## Multi-Criteria Decision Making (MCDM) Methods and Concepts

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Multi-criteria decision-making (MCDM) is one of the main decision-making problems which aims to determine the best alternative by considering more than one criterion in the selection process. MCDM has manifold tools and methods that can be applied in different fields from finance to engineering design. This entry aims to provide a survey on the MCDM concept, its applications, main categories, and different methods. The final section provides manifold information and statistics on the published works in the MCDM fields. Some of the main methods are also listed in this section.

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There is no decision that can be addressed without referring to the decision-making process. Decision-making, as a mental complex process, is a problem-solving program that aims to determine a desirable result considering different aspects. This process can be rational or irrational, and on the other hand, it can use implicit or explicit assumptions that are influenced by several factors such as physiological, biological, cultural, social, etc. All these aspects together with authority and risk levels can affect the complexity level of a decision-making process. Nowadays, complex decision-making problems can be solved by utilizing mathematical equations, manifold statistics, mathematics, economic theories, and computer devices that help to calculate and estimate the solutions to decision-making problems automatically.

Multi-Criteria Decision Making (MCDM) or Multi-Criteria Decision Analysis (MCDA), is one of the most accurate methods of decision-making, and it can be known as a revolution in this field <sup>[1][2]</sup>. One of the first research studies on multi-criteria decision-making was developed by Benjamin Franklin when he published his research on the moral algebra concept. Several empirical and theoretical scientists have worked on MCDM methods to examine the mathematical modeling capability of these methods since the 1950s to provide a framework that can help to structure decision-making problems and generate preferences from alternatives. MCDM includes different methods that differ from each other in different aspects which will be discussed in the next sections <sup>[3]</sup>.

This method considers different qualitative and quantitative criteria that need to be fixed to find the best solution. For example, cost or price and quality of the processes are among the most common criteria in many decisionmaking problems <sup>[4]</sup>. In addition, in these problems, expert groups provide different weights to the criteria that are based on the importance of each criterion in that specific case.

MCDM can be used for everyday problems in human lives. Still, when the problem is based on the more important subjects, for example in capital levels, the evaluation of criteria is an important issue. Therefore, in these situations,

decision-making needs to be based on proper structuring and explicit evaluation of all the criteria using appropriate software and tools. Practically, MCDM is used to deal with structuring, decision-making, and planning steps when the domain possesses manifold criteria to reach an optimum solution based on the deciders' preferences <sup>[4]</sup>.

There are several types of MCDDM methods that are developed or improved by different authors during the last decades. The main differences between these methods are related to the complexity level of algorithms, the weighting methods for criteria, the way of representing preferences evaluation criteria, uncertain data possibility, and finally, data aggregation type <sup>[5]</sup>.

In addition, all different types of MCDM possess specific and different merits and demerits that are expected to be explained specifically based on the methods. For example, Analytic Hierarchy Process (AHP) is easy to use and faces issues due to the interdependence between criteria and alternatives. On the other hand, in Fuzzy Set Theory (FST) using imprecise input is possible; however, this method is not easy to develop. In general, all MCDM methods have the advantage of considering decisions' disproportionate and contradictory impacts. On the negative side, the solutions that are generated by these methods are a compromise among several goals and this leads to not obtaining the optimal point due to the nature of the problem <sup>[3]</sup>.

MCDM possesses manifold applications in different disciplines and areas ranging from economics and finance to engineering design and medicine. A recent article by Pramanik et al. <sup>[6]</sup> provided a comprehensive review of the application of different MCDM methods. A summary of their results is listed in **Table 1**.

Application Fields	Examples of the Application Focus
Healthcare	The assessment of COVID-19 regional safety, occupational health, and safety risk assessment
Energy sector	Ranking renewable energy sources, techniques for energy policy
Engineering and Production	Engineering, material selection for optimal design, Optimum Process Parameters
Career and Job	Occupational stressors among firefighters, personnel selection problems, Job Choice
Supply chain management	Supporting sustainable supplier selection, green supplier evaluation, and selection
Organizations and corporates	System Selection Process in Enterprises, corporate sustainability
Education	Contextual Learner Modelling in Personalized and Ubiquitous Learning, E- learning
Transportation	Urban passenger transport systems, integrated transportation systems

Table 1. Applications of MCDM <sup>[6]</sup>.

Application Fields	Examples of the Application Focus	
Civil Engineering	Flood disaster risk analysis	
Finance/economics	Project portfolio management	log

anyone interested in learning about and working in decision-making. After gaining an overview of the MCDM concept and its applications, the following sections are provided to discuss MCDM problems more specifically. For this, <u>Section 2</u> will simply introduce the mathematical form of these methods, then different classifications of MCDM methods will be discussed in <u>Section 3</u>. Finally, the published articles on multi-criteria decision-making will be investigated, and some methods will be listed in the final section.

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