Equation (3).

$$\tilde{\mathscr{F}}_{\gamma\psi} = \left[(\tilde{\mathscr{F}}_{\gamma\psi})_1 \times (\tilde{\mathscr{F}}_{\gamma\psi})_2 \times \cdots \times (\tilde{\mathscr{F}}_{\gamma\psi})_k \times \cdots \times (\tilde{\mathscr{F}}_{\gamma\psi})_e\right]^{\frac{1}{e}} \tag{3}$$

where $\gamma = 1, 2, \ldots, a$ and $\psi = 1, 2, \ldots, f$. Then the aggregated decision matrix $(\tilde{\mathscr{H}}^c)$ formed as

$$(\tilde{\mathscr{H}}^c) = [\tilde{\mathscr{F}}_{\gamma\psi}]_{a\times f} = \begin{bmatrix} \tilde{\mathscr{F}}_{11} & \tilde{\mathscr{F}}_{12} & \cdots & \tilde{\mathscr{F}}_{1f} \\ \tilde{\mathscr{F}}_{21} & \tilde{\mathscr{F}}_{22} & \cdots & \tilde{\mathscr{F}}_{2f} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{\mathscr{F}}_{a1} & \tilde{\mathscr{F}}_{a2} & \cdots & \tilde{\mathscr{F}}_{af} \end{bmatrix} \tag{4}$$

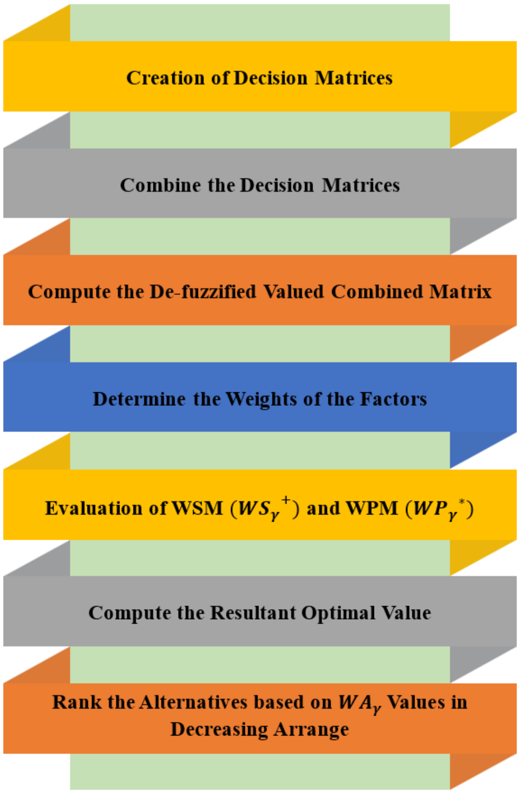

Figure 2: Structural framework for WASPAS technique

C. Compute the de-fuzzified valued combined matrix $(\mathscr{H}^c)$:
De-fuzzification is like a strategy to turn fuzzy thoughts into clear, definite numbers. This is accomplished by various methods, such as Center of Gravity (COG), Center of Area (COA), Weighted average method (WAM), etc., each method contributes to changing fuzzy information in clear numbers.

Now, a combined decision matrix with de-fuzzified values is generated from the above combined (or aggregated) decision matrix by applying an appropriate de-fuzzification process (which will be considered for the model). The de-fuzzified valued combined matrix looks like

$$(\mathscr{H}^c) = [\mathscr{F}_{\gamma\psi}]_{a\times f} \tag{5}$$

where $\mathscr{F}_{\gamma\psi}$ is the de-fuzzified (or crisp) value of the fuzzy number $\tilde{\mathscr{F}}_{\gamma\psi}$ for $\gamma = 1,2,\ldots,a$ and $\psi = 1,2,\ldots,f$.

D. Normalize the de-fuzzified valued combined matrix:
Normalized the de-fuzzified valued combined matrix $(\mathscr{H}^{nc})$ determined using

Equation (6), as follows

$$\mathscr{H}^{nc} = \left[\mathscr{F}^{n}_{\gamma\psi}\right]_{a\times f} = \left[\frac{\mathscr{F}_{\gamma\psi}}{\max\limits_{1\leq\gamma\leq a} \mathscr{F}_{\gamma\psi}}\right]_{a\times f} \tag{6}$$

where $\mathscr{F}^{n}_{\gamma\psi}$ is the normalized de-fuzzified value of the de-fuzzified value of the combined matrix's $\gamma\psi$th entry with $\gamma = 1,2,\ldots,a$ and $\psi = 1,2,\ldots,f$.

E. Determine the weights of the factors:
All factor weights $\mathscr{W}_{\psi}$ for $\psi = 1,2,\ldots,f$ are determined using an appropriate weighted method, which will be selected for the model. Various weighted methods exist in MCDM methodology, such as AHP, CRITIC, and Entropy. An appropriate method is chosen, and then all factor weights are calculated accordingly.

F. Evaluation of Weighted Sum model (WSM):
The weighted sum, indicated as WS^{+}_{γ}, speaks to the introductory degree of relative significance. It is computed from the normalized de-fuzzified valued combined matrix $(\mathscr{H}^{nc})$ with the corresponding factor weights $\mathscr{W}_{\psi}$. This process ensures that the contribution of each factor is accurately calculated according to the weight assigned to it, reflecting its importance in the overall evaluation. The weighted sum, WS^{+}_{γ} is represented as follows:

$$WS^{+}_{\gamma} = \sum_{\psi=1}^{f} \left(\mathscr{W}_{\psi} \times \mathscr{F}^{n}_{\gamma\psi}\right) \tag{7}$$

where $\mathscr{F}^{n}_{\gamma\psi}$ is the normalized de-fuzzified (or crisp) value of the fuzzy number $\tilde{\mathscr{F}}_{\gamma\psi}$ and $\mathscr{W}_{\psi}$ are computed in step **D** with $\gamma = 1,2,\ldots,a$ & $\psi = 1,2,\ldots,f$.

G. Evaluation of Weighted Product model (WPM):
The weighted product, WP^{*}_{γ} is derived from the de-fuzzified valued combined matrix $(\mathscr{H}^{c})$ using the respective factor weights $\mathscr{W}_{\psi}$. It involves weighing various factors based on their relative importance. Then multiply each alternative's score for each factor by its weight and add these products together to decide the general score for each option (or alternative). The weighted product, WP^{*}_{γ} is mathematically described as follows:

$$WP^{*}_{\gamma} = \sum_{\psi=1}^{f} \left(\mathscr{F}_{\gamma\psi}\right)^{\mathscr{W}_{\psi}} \tag{8}$$

where $\mathscr{F}_{\gamma\psi}$ and $\mathscr{W}_{\psi}$ are evaluated in previous step with $\gamma = 1,2,\ldots,a$ & $\psi = 1,2,\ldots,f$.

H. Resultant optimal value:
At long last, the Weighted Aggregated Sum Product Assessment (WASPAS) strategy, a one of a kind combination of WSM and WPM utilized for ranking factors (or alternatives), can be communicated as

$$W\mathscr{A}_{\gamma} = \alpha WS^{+}_{\gamma} + (1-\alpha)WP^{*}_{\gamma} \tag{9}$$

Here, α represents the coefficient of optimal combination with $\alpha \in [0,1]$. If both the Weighted Sum Model (WSM) and Weighted Product Model (WPM) contribute similarly to the combined optimal figure, the esteem of α is 0.5.

Rank the alternatives according to the value of $W\mathscr{A}_\gamma$ as assessed in Equation (9), prioritizing those with higher values as optimal, in decreasing order.

4.2. Numerical expression of CoCoSo method

Yazdani, M. et al. [29] first introduced the Combined Compromise Solution (CoCoSo) method in 2019. This strategy is an improved and refined adaptation of the Weighted Aggregated Sum Product Assessment (WASPAS) methodology. The early phases of the CoCoSo strategy are, therefore, identical to those of the WASPAS plan. This preparation includes an arrangement of steps planned to address decision-making issues, especially those that include different factors and options (or alternatives). Consider a decision-making arrangement that integrates f factors and a options (or alternatives). Inside this system, there are e choice producers (or experts) who give their assessments utilizing linguistic terms. These linguistic terms are, at that point, changed over into a suitable fuzzy number, which is chosen based on the particular necessities of the demonstration. The structural framework of the CoCoSo method is presented in Figure 3. The CoCoSo method involves the following steps:

I. Formation of decision matrices $((\tilde{\mathscr{H}}^c)_k)$:
The decision matrices $((\tilde{\mathscr{H}}^c)_k)$ is created by $k-$th choice producers (or experts) who provide their linguistic information, where $k = 1,2,3,\ldots,e$. In Section 4.1, the formation of the decision matrices $((\tilde{\mathscr{H}}^c)_k)$ is broadly discussed.

II. Combining the decision matrices $(\tilde{\mathscr{H}}^c)$:
Section 4.1 displays the combined decision matrix, denoted as $(\tilde{\mathscr{H}}^c)$.

III. Derive the de-fuzzified valued combined matrix $(\mathscr{H}^c)$:
In Section 4.1 (see Equation (5)), we have presented the de-fuzzified valued combined decision matrix, indicated as $(\mathscr{H}^c)$.

IV. Normalize the de-fuzzified valued combined matrix:
Normalized de-fuzzified valued combined matrix $(\mathscr{H}^{nc})$ evaluated using the Equation (6) and use it for further computations.

V. Find out the weights of the factors:
The weights $\mathscr{W}_\psi$ for all factors, where $\psi = 1,2,\ldots,f$, are established through a suitable weighted approach chosen specifically for the model.

VI. Determination of Weighted Sum Model (WSM):
The weighted sum WS_γ^+ corresponding to each factor (or criteria) is computed in the section earlier (Section 4.1) and is presented in Equation (7).

VII. Finding the Weighted Product Model (WPM):
In the prior section (Section 4.1), the weighted item WP_γ^* for each factor is calculated and outlined in Equation (8). This step is important because it provides a quantitative measure of the suitability of each alternative based on the assigned weights.

VIII. Assess the values of K_γ^a, K_γ^b and K_γ^c:
To determine the values of K_γ^a, K_γ^b and K_γ^c, we need to use Equations (10), (11)

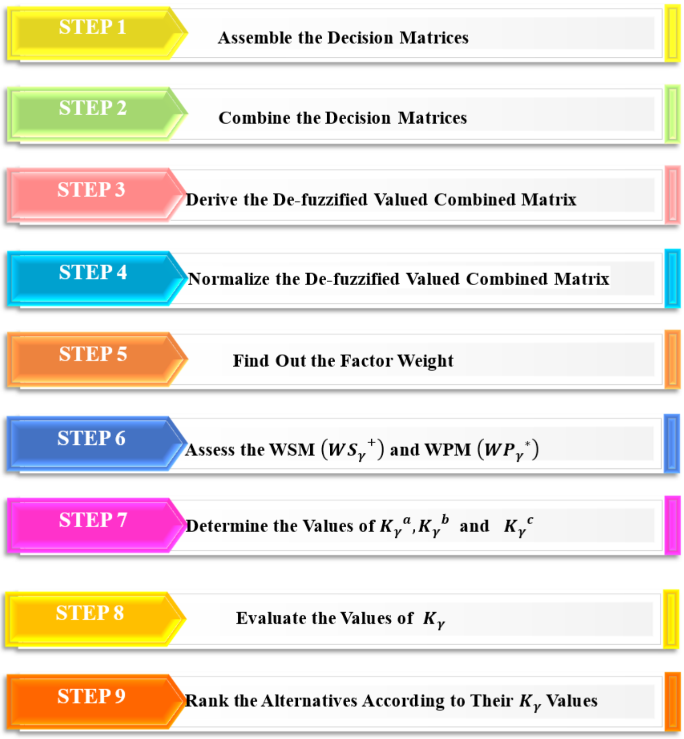

Figure 3: Framework for implementing the CoCoSo method

and (12) respectively. This process requires applying the weighted sum method (WSM), denoted as WS_γ^+, from Equation (7), as well as the weighted product method (WPM), denoted WP_γ^*, comes from Equation (8). By following these steps, we can accurately calculate the required values.

$$K_\gamma^a = \frac{(WS_\gamma^+ + WP_\gamma^*)}{\sum_{\gamma=1}^{a} (WS_\gamma^+ + WP_\gamma^*)} \tag{10}$$

$$K_\gamma^b = \frac{WS_\gamma^+}{\min\limits_{1\leq\gamma\leq a} WS_\gamma^+} + \frac{WP_\gamma^*}{\min\limits_{1\leq\gamma\leq a} WP_\gamma^*} \tag{11}$$

$$K_\gamma^c = \frac{\alpha WS_\gamma^+ + (1-\alpha) WP_\gamma^*}{\alpha \max\limits_{1\leq\gamma\leq a} WS_\gamma^+ + (1-\alpha) \max\limits_{1\leq\gamma\leq a} WP_\gamma^*} \tag{12}$$

where $\alpha \in [0,1]$. Usually consider, $\alpha = 0.5$.

IX. Evaluates the values of K_γ:
The relative coefficients values (K_γ) are calculated using Equation (13), which is presented in detail below

$$K_\gamma = \left(K_\gamma^a \times K_\gamma^b \times K_\gamma^c\right)^{\frac{1}{3}} + \frac{K_\gamma^a + K_\gamma^b + K_\gamma^c}{3} \tag{13}$$

where $\gamma = 1, 2, \ldots, a$.

To rank the alternatives, we use their relative coefficient values (K_γ), where $\gamma = 1, 2, \ldots, a$, in ascending order. This process involves organizing the alternatives according to their K_γ value, starting from the smallest value (with $\gamma = 1$) and moving towards the largest value (with $\gamma = a$). In doing so, we establish a hierarchy that facilitates decision-making, ensuring that each alternative is carefully evaluated and placed against others based on these coefficients.

4.3. Pseudo code of WASPAS and CoCoSo methodologies

Pseudocode describes the different steps of a program's algorithm in such a way that there is no need to consider any complex programming language syntax or any hidden technical usage. Pseudo code is not a real programming language; it is usually used to create a description or design of a program before it is published. By using pseudo code, programmers can get a serious understanding of different projects and thus they can organize the necessary code and implement it in different models. The pseudo codes for the CoCoSo and WASPAS approaches are described below.

4.3.1. Pseudo code for WASPAS technique

The framework is set up with a finite number of criteria, denoted by f, and multiple alternatives, denoted by a. Choice producers (or experts) express their expert knowledge using linguistic terms, which are then converted into a specific fuzzy number (which is chosen based on the requirements of the mode). MCDM techniques are used to place weights on criteria and rank alternatives accordingly. e decision matrices, each of order af, serve as input data for this process and the output of the model represents the ranking of alternatives.

4.3.2. Pseudo code for CoCoSo technique

Establish a decision-making system that integrates f number of factors and a number of options (or alternatives). Within this system, there are e number of choice producers (or experts) who evaluate them using linguistic terms, which are then replaced by an appropriate fuzzy number (chosen based on the specific requirements of the model). MCDM procedures are utilized to allot weights to criteria and rank the choices appropriately. e decision matrices, each of order af, serve as input information for this preparation and the output of the model is a ranking of alternatives.

4.4. Computational Complexity of WASPAS and CoCoSo techniques

Computational Complexity (or time complexity) is determined by the number of computational steps required to run an algorithm based on the size of the input data. This measure indicates how the running time of an algorithm increases as the input size increases.

Algorithm 1 Pseudocode of the WASPAS method

INPUT: Decision matrices of $a \times f$ order in terms of a suitable fuzzy number (based on the requirements of the model)
OUTPUT: Ranking the available alternatives
COMPUTE: Weights of the criteria (a suitable weighted method like AHP, CRITIC, Entropy, etc. is chosen based on the specific requirements of the model)

1. MERGE the e numbers of DMs input in the decision matrix
2. THEN defuzzify and normalize the decision matrix
3. CALCULATE the weight of the factors by the given weighted method
4. FOR WASPAS
5. COMPUTE WSM (WS_γ^+) and WPM (WP_γ^*)
6. FIND the optimal score $(W\mathscr{A}_\gamma)$
7. DETERMINE the rank of alternatives
8. END FOR

Algorithm 2 Pseudocode of the CoCoSo method

INPUT: Decision matrices of $a \times f$ order in terms of a suitable fuzzy number (based on the requirements of the model)
OUTPUT: Ranking the alternatives
COMPUTE: Weights of the criteria (a suitable weighted method like AHP, CRITIC, Entropy, etc. is chosen based on the specific requirements of the model)

1. MERGE the e numbers of DMs input in the decision matrix
2. THEN defuzzify and normalize the decision matrix
3. CALCULATE the weight of the factors by the given weighted method
4. FOR CoCoSo
5. COMPUTE WSM (WS_γ^+) and WPM (WP_γ^*)
6. FIND the values of K_γ^a, K_γ^b and K_γ^c
7. EVALUATE the values of K_γ
8. DETERMINE the rank of alternatives
9. END FOR

Each step of an algorithm represents a specific operation or series of operations that require a certain amount of time. The overall time complexity is usually expressed as an arithmetic function. Realizing the time complexity makes it easier to evaluate the performance and scalability of the algorithm. In MCDM and various computational endeavors, time complexity helps to choose appropriate methods for handling complex datasets and complex problems. Various researchers have discussed the time complexity of different MCDM methods in their studies [210, 211, 212, 213, 214]. This section discusses in detail how the time complexity of the WASPAS and CoCoSo methods is measured.

4.4.1. Computational Complexity for WASPAS technique

Consider a setting with f factors and a choices. Within this system, there are e choice producers, or experts, who express their views through linguistic terminology. The following steps are taken to compute the computational complexity of the WASPAS technique.

(a) A decision matrix of order $a \times f$ is formed by every expert. For e experts, $e \times a \times f$ entries are required to generate the decision matrices, $((\tilde{\mathscr{H}}^c)_k)$, $k = 1, 2, 3, \ldots, e$.

(b) By combining the appropriate elements from the e matrices, each element, $\tilde{\mathscr{F}}_{\gamma\psi}$ of the combined (or aggregated) matrix is calculated. So, $a \times f$ operations are needed to perform this step.

(c) Each element of the combined (or aggregated) matrix needs to be defuzzified by applying a suitable defuzzification technique, and the $a \times f$ operation is required to perform this.

(d) To normalize each element of the combined defuzzified matrix $(\mathscr{H}^c)$, $a \times f + f$ number of operations must be performed.

(e) Criteria weight of the selected criteria are determined by the weighted method.

(f) To calculate the weighted sum $(W\mathscr{A}_\gamma)$, total $a \times f + a$ operations are required.

(g) As with WPM, a total of $a \times f + a$ operations are required to calculate the weighted product (WP^*_γ).

(h) To calculate the final score, i.e., to compute the resultant optimal value for each option using weighted sums and weighted products, a total of a operations are needed.

(i) Finally, to determine the rank of the alternatives, a total of a operations are required.

Hence, the total number of operations performed is $af + af + af + f + af + a + af + a + a + a = 5af + 4a + f$, i.e., the computational complexity of the WASPAS strategy (illustrated in Section 4.1) includes $(5af + 4a + f)$ operations for given factors, options, and experts.

4.4.2. Computational Complexity for CoCoSo technique

Here, we consider the same setting as the WASPAS method, i.e., the setting consists of f factors, a choices, and e choice producers, or experts, who express their opinions through linguistic terms. Now, the computational complexity of the CoCoSo technique is illustrated by the following steps.

(i) The first seven steps of the CoCoSo method (detailed in Section 4.2) are similar to the WASPAS technique, including decision matrix formation, decision matrix combination, defuzzification, normalization, factor weighting, weighted summation, and weighted product. So, the time complexity of the CoCoSo method up to the seventh step is exactly the same as that of the WASPAS technique, and the time complexity is $5af + 2a + f$.

(ii) To calculate K^a_γ, K^b_γ and K^c_γ, a total of $3a$ operations are required.

(iii) To determine the values of K_γ, a operations are needed.

(iv) Finally, to rank the a options according to their K_γ values, a operations are required.

So, the overall amount of the entire operation is equal to $5af + 2a + f + 3a + a + a = 5af + 7a + f$, i.e., the computational complexity (or time complexity) of the CoCoSo technique includes $(5af + 7a + f)$ operations for given factors, options, and experts.

5. COMPARATIVE ANALYSIS BETWEEN WASPAS AND CoCoSo METHODOLOGIES

When comparing the two methodologies, it is crucial to carefully consider and assess each approach's similarities, differences, benefits, and drawbacks in the multi-criteria decision-making process. By pursuing a comparative analysis, researchers and policy-makers can thoroughly understand various issues, such as the relative effectiveness of different methods in the decision-making process, which method is most relevant in a given decision-making context, numerical efficiency, decision-making capacity, assimilation with other methods, etc. In this section, we have discussed in detail the comparative study between two multi-criteria decision-making (MCDM) methods, namely, the Weighted Aggregated Sum Product Assessment (WASPAS) method and the Combined Compromise Solution (CoCoSo) method.

5.1. Similarities between WASPAS and CoCoSo methods

Analyzing the similarities across various multi-criteria decision-making (MCDM) techniques can provide profitable knowledge for their application and viability. Significant similarities between WASPAS (Weighted Aggregated Sum Product Assessment) and CoCoSo (Combined Compromise Solution) techniques can be observed in various aspects, such as integration of different decision-making methods, weighting of criteria, ranking of alternatives, computational efficiency, effective decision-making under uncertain conditions, etc. The similarities between the two approaches have been identified through studies conducted by various researchers over time. By understanding these commonalities, decision-makers can develop a balanced approach, enhancing the robustness and reliability of their decision-making outcomes. Table 3 provides a detailed discussion of the similarities between the WASPAS and CoCoSo methods, including their sources.

5.2. Differences between WASPAS and CoCoSo techniques

Multi-criteria decision-making methods are widely used in decision-making. Various MCDM methods have been developed by researchers over time, from the beginning to the present. Among these various MCDM methods, Weighted Aggregate Sum Product Assessment (WASPAS) and Combined Compromise Solution (CoCoSo) are two particular decision-making methods that have different approaches and applications. Research articles published by various researchers highlight the contrasts between the two methods, making the methods suitable for a wide variety of decision-making situations.

This section outlined the differences between WASPAS (Weighted Aggregated Sum Product Assessment) and CoCoSo (Combined Compromise Solution) methodologies. One of the primary differences between WASPAS and CoCoSo is the computational approach. WASPAS delivers its simplicity and efficiency through WSM and WPM integration. In contrast, CoCoSo's power weight function and normalization introduce complexity, enabling it to capture complex metric relationships for refined analysis. Also, several differences can be observed regarding the normalization technique, application context, final score calculation method, etc., which are listed in Table 4.

Table 3: Similarities between WASPAS and CoCoSo technique

Aspect	**Source(s)**	**Description**
Objective	[9, 29, 69, 128, 212]	Both approaches are outlined to aid planning and sound decision-making while considering multiple complex criteria in the decision-making process.
Utilization	[11, 23, 24, 68, 94, 95, 108, 143, 149, 151, 155, 171, 175, 183, 199, 201, 204, 205]	WASPAS and CoCoSo are commonly used in various fields such as financial matters, healthcare, transportation, construction, energy, stock management, etc. These MCDM methods help decision-makers evaluate and rank alternatives by considering various factors and their importance for balanced decisions.
Hybrid Manner	[128, 130, 137, 190, 197, 208]	WASPAS and CoCoSo integrate different methods. CoCoSo explicitly integrates compromise solutions and the WASPAS approach combines the Weighted Sum Model (WSM) and Weighted Product Model (WPM).
Criteria weight	[20, 97, 98, 148, 151, 184]	The WASPAS and CoCoSo methods require weights for each decision-making criterion. This weight shows the importance of each factor. Weights can be determined using methods such as AHP, CRITIC, and Entropy.
Aggregation of criteria (or factor)	[108, 148, 175, 212]	The WASPAS and CoCoSo methods aggregate criteria values to determine a composite score for each option, providing comprehensive decision support.
Normalization	[105, 108, 109, 175]	Standardisation of decision matrices are necessary for both CoCoSo and WASPAS to aggregate criteria at various scales and conduct fair comparisons. This procedure preserves the integrity of the decision-making process to suitably assess alternatives while standardizing quality and ensuring a consistent scale.
Ranking of alternatives	[105, 148, 175, 212]	WASPAS and CoCoSo provide a ranking of the alternatives, identifying the most preferred option based on the highest composite score.
Adaptability and versatility	[105, 108]	The WASPAS and CoCoSo methods are flexible and adaptable to a wide range of decision-making processes. Their thoroughness in combining multiple criteria is important for complex decisions in various fields.
Intricacy and computational proficiency	[175, 212]	WASPAS and CoCoSo techniques efficiently handle multi-criteria decision-making tasks by adjusting complexity and computational power. Since both methods are computationally efficient, they can be applied in various practical settings. They contain simple calculations that can be done using a basic spreadsheet application or basic programming.
Managing uncertainty	[212]	The CoCoSo and WASPAS methods can be used to efficiently manage ambiguous or uncertain concepts throughout the decision-making process. When evaluating alternatives in the face of uncertainty, these techniques excel at integrating numerous criteria and evaluation systems.

Table 4: Difference between two MCDM methods

Category	**Weighted Aggregated Sum Product Assessment (WASPAS)** [9]	**Combined Compromise Solution (CoCoSo)** [29]
Calculation Procedure	WASPAS calculates WSM and WPM separately, then combines the two findings using a weighted formula to get a comprehensive score that takes into account the link between additive and multiplicative criteria.	Adopts more integrated calculations in which the compromise answer is obtained by directly merging several aggregation approaches.
Normalization Approach	Conventionally, a linear normalization is utilized to the performance values.	Similar normalization strategies are available, but normalization is done relative to the sum of each criterion's performance across all alternatives.
Computation of Final Score	WASPAS uses a parameter $\alpha \in [0,1]$ to balance WSM and WPM. The final score can be computed as follows; $W\mathscr{A}_\gamma = \alpha WS^+_\gamma + (1-\alpha)WP^*_\gamma$, where WS^+, WP^* are weighted sum and weighted product, respectively (see Equation (9)).	CoCoSo takes the average of the product, the total, and a compromise factor. Here, the final score can be calculated as follows; $K_\gamma = \{K^a_\gamma \times K^b_\gamma \times K^c_\gamma\}^{\frac{1}{3}} + \frac{K^a_\gamma + K^b_\gamma + K^c_\gamma}{3}$, where the symbols are illustrated in the Equation (13).
Context of the Application	Due to its hybrid nature, WASPAS is very flexible and can be applied to a variety of decision-making problems, from technical to economic. Especially appropriate in situations when the impacts of both linear and non-linear criteria are substantial.	Ideal for use in situations where balancing competing priorities is crucial, such as project selection or resource distribution. Perfect in circumstances when a balanced performance across options is needed, considering both the best and worst-case scenarios.

5.3. Advantages and disadvantages of WASPAS and CoCoSo methods

The multi-criteria decision-making (MCDM) process includes multiple decision-making methods. Each method is suitable for different decision-making contexts and each method has its own advantages and disadvantages. WASPAS and CoCoSo are two important multi-criteria decision-making (MCDM) techniques, which are outlined to help in various real-life evaluation and selection processes where multiple criteria are considered. WASPAS is useful in a wide range of applications due to its practical simplicity and adaptability. It can cope with the weighting of criteria or in situations where more than one criterion is involved, it is sufficiently appreciated that decisions can be made in all those situations. CoCoSo, on the other hand, focuses on identifying a compromise solution that best satisfies all criteria. By considering the advantages and disadvantages of both the WASPAS and CoCoSo methods, decision-makers can choose which method to use based on their specific needs and the nature of the decision, constraints. This knowledge helps them achieve optimal decision-making results. Table 5 and Table 6 below illustrate the advantages and disadvantages of CoCoSo and WASPAS methods, respectively.

Table 5: Advantages and disadvantages of WASPAS methodology

Method	Advantages	Disadvantages
WASPAS	• The WASPAS approach makes use of the advantages of WSM and WPM methodologies. The combination of these two methods makes WASPAS a more trustworthy and durable method for decision-making. • Implementation of the WASPAS methodology is computationally simpler. • The WASPAS method strives to provide the highest level of accuracy. • Due to the flexibility and utility of the WASPAS method, it can be used in decision-making in many fields such as healthcare, construction, energy, site selection, supply chain management, engineering, etc. • WASPAS assigns distinct weights to beneficial and non-beneficial criteria in problems. • By consolidating fuzzy logic, probabilistic analysis, or other methods, WASPAS can be adapted in uncertain situations to manage ambiguity among criteria and alternatives.	• When working with very big datasets or numerous criteria, the WASPAS technique is less practical for large-scale, real-time decision-making. • The full range of performance scores for each criterion is not always considered by WASPAS. It considers minimum and maximum values for non-beneficial or beneficial criteria respectively. • The linear nature of WASPAS may not effectively capture complex relationships between criteria.

Table 6: Advantages and disadvantages of CoCoSo technique

Method	Advantages	Disadvantages
CoCoSo	• The CoCoSo method is capable of easy integration with other MCDM methods or optimization techniques and helps in taking appropriate steps in complex decision-making tasks arising from various problems. • This approach combines different criteria to find a compromise solution by balancing different conflicting goals. • The Cocoso approach offers a strong, trustworthy ranking that makes it easy to choose the best alternatives from the specified criteria. • CoCoSo combines inferential reasoning, probabilistic concepts, and several extensions to provide unique contributions to decision making in uncertain environments. • The CoCoSo approach is useful in many sectors, including as engineering, healthcare, agriculture, transportation, and finance. The technique proves its adaptability and efficiency in various fields.	• For large-scale problems with different criteria and alternatives, the computational burden of CoCoSo technology can be significant and requires a considerable amount of computer resources. • The CoCoSo approach may lead to the rank reversal problem, in which the inclusion or exclusion of additional options alters the order of alternatives. • Interpreting the final results of the CoCoSo method can be challenging, especially for stakeholders who are not well versed in the mathematical basis of the technique.

6. APPLICATIONS OF MCDM METHODS

The applications of the WASPAS and CoCoSo methods are discussed in this section. Here, we consider two real-life applications and analysis the ranking of the alternatives based on the said methods. The first application is to determine the sustainable hospital location selection in Saudi Arabia [215] and the second application is to evaluate the best state in India based on sustainable women empowerment [216]. The detailed numerical evaluations of the applications are described as follows:

6.1. Sustainable Hospital Site Selection in Saudi Arabia

Building a sustainable hospital in a developing country is challenging work and depends on multiple variables. Gazi, K. H. et al. [215] studies on a sustainable hospital site selection in Saudi Arabia considering various factors and sub-factors in a complex system. To find suitable locations for the hospital, the authors have taken five criteria and thirty-two sub-criteria to identify variables and optimise the efficiency of the hospital. Also, seven proposed locations were considered as alternatives for choosing the best site for building hospitals and three decision makers (DMs) were given data for numerical computation, which were professional, experienced and unbiased in their fields.

The entropy weighted method is a weighted calculation method invented by C. E. Shannon [217] in 1948. The weights of criteria and sub-criteria are calculated by this method, which are described as local weights, and the global weights are further determined by incorporating them with criteria weights. The weights of the criteria and sub-criteria are shown in Table 7 and graphically presented through the Pi diagram in Figure 4.

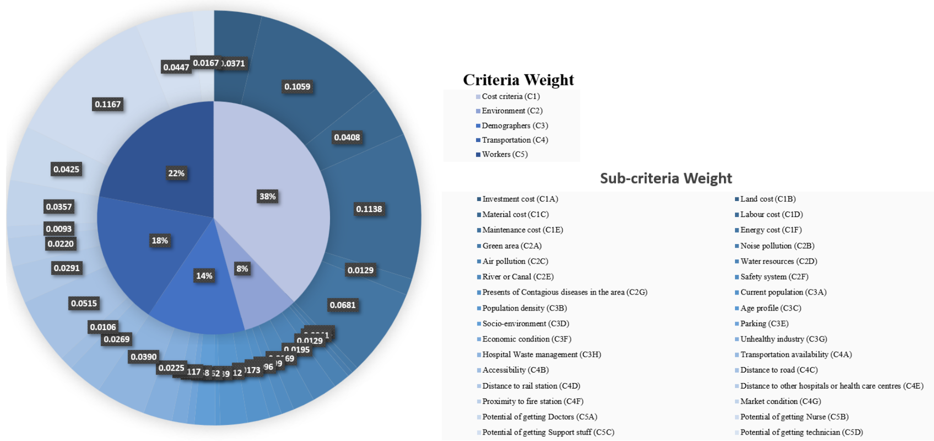

Figure 4: Weight of the criteria and sub-criteria of site selection for hospital

Table 7: Weight of the criteria and sub-criteria for sustainable hospital site selection determined by Entropy method

Criteria Weight		**Sub-criteria Weight**		
Criteria	Weight	Sub-criteria	Local weight	Global weight
Cost criteria (C_1)	0.3787	Investment cost (C_{1A})	0.0981	0.0371
		Land cost (C_{1B})	0.2797	0.1059
		Material cost (C_{1C})	0.1077	0.0408
		Labour cost (C_{1D})	0.3007	0.1138
		Maintenance cost (C_{1E})	0.0340	0.0129
		Energy cost (C_{1F})	0.1799	0.0681
Environment (C_2)	0.0781	Green area (C_{2A})	0.0653	0.0051
		Noise pollution (C_{2B})	0.0522	0.0041
		Air pollution (C_{2C})	0.1658	0.0129
		Water resources (C_{2D})	0.2494	0.0195
		River or Canal (C_{2E})	0.2169	0.0169
		Safety system (C_{2F})	0.1273	0.0099
		Presents... area (C_{2G})	0.1232	0.0096
Demographers (C_3)	0.1375	Current population (C_{3A})	0.1257	0.0173
		Population density (C_{3B})	0.1542	0.0212
		Age profile (C_{3C})	0.0281	0.0039
		Socio-environment (C_{3D})	0.1177	0.0162
		Parking (C_{3E})	0.0425	0.0058
		Economic condition (C_{3F})	0.0847	0.0117
		Unhealthy industry (C_{3G})	0.1636	0.0225
		Hospital Waste M. (C_{3H})	0.2835	0.0390
Transportation (C_4)	0.1852	Transportation availability (C_{4A})	0.1455	0.0269
		Accessibility (C_{4B})	0.0574	0.0106
		Distance to road (C_{4C})	0.2782	0.0515
		Distance to rail station (C_{4D})	0.1570	0.0291
		Distance to... (C_{4E})	0.1188	0.0220
		Proximity to fire station (C_{4F})	0.0502	0.0093
		Market condition (C_{4G})	0.1929	0.0357
Workers (C_5)	0.2205	Potential of getting D. (C_{5A})	0.1927	0.0425
		Potential of getting Nurse (C_{5B})	0.5292	0.1167
		Potential of getting S. stuff (C_{5C})	0.2026	0.0447
		Potential of getting T. (C_{5D})	0.0755	0.0167

The WASPAS method is applied to evaluate the most suitable location for a sustainable hospital location in Saudi Arabia and the methodology is described in Section 4.1. For numerical evaluation, the criteria and sub-criteria weights are considered as mentioned in the previous Table 7, determined by the Entropy method. The alternative ranking and associated data ($W\mathscr{S}^+_\gamma$, $W\mathscr{P}^*_\gamma$ and $W\mathscr{A}_\gamma$ for $\gamma = 1, 2, \ldots, a$) are mentioned in Table 8.

The most suitable site for a sustainable hospital in Saudi Arabia using the MCDM based optimization technique, namely the CoCoSo method (see Section 4.2) is calculated. The weights of the criteria and sub-criteria are determined by the Entropy method and shown in Table 7. The ranking of the alternatives and related data (K^a_γ, K^b_γ, K^c_γ and K_γ for $\gamma = 1, 2, \ldots, a$) are shown in Table 9.

Table 8: Ranking of proposed locations for hospital site selection evaluated using WASPAS method

Alternative	$\mathbf{W}\mathscr{S}_\gamma^+$	$\mathbf{W}\mathscr{P}_\gamma^*$	$\mathbf{W}\mathscr{A}_\gamma$	**Ranking**
Addiriyah (L_1)	0.6766	31.6075	16.1421	2
Alkharj (L_2)	0.7447	31.6991	16.2219	1
Adduwadimi (L_3)	0.6461	31.5573	16.1017	6
Almajmaah (L_4)	0.6478	31.5585	16.1031	5
Alquwayiyah (L_5)	0.6078	31.5035	16.0556	7
Wadi Addawasir (L_6)	0.6703	31.5980	16.1342	4
Azzulfi (L_7)	0.6773	31.6022	16.1397	3

Table 9: Proposed locations ranking for hospital site selection find out by CoCoSo method

Alternative	$\mathbf{K}_\gamma^\mathbf{a}$	$\mathbf{K}_\gamma^\mathbf{b}$	$\mathbf{K}_\gamma^\mathbf{c}$	$\mathbf{K}_\gamma$	**Ranking**
Addiriyah (L_1)	0.1430	2.1167	0.9951	1.7552	3
Alkharj (L_2)	0.1437	2.2315	1.0000	1.8095	1
Adduwadimi (L_3)	0.1426	2.0648	0.9926	1.7303	6
Almajmaah (L_4)	0.1426	2.0677	0.9927	1.7317	5
Alquwayiyah (L_5)	0.1422	2.0000	0.9898	1.6994	7
Wadi Addawasir (L_6)	0.1429	2.1059	0.9946	1.7501	4
Azzulfi (L_7)	0.1430	2.1176	0.9949	1.7555	2

The alternatives ranking using the WASPAS and CoCoSo methods are depicted in Table 8 and Table 9, respectively. From the evaluated results, we can conclude that the optimal location for building a sustainable hospital in Saudi Arabia is almost similar. The best site for the hospital is Alkharj (L_2). In the WASPAS method, the locations Addiriyah (L_1) and Azzulfi (L_7) are the second and third prioritized alternatives, whereas in the CoCoSo method, its rank is reversed. Further, the sites Wadi Addawasir (L_6), Almajmaah (L_4), Adduwadimi (L_3) and Alquwayiyah (L_5) are fourth, fifth, sixth and seventh positions by two MCDM methods, respectively. The graphical presentation of the ranking locations by two MCDM techniques is picturised in Figure 5.

6.2. Ranking of States in India Based on Sustainable Women Empowerment

Empowering women in a country is a difficult job and it is necessary to develop the country. Adhikari, D. et al. [216] work on measuring women's empowerment from different perspectives and conduct a comparative analysis of various states in India. In her studies, she measured different states in India by several parameters and ranked them based on their performance. To evaluate the result, the authors considered eleven criteria for ranking the eight states in India in an uncertain environment, namely generalized triangular intuitionistic fuzzy number (GTIFN). All the data are collected from four DMs, which are unbiased and professional in their work.

In the numerical analysis, the criteria weight of the state ranking in India based on women empowerment will first be determined using the entropy method [217]. The weight of the criteria appears in Table 10 and the geometric representation by the Pi diagram in Figure 6.

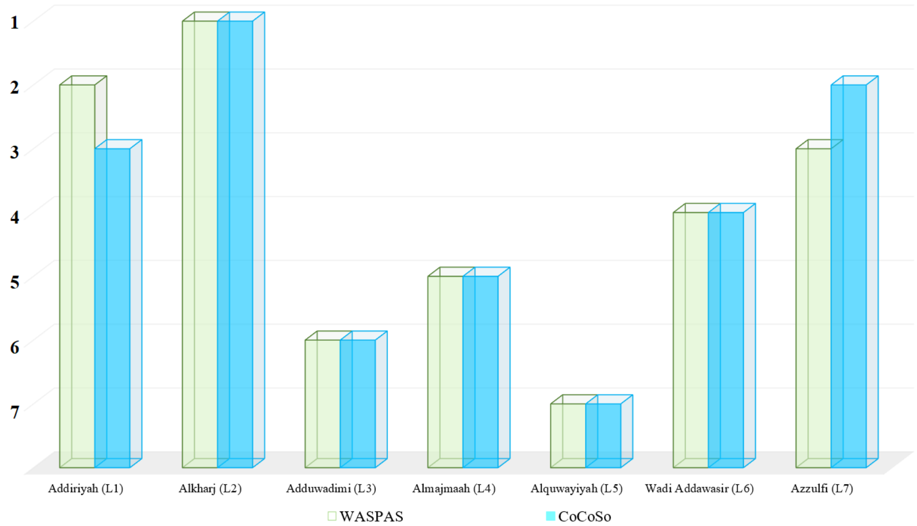

Figure 5: Ranking of the sites for hospital using WSPAS and CoCoSo methods

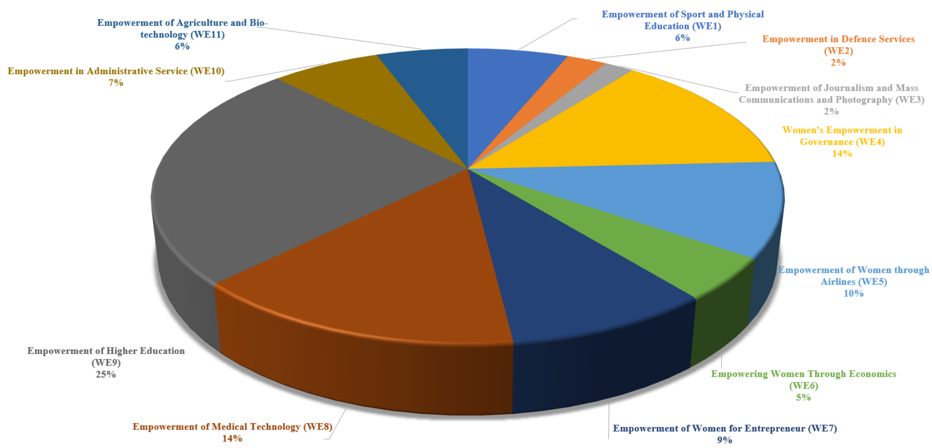

Figure 6: Weight of the criteria for state of India ranking study

The numerical evaluation of ranking alternatives (states in India) is calculated by the MCDM based optimization technique, namely the WASPAS method, which is discussed in Section 4.1 and the weight of the criteria are considered from Table 10. The ranking of the states in India through women empowerment and related data ($W\mathscr{S}_\gamma^+$, $W\mathscr{P}_\gamma^*$ and $W\mathscr{A}_\gamma$ for $\gamma = 1, 2, \ldots, a$) are presented in Table 11.

Table 10: Criteria weight of the sustainable women empowerment determined using Entropy method

Criteria of Choose Women Empowerment	Criteria Weight
Empowerment of Sport and Physical Education (WE_1)	0.06133
Empowerment in Defence Services (WE_2)	0.02433
Empowerment of Media science (WE_3)	0.01795
Empowerment of Women in Governance (WE_4)	0.13708
Empowerment of Women through Airlines (WE_5)	0.10270
Empowering Women Through Economics (WE_6)	0.04605
Empowerment of Women for Entrepreneur (WE_7)	0.09439
Empowerment of Medical Technology (WE_8)	0.14391
Empowerment of Higher Education (WE_9)	0.25034
Empowerment in Administrative Service (WE_{10})	0.06614
Empowerment of Agriculture and Bio-technology (WE_{11})	0.05579

Table 11: Ranking of the states in India based on women empowerment by WASPAS method

Alternative	$\mathbf{W}\mathscr{S}_\gamma^+$	$\mathbf{W}\mathscr{P}_\gamma^*$	$\mathbf{W}\mathscr{A}_\gamma$	Ranking
State A	0.1436	9.2773	4.7105	1
State B	0.1306	9.2019	4.6663	3
State C	0.1149	9.1181	4.6165	7
State D	0.1113	9.0819	4.5966	8
State E	0.1309	9.2204	4.6756	2
State F	0.1244	9.1724	4.6484	5
State G	0.1256	9.1737	4.6497	4
State H	0.1186	9.1438	4.6312	6

The most optimised state in India based on women's empowerment is determined by the CoCoSo method and theoretical evaluation mentioned in Section 4.2. The criteria weights are considered from the Entropy weighted method in Table 10. The ranking of the alternatives with associated data are (K_γ^a, K_γ^b, K_γ^c and K_γ for $\gamma = 1, 2, \ldots, a$) are presented in Table 12.

Table 12: Ranking of the states in India based on women empowerment using CoCoSo method

Alternative	$\mathbf{K}_\gamma^\mathbf{a}$	$\mathbf{K}_\gamma^\mathbf{b}$	$\mathbf{K}_\gamma^\mathbf{c}$	$\mathbf{K}_\gamma$	Ranking
State A	0.1266	2.3116	1.0000	1.8101	1
State B	0.1255	2.1863	0.9906	1.7485	3
State C	0.1241	2.0361	0.9800	1.6747	7
State D	0.1236	2.0000	0.9758	1.6556	8
State E	0.1257	2.1908	0.9926	1.7520	2
State F	0.1250	2.1275	0.9868	1.7200	5
State G	0.1250	2.1381	0.9871	1.7248	4
State H	0.1245	2.0716	0.9832	1.6927	6

The ranking of the states in India based on women's empowerment through two MCDM techniques (WASPAS and CoCoSo methods) are displayed in Table 11 and Table

12, respectively. From the determined results, we can easily conclude that the ranking of the alternatives is identical. State A is the optimal state in India based on women's empowerment and State E is the second most optimal state in India. Further, the states State B, State G, State F, State H, State C and State D in India are third, fourth, fifth, sixth, seventh and eighth ranked states in India on the basis of women's empowerment, respectively. The graphical representation of the comparative ranking of the alternatives is presented in Figure 7.

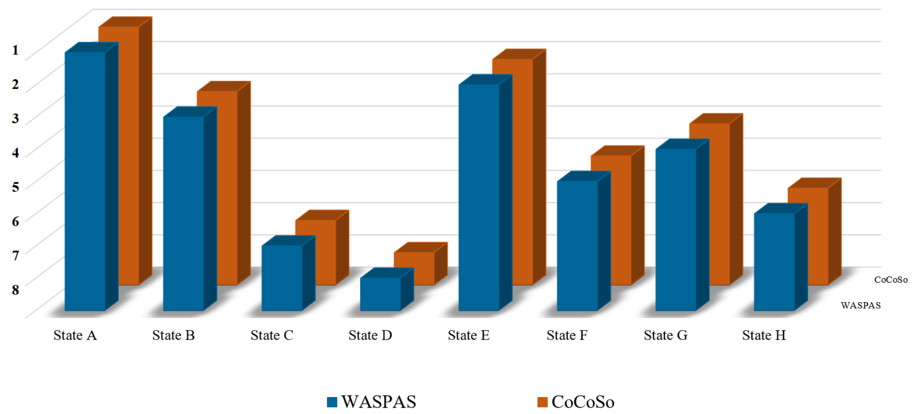

Figure 7: Ranking of the state of India based on women's empowerment

6.3. Analysis of Computational Complexity

The computational complexity of these applications is presented in this section. There are two applications in this study and we calculate their computational complexity using two MCDM methods. The numerical procedure of the computational complexity is presented in Section 4.4. First, the computational complexity of the sustainable hospital site selection problem will be evaluated and then the computational complexity of the ranking of the state of India will be evaluated based on the women's empowerment problem.

The computational complexity of the sustainable hospital site selection problem is

a). For WASPAS method
The number of computations is $(5af + eaf + 2a + f)$ for the criteria and $(5ag_f + eag_f + 2a + g_f)$ for the sub-criteria where f is criteria number, g_f is sub-criteria number for criteria f, a is numbers of alternatives and e is numbers of decision makers (DMs). That is $(5 \times 7 \times 5 + 3 \times 7 \times 5 + 2 \times 7 + 5) = 299$ number of calculation for criteria and $(5 \times 7 \times 32 + 3 \times 7 \times 32 + 2 \times 7 + 32) = 1838$ number of calculation for sub-criteria. Therefore, total of 2137 calculations were conducted to evaluate the result by the WASPAS method.

b). For CoCOSo method
The number of calculations is $(5af + 7a + f)$ for the criteria and $(5ag_f + 7a + g_f)$

for the sub-criteria where f is number of criteria, g_f is number of sub-criteria for criteria f, a is alternative numbers and e is decision makers (DMs) number. That is $(5 \times 7 \times 5 + 7 \times 7 + 5) = 229$ number of calculation for criteria and $(5 \times 7 \times 32 + 7 \times 7 + 32) = 1201$ number of computation for sub-criteria. Therefore, total of 1430 calculations were conducted to determine the ranking by the CoCoSo method.

The computational complexity of the ranking of the state in India based on women's empowerment problem is

i). For WASPAS method
The number of calculations is $(5af + eaf + 2a + f)$ for evaluating the ranking of states in India where f is criteria number, a is number of alternatives and e is number of decision makers (DMs). That is $(5 \times 8 \times 11 + 3 \times 8 \times 11 + 2 \times 8 + 11) = 731$ number of calculations were conducted to determine the result using the WASPAS method.

ii). For CoCoSo method
The number of numerical operations is $(5af + 7a + f)$ to determine the ranking of the states in India where f is number of criteria, a is alternatives number and e is decision makers (DMs) number. That is $(5 \times 8 \times 11 + 7 \times 8 + 11) = 507$ calculations were conducted to evaluate the result by the CoCoSo method.

7. CONCLUSION

The conclusion of this paper is briefly presented in this section. The main purpose of this study is to study the two popular MCDM methods, namely, WASPAS and CoCoSo methods. Here, summarise the history, evaluation, methodologies, key contributions, advantages, limitations and applications of the two MCDM methods in detail. Both methods offer a unique solution to prioritizing and aggregating decisions considering multiple conflicting criteria and sub-criteria in complex scenarios. Those techniques are applied in engineering, management, industries, supply chain management and economics.

The WASPAS and CoCoSo methods have a range of advantages, including computational efficiency, simplicity of use and the capability to handle complex multi-criteria decision-making tasks. However, every method has its limitations and boundaries, which are described in the previous section. All things considered, the decision between WASPAS and CoCoSo techniques depends on the particular problem and the relation between criteria and alternatives. However, the two MCDM methods are very useful, easily computable and popular methodologies applied in sustainability and artificial intelligence fields.

This study's shortcoming is that only two MCDM methods are considered for this review article. Further, the methods are applied in fuzzy and neutrosophic uncertain environments, which may applied in crisp or other uncertain environments. Additionally, there are only two real life applications are discussed in this research.

7.1. Future Research Scope

This section describes the future research scope in detail. From the details discussed on the two MCDM techniques in this paper, there are several challenges and research scopes in future as follows:

1. In this study, we consider two MCDM methods, namely, WASPAS and CoCoSo techniques. This study may be extended by considering other MCDM methods, like AHP, CRITIC, Entropy, TOPSIS, COPRAS, VIKOR, MOORA, etc.
2. The application of WASPAS and CoCOSO methods only considers two numerical examples: sustainable hospital site selection [215] and state of India ranking based on women empowerment [216]. In future, we shall apply other fields and stability analyses to the results.
3. In future research, we can evaluate the results in various uncertain environments, like fuzzy numbers, intuitionistic fuzzy numbers, neutrosophic numbers, grey numbers, etc.
4. In future, we shall review the other MCDM methods and conduct a comparative study on them.

Acronyms or Abbreviations: The following acronyms or abbreviations were used in this study:

Acronyms	**:**	**Full Name**
3PL	:	Third-party logistics
3PRLP	:	Third-party reverse logistics providers
AHP	:	Analytic Hierarchy Process
ANP	:	Analytic Network Process
ARAS	:	Additive Ratio Assessment
ASCF	:	Agricultural supply chain finance
BCM	:	Base Criterion Method
BWM	:	Best Worst Method
CILOS	:	Criterion Impact LOSs
COA	:	Center of Area
CODAS	:	COmbinative Distance-based ASsessment
CHP	:	Combined Heat and Power
CoCoSo	:	Combined Compromise Solution
COG	:	Center of Gravity
COMSAM	:	Comprehensive Sensitivity Analysis Method
COPRAS	:	Complex Proportional Assessment
COVID-19	:	Coronavirus disease 2019
CRITIC	:	CRiteria Importance Through Inter-criteria Correlation
DEA	:	Data Envelopment Analysis
DEMATEL	:	Decision-making Trial and Evaluation Laboratory
EDAS	:	Evaluation based on Distance from Average Solution
ELECTRE	:	ÉLimination Et Choix Traduisant la REalité
ES	:	Emergency services
EU	:	European Union
EURO	:	European Operational Research Societies
EXPROM	:	EXtension of the PROMethee
FFS	:	Fermatean fuzzy sets
FMEA	:	Failure Mode and Effect Analysis
FUCOM	:	Full Consistency Method
HCW	:	Healthcare waste
HFS	:	Hesitant fuzzy set
HSCMB	:	Humanitarian supply chain management barriers

Acronyms	**:**	**Full Name**
IDOCRIW	:	Integrated Determination of Objective Criteria Weights
IFS	:	Intuitionistic fuzzy set
IP	:	Infrastructure projects
IT2FS	:	Involving interval type-2 fuzzy sets
IVFNN	:	Interval-valued fuzzy neutrosophic number
IVIFS	:	Interval-valued intuitionistic fuzzy set
KEMIRA	:	KEmeny Median Indicator Ranks Accordance
LBWA	:	Level Based Weight Assessment
LMAW	:	Logarithm methodology of additive weights
LOPCOW	:	Logarithmic Percentage Change-Driven Objective Weighting
MABAC	:	Multi-Attributive Border Approximation area Comparison
MACBETH	:	Measuring Attractiveness by a Categorical Based Evaluation Technique
MADM	:	Multi-attribute decision-making
MCDM	:	Multi-criteria decision making
mGqNNs	:	$m-$generalized $q-$neutrosophic sets
MOORA	:	Multi-Objective Optimization on the Basis of Ratio Analysis
MULTIMOORA	:	Multiplicative Multi-objective Optimization by Ratio Analysis
PIPRECIA	:	PIvot Pairwise RElative Criteria Importance Assessment
PIV	:	Proximity index value
PROMETHEE	:	Preference Ranking for Organization Method for Enrichment Evaluation
q-ROFS	:	q-rung orthopair fuzzy set
q-ROFEA	:	q-rung orthopair fuzzy Einstein average
QFD	:	Quality Function Deployment
QoS	:	Quality of Service
RPR	:	Relative preference alternative
SAW	:	Simple additive weighting
SCM	:	Supply chain management
SECA	:	Simultaneous Evaluation of Criteria and Alternatives
SERVQUAL	:	Service quality measurement model
SFS	:	Spherical fuzzy sets
SOFC	:	Solid Oxide Fuel Cell
SSS	:	Sustainability supplier selection
SVNS	:	Single-valued neutrophil set
SWARA	:	Stepwise Weight Assessment Ratio Analysis
SWOC	:	Strengths weaknesses opportunities challenges
TCSP	:	Trustworthy Cloud Service Providers
TODIM	:	TOmada de Decisão Iterativa Multicritério
TOPSIS	:	Technique for Order Preference by Similarity to Ideal Solution
VIKOR	:	VIšekriterijumsko KOmpromisno Rangiranje
WAAM	:	Wire Arc Additive Manufacturing
WAM	:	Weighted average method
WASPAS	:	Weighted Aggregated Sum Product Assessment
WISP	:	Simple Weighted Sum Product
WPM	:	Weighted product model
WSM	:	Weighted sum model

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