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Analytic Network Process (ANP) Method: A Thorough Examination of Uses, Benefits, and Drawbacks

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Abstract: These days, there are several uses for multi-criteria decision-making (MCDM) techniques in a variety of fields, including supply chain, management, and engineering. One of the most popular MCDM techniques is the analytic network process (ANP) method. An expanded form of the analytic hierarchy process, ANP facilitates interactions and feedback both within and between clusters, making it a more complete tool for decision-making. The concept, phases in the process, application areas, benefits, and drawbacks of the ANP approach are all thoroughly reviewed in this study. ANP has been used to solve a variety of decision-making issues, such as supplier selection, project management, risk assessment, and product design. The capacity to manage intricate decision-making issues including several criteria, subjective inputs, and interdependent relationships among criteria is one of ANP's primary advantages. In order to assist researchers and practitioners in making better judgments while utilizing the ANP method, this study attempts to present a thorough explanation of the strategy.

Keywords: Decision-making, Multi-criteria decision-making, Analytic network process, ANP method,

Multi-attribute decision-making.

1. Introduction

The enormous increase in the complexity of the decisions that businesses must make in order to survive and achieve their competitive objectives has had a significant impact on organizational decision-making processes (Dias & Mousseau, 2018). Decision-makers typically find themselves in a situation where multiple companies have expressed multiple goals, each of which then explodes into multiple criteria and options (Toloie-Eshlaghy & Homayonfar, 2011). This has led to the development of a more clear form of the decision-making process. The decision-maker must now look for new approaches and methodologies that help and support them in the decision-making process, as they can no longer rely just on an estimate or intuition of an examination of the possibilities (Greco et al., 2016).

Growing environmental concerns during the 1980s led to a change in the way decisions were made based on individual factors (Taherdoost & Brard, 2019; Wang et al., 2009). Because of this, environmental preservation considers more factors than only economic ones, which forces decision-makers to employ multi-criteria decision-making (MCDM) methodologies in order to identify practical answers to energy-related problems (Büyüközkan et al., 2018).

Researchers in a variety of disciplines, including business, science, engineering, and finance, have recently begun using MCDM methodologies. These techniques are applied to rank, sort, assess, and choose among several options (Kheybari et al., 2020). Many MCDM techniques have been created, and even minor changes to current techniques have allowed MCDM to be used in various contexts (Velasquez & Hester, 2013).
The analytic network process (ANP) approach is one of the primary MCDM methodologies. ANP is a new, deeper, and more comprehensive version of Saaty's (1980) analytic hierarchy process (AHP) method. Even for uncertain judgments with varying numbers of alternatives, AHP is a comprehensive approach that can handle a wide range of multi-objective, multi-actor, and multi-criteria problems (Bayazıt, 2002; Velasquez & Hester, 2013). Despite addressing many of the shortcomings of some other MCDM systems, AHP assumes the factors individually and ignores any relationships between them. In certain internal and external environmental consequences, this assumption is inappropriate. These problems must be founded on network systems with functional dependencies allowing for feedback among the clusters and high-level factors depending on low-level ones (Yüksel & Dagdeviren, 2007).

In a 1996 book that was updated in 2001, Saaty (1996) expanded AHP as the ANP approach in order to address this. Because ANP permits interactions and feedback between and within the clusters, it can be applied to extremely complex MCDM issues. As a result, ANP enables decision-making systems to handle feedback and reliance in a methodical manner. It is a broader version of AHP that takes interactions into account, enabling the intricate linkages between various qualities and decision-making levels.

In ANP, a feedback technique takes the role of linear top-to-bottom hierarchy systems. In ANP, the significance of the alternatives can affect the significance of the criteria, in contrast to the hierarchy where only the criteria affect the alternatives' importance. Consequently, it is impossible to simply depict interactions between levels using terms like

dominant/subordinate, higher/lower, and direct/indirect (Yüksel & Dagdeviren, 2007). There are two components to the ANP:

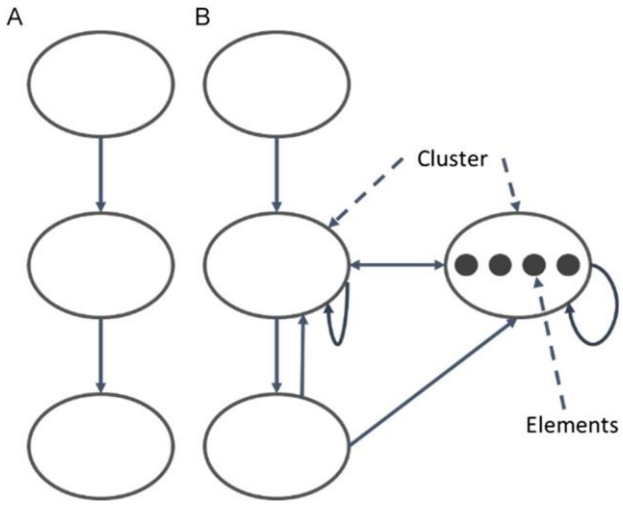
• The first component is the control hierarchy, which is a network of criteria and sub-criteria designed to regulate the interactions of the understudy system;A network of influences between the elements and clusters makes up the second section.

A control hierarchy/network for benefits, a second one for opportunities, a third for costs, and a fourth for risks (BOCR) are used to study decision problems in the 2001 revision of the ANP technique. A decision using this method has elements, linkages, and clusters. Within a network or sub-network, the clusters are a collection of pertinent pieces. For every control criterion—opportunities, rewards, risks, and costs—the system's clusters and their components are computed.

Inner and outer dependencies, which are connected to all of the feedback and interactions within and between clusters, respectively, are another key idea in these systems. These ideas aid in illustrating and encapsulating the ideas of influencing and being influenced by both clusters and components associated with a decision-making criterion (Bayazıt, 2002; Saaty & Vargas, 2013). To sum up, in ANP, a network is used to depict a system with feedback. Figure 1 clearly illustrates the distinctions between the hierarchy structure in the AHP approach and the network architecture in ANP. In a network, it is evident that the components of one cluster can influence all or a subset of the components in any other cluster. Arcs are utilized to illustrate the relationships inside a network, which consists of sources, intermediates, and clusters. Here, the directional dependency is affected by the arcs' directions. Additionally, the inner (among elements of a cluster) and outer (between two clusters) dependencies are depicted by looped arcs and two-way arrows, respectively (Yüksel & Dagdeviren, 2007).
Because it takes into account the intricate and interconnected links between the components of decision-making problems, the ANP technique is now frequently used to handle a wide range of real-world difficulties. Additionally, both qualitative and quantitative qualities can be applied simultaneously using this method (Kheybari et al., 2020).

This paper's goal is to provide a thorough analysis of the ANP technique, covering its core idea, steps in the process, application domains, advantages, and disadvantages. In decision-making situations like project management, risk assessment, supplier selection, and product design, the ANP methodology has found widespread use. Among ANP's.

Figure 1 shows the structures of a network and a hierarchy.



Its capacity to handle complex decision-making scenarios comprising several criteria, subjective input, and interdependent relationships among criteria is one of its main advantages. In order to help academics and practitioners make better judgments while using the ANP approach, this study aims to provide a thorough understanding of the strategy.

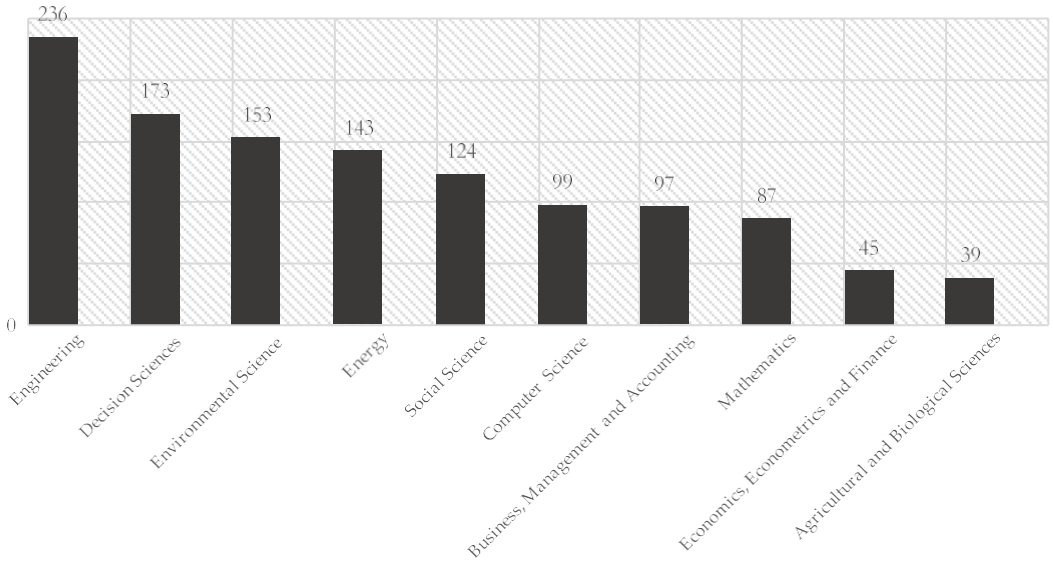
2. ANP applications

Most human tasks require making decisions. Each of these choices is based on an examination of the several possibilities

available to the decision-maker, which is usually based on their preferences, background, and other knowledge (Sałabun et al., 2020). While some choices are simple, others require more thought (Behzadian et al., 2012). While some judgments are quite difficult and have major ramifications, others are rather straightforward, especially if the consequences of making the wrong choice are little (Govindan and Jepsen, 2016; Kahraman et al., 2015). Real-life problem-solving generally comprises numerous conflicting opinions that, to arrive at a sensible decision, need to be taken into consideration (Wang et al., 2008). According to formal definitions, a decision can be defined as either a plan of action intended to handle a specific decision issue or a choice made in light of the facts at hand (Greco et al., 2016).

MCDM has numerous applications in a variety of sectors, including engineering design, medical, finance, and economics. The multifaceted nature of this crisis and the intricacy of the socioeconomic and health systems have led to a greater usage of MCDM techniques to model COVID-19 problems. It should be emphasized that the development of sustainable solutions is directly impacted by MCDM tactics. This demonstrates the importance of MCDM techniques and their rapid growth. Numerous industries, including the business and energy sectors, use MCDM methodologies. MCDM techniques are used in a number of academic fields, such as computer science, energy, mathematics, etc. (Taherdoost & Madanchian, 2023). In a similar vein, there are numerous application areas for the ANP approach. Numerous industries, including engineering, manufacturing, supply chain management, waste management, civil works, economics, construction, agriculture, finance, and healthcare, can benefit from this approach (Chen et al., 2019; Khan & Ali, 2020). Figure 2 illustrates the number of publications that applied the ANP approach in various subject areas in the "ScienceDirect" database as of May 21, 2022, to provide a more comprehensive and general understanding of the ANP application fields. The search phrase "ANALYTIC NETWORK PROCESS" in the title, abstract, or author-specified keywords was used to locate the research publications. The graphic displays the subject regions for the obtained results. The findings demonstrate the ANP's wide range of application in disciplines like environmental science, engineering, and decision-making.

Figure 2: Subjects areas of ANP research articles



Using nine distinct categories, Kheybari et al. (2020) examined the ANP method's areas of use in greater detail. To give you an idea of how this method is used in various fields, some of the findings are shown in Table 1. It should be mentioned that while ANP is used as a single method in some studies, it is also used in others as part of integrated or hybrid approaches that combine ANP with other MCDM techniques, such as the decision-making trial and evaluation laboratory (DEMATEL) and the technique for order of preference by similarity to ideal solution (TOPSIS).

Table 1: ANP method application areas (Kheybari et al., 2020)

No.	Category	Examples of specific areas	Description
1	Health, safety, and environmental management	financial management	• Assessing safety management in airlines, maritime industry, and construction industry; • Selecting the best place for waste disposal; • Selecting the best method for recycling wastes • Etc.
2	Hydrology and water management		• Evaluating and prioritizing watershed plans; • Vulnerability assessment of water supply systems; • Etc.
3	Business and		

		• Assessing performance of airlines, research, and development (R&D) projects, hospital services, banking industry; • Selecting information system, R&D, and power projects; • Ranking mining strategies; • Evaluating information security risks; • Assessing industrial lands in urban areas; • Studying the factors impacting the economic performance of businesses; • Etc.	Articles in the fields of waste management life cycle management, environmental impact assessment, and land-use planning Articles based on water management strategy assessment, irrigation planning, and sustainable water resource planning fields Articles in the main aspects of management, for example, measurement of performance, analysis of investments, portfolio management, etc.
4	Tourism	• Investigating the factors impacting the medical tourism development; • Assessing ecotourism sites • Assessing and ranking the national park websites; • Etc.	Articles related to tourism and hotel related to tourism, pilgrimage, and medicine, policies related to tourism and hotel industries, etc.
5	Logistics and supply chain management	• Select suppliers in different industries such as the automotive industry, electronic companies, and manufacturing companies	Related to the location problems, outsourcing and supplier selection in various fields
6	Design, engineering, and manufacturing systems	• Prioritizing and ranking the requirements for design in companies; • Investigating the most vital product components at the design stage by considering the resource constraints in manufacturing companies; • Etc.	Related to automation, material engineering, product design, modern manufacturing systems, etc.
7	Energy management	• Selecting a strategy for risk reduction in the energy industry; • Studying the important factors to determine the location of power plants; • Etc.	Related to assessment and selection of the methods of energy generation, the energy systems' performance assessment, etc.
8	Human resources management	• Selecting snipers and personnel for different companies	Related to the employment of candidates
9	Other topics	• Assessing the innovation support systems performance in different sectors such as higher education institutions; • Ranking the systems used for performance improvement in universities; • Etc.	Related to areas such as medicine, sports, education, agriculture, and government

3. Advantages and Disadvantages

According An extension of the AHP approach that focuses on a networked-structure format is the ANP. Similar to other MCDM techniques, the ANP has a variety of benefits and drawbacks. Table 2 provides a summary of the primary ones.

Table 2: Merits and demerits of the ANP method (Aruldoss et al., 2013; Velasquez & Hester, 2013)

Advantages	Disadvantages
• Handling multiple inputs and outputs; • No need for relations between outputs and inputs; • Possibility of different units for inputs and outputs; • Directly comparisons against peers; • Both allowing for dependence and including independence; • The ability to prioritize clusters/groups of elements; • Supporting complex problems with intangible criteria better than AHP.	• Ignoring different effects among clusters; • Possibility of significant problems due to the measurement error; • Being demanding in the case of large problems; • Disability to measure absolute efficiency; • Inapplicability of statistical tests

4. The ANP Method Procedure

There are four primary steps in the ANP technique approach. Figure 3 illustrates these steps, which are also thoroughly covered in this section.

Step 1: Model Construction and Problem Structure

The problem network's structure can be obtained by the decision-makers using a variety of techniques, including brainstorming.

Step 2: Getting the Priority Vectors and Pairwise Comparison Matrices Ready
Priority vectors and pairwise comparison matrices ought to be created in the second phase. In order to do this, each cluster's element pairings must be compared, taking into account how important each element is in relation to its control criteria. The AHP comparison step and this step are comparable. Additionally, the clusters' contributions to the goal must be taken into account when comparing them pairwise. In order to evaluate their contribution to the particular criteria of their upper level, this phase entails answering pairwise comparison series (between two clusters or two elements). Furthermore, additional pairwise analyses are required to determine the interdependencies between the components of a cluster. Each element's influence on the others is represented by an eigenvector.

In the ANP technique, decision-makers can also utilize the basic AHP comparison scale (1–9) to estimate the relative importance values by taking into account the linked criterion and to determine the frequency with which one factor dominates another. Additionally, it can be utilized to intuitively incorporate decision-makers' knowledge and expertise. Rather of using ratios, intervals, or ordinals, this scale use absolute numbers (Bayazıt, 2002). Decision-makers' descriptive preferences can be converted into numerical values using this method. This table, for instance, uses 1 to indicate that the components are equally important, and 9 to indicate that one element in the matrix—the row cluster—is extremely important in relation to another element, the column cluster. The 1–9 scale utilized in this procedure is displayed in Table 3.

Table 3: The fundamental 1–9 Scale (Saaty, 1996)

Intensity of importance	Explanation	Definition
1	Two activities contribute equally to the objective	Equal importance
3	Experience and judgment slightly favor one over another	Moderate importance
5	Experience and judgment strongly favor one over another	Strong importance
7	Activity is strongly favored, and its dominance is demonstrated in practice	Very strong importance
9	The highest possible order for the importance of one factor over another one is considered	Absolute importance
2, 4, 6, 8 values	Compromising between the above priorities	Intermediate

This step involves structuring the problem and building the model. The decision-maker should do this by clearly stating the issue and breaking it down into a network of logical systems.

The ith element's importance is represented by factor, and the jth element's importance is represented by aji. The pairwise comparisons are displayed using a matrix in the ANP approach, which is comparable to the AHP. Local relatives have long-term effects on one another. Raising the former matrix to exponential powers is advised for this. For this reason, many values (k, 2k + 1, etc.) are recommended. To bring all the elements of the weighted super-matrix together, for instance, apply equation (4). Keep in mind that the operations continue until all of the super-matrix's elements are the same.

5. Conclusions

To sum up, the ANP approach is a flexible and broadly used MCDM technique that has several benefits over other comparable approaches, including AHP. The purpose of this work was to present a thorough analysis of the ANP approach, highlighting its salient characteristics and advantages. We illustrated the potential of the ANP approach in a number of domains by going over the application areas and offering a few research examples. We also talked about the method's benefits and drawbacks, emphasizing its advantages—like the ability to compare directly with peers—and disadvantages—like the difficulty to quantify absolute efficiency. This paper outlined the four primary steps that make up the ANP approach. These procedures include of the problem's structure, network design, priority synthesis, and sensitivity analysis. In order to guarantee accurate and trustworthy outcomes, each of these steps is essential to the ANP approach and needs to be carefully studied. All things considered, the ANP method provides a strong and adaptable approach to MCDM that could greatly enhance decision-making procedures across a variety of industries. As a result, it is a valuable resource for scholars and professionals looking to improve their capacity to make wise choices in challenging and unpredictable situations.

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