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# APPLICATION OF TOPSIS IN CIVIL ENGINEERING- A REVIEW

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**Abstract**

The real world has many problems to be solved, including selection decisions, and one initial step is to identify problem characteristics and obtain their measures. This is termed as modelling process. TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is a prominent distance-based MCDM/MADM (multi-criteria or multi-attribute decision making) technique. TOPSIS is a useful technique to handle real world MCDM problems. It helps decision maker(s) (DMs) conduct analysis, comparisons, and rankings of available alternatives when multiple criteria are involved. This paper will review its origin followed by developments in various fields of civil engineering.

## I. Introduction

The Technique for Order of Preference by Similarity to Ideal Solution is a multi-criteria decision analysis method. It selects the alternative that is closest to the ideal solution and farthest from the negative-ideal solution. The method calculates the geometric proximity between each option and the ideal/negative-ideal solutions. The optimal alternative has the minimal distance from the ideal solution and the maximal distance from the negative-ideal solution. TOPSIS is used across diverse fields, including business analytics (Fox & Everton, 2013), customer satisfaction evaluation (Zong, 2011), and group decision-making(Shih et al., 2007). TOPSIS is also applied in different sectors of civil engineering.

The TOPSIS method involves several key steps. Initially, a decision matrix is formed, with each row representing an alternative and each column denoting an attribute or criterion. The decision matrix is then normalized to account for different measurement scales among the criteria. Next, the positive-ideal and negative-ideal solutions are identified, which represent the best and worst possible outcomes for each criterion, respectively.

The TOPSIS has emerged as a prominent multi-criteria decision-making method in the past few decades. Originating in the late 1970s, the TOPSIS approach has been widely adopted across diverse domains, including higher education, pharmaceuticals, water resources management , manufacturing, agriculture, and renewable energy (Krishnan et al., 2023).

While TOPSIS shares similarities with other MCDM techniques, it offers unique features that have contributed to its widespread adoption. For instance, TOPSIS does not require normalization, which can introduce distortions in the data, and it can handle non-monotonic criteria, providing greater flexibility in decision-making(Chen & Lee, 2010).

Ultimately, the widespread adoption of TOPSIS in multi-criteria decision-making can be attributed to its intuitive and logical approach, its ability to handle complex and conflicting criteria, and its proven track record in delivering robust and reliable results across a diverse range of industries and applications.

## II. TOPSIS Algorithm

➢ **Steps involved in the TOPSIS method**

The TOPSIS method is a widely adopted multi-criteria decision-making method that provides a systematic and comprehensive approach to evaluating and ranking alternatives based on their relative proximity to the ideal solution. The TOPSIS method offers a unique perspective by simultaneously considering the distances to both the positive and negative ideal solutions, allowing decision-makers to make informed choices that balance the trade-offs between different criteria.

The TOPSIS method typically involves the following steps ("Decision Support System Best Employee Assessments with Technique for Order of Preference by Similarity to Ideal Solution," 2017) (Shih et al., 2007).

i. Establish the Decision Matrix- The first step in the TOPSIS process is to construct a decision matrix that represents the performance of each alternative across multiple criteria.

ii. Normalize the Decision Matrix- To ensure that the different criteria are on a comparable scale, the decision matrix is normalized using various techniques, such as vector normalization or linear normalization(Krishnan et al., 2023).

iii. Determine the Ideal and Negative-Ideal Solutions- Subsequently, the ideal solution, which encapsulates the optimal values for each criterion, and the negative-ideal solution, which encompasses the least desirable values, are identified(Krishnan et al., 2023).

iv. Next, the separation of each alternative from the ideal and negative-ideal solutions is calculated using the Euclidean distance measure, which quantifies the geometric distance between the alternative and the ideal/negative-ideal solutions.

v. The final step entails calculating the relative proximity of each alternative to the ideal solution, which reflects the overall performance of the alternative. The alternative demonstrating the greatest relative closeness is deemed the most preferred option.

The TOPSIS method's strength lies in its ability to provide a clear and objective ranking of alternatives based on their relative performance, making it a popular choice for a wide range of decision-making scenarios, including resource allocation, product selection, and personnel evaluation.

## ➢ Advantages and limitations

The TOPSIS method is a widely adopted multi-criteria decision-making technique that aims to select the most favourable alternative from a set of options based on the relative proximity of each alternative to the ideal solution. The fundamental principle underlying TOPSIS is that the preferred alternative should demonstrate the shortest Euclidean distance from the positive ideal solution and the greatest Euclidean distance from the negative ideal solution.

One of the key advantages of TOPSIS is its simplicity and ease of implementation. The method is straightforward and can be easily understood and applied by decision-makers, making it a popular choice in various fields. Additionally, TOPSIS takes into account both the distance to the positive ideal solution and the distance to the negative ideal solution, providing a more comprehensive evaluation of the alternatives(Shih et al., 2007).

Another advantage of TOPSIS is its ability to handle both qualitative and quantitative criteria, making it a versatile tool for decision-making. TOPSIS has been successfully applied in a wide range of domains, including water resources management, renewable energy, higher education, manufacturing, agriculture, and pharmaceutical industries, among others (Krishnan et al., 2023).

However, TOPSIS is not without its limitations. One of the main limitations is its sensitivity to the scaling of the decision matrix.

The relative importance of the criteria can also significantly impact the final ranking of the alternatives, and determining the appropriate weights for the criteria can be a challenging task. Additionally, TOPSIS assumes that the criteria are independent and does not consider the interdependence between them, which can be a limitation in some real-world decision- making scenarios(Liu & Zhang, 2013).

## III. Applications in civil engineering

### ➢ Application of TOPSIS in Structural Engineering

TOPSIS is a multi-criteria decision-making method that has found various applications in the field of structural engineering, particularly in material selection and structural design optimization. The technique has the ability to identify the best alternative from a finite set of alternatives by comparing their geometric distances from the positive-ideal and negative-ideal solutions.

In the context of structural engineering, TOPSIS can be used to evaluate and select the most suitable materials for construction, such as steel, concrete, or composites, based on criteria like strength, durability, cost, and environmental impact.

TOPSIS has also been successfully applied to optimize the design of structural systems, including trusses, beams, and frames. By considering multiple objectives, such as minimizing weight, maximizing strength, and ensuring cost-effectiveness, TOPSIS can help engineers arrive at the optimal design solution that balances these competing requirements.

### ➢ Application of TOPSIS in Geotechnical engineering

Geotechnical engineering is a critical field that encompasses the design, construction, and maintenance of structures built upon or within the earth's surface. One of the key challenges in geotechnical engineering is decision-making, particularly in areas such as site selection and foundation type selection. The Technique for Order of Preference by Similarity to Ideal Solution is a multi-criteria decision-making method that can be effectively applied to address these challenges.

In the context of geotechnical engineering, TOPSIS can be used to evaluate and select the most suitable site for infrastructure development, considering factors such as soil type, groundwater conditions, and accessibility(Shih et al., 2007). Additionally, TOPSIS can be employed to determine the optimal foundation type for a given structure, taking into account criteria like load-bearing capacity, cost, and environmental impact(Yadav et al., 2018).

In conclusion, the TOPSIS method has proven to be a valuable tool for decision-making in geotechnical engineering, particularly in the areas of site selection and foundation type selection. Its ability to simultaneously consider multiple criteria, while accounting for the decision-maker's risk attitude, makes it a robust and reliable approach for addressing complex problems in the field.

- **Application of TOPSIS in Transportation engineering**

Transportation engineering is a crucial field that encompasses various aspects of infrastructure planning, design, and management. One of the key decision-making tools utilized in this domain is the Technique for Order Preference by Similarity to Ideal Solution. , a multi-criteria decision analysis method(Shih et al., 2007).TOPSIS has been extensively applied in transportation engineering, particularly in areas such as route selection and pavement material selection.

TOPSIS has been utilized in the selection of pavement materials for road construction and maintenance. Factors such as cost, durability, skid resistance, and environmental sustainability can be considered in the decision-making process, allowing engineers to select the most suitable pavement material for a specific project.

The application of TOPSIS in transportation engineering has been demonstrated in various studies. Researchers have highlighted the versatility of TOPSIS in evaluating different alternatives and prioritizing them based on multiple criteria, making it a valuable tool for transportation decision-makers.

- **Application of TOPSIS in Construction Management**

The construction industry is a complex and dynamic field that requires robust decision- making processes to ensure the successful delivery of projects. One technique that has been gaining prominence in construction management is the Technique for Order Preference by Similarity to Ideal Solution, a multi-criteria decision-making method that has been applied in various industries(Yadav et al., 2018).

TOPSIS is a versatile tool that can be used to address a wide range of construction management challenges, such as contractor selection and project risk assessment. In the case of contractor selection, TOPSIS can be used to evaluate and rank potential contractors based on a set of criteria, such as technical expertise, financial stability, and past performance. , This approach allows construction managers to make informed decisions and select the most suitable contractor for a given project.

The application of TOPSIS in construction management is not limited to these examples. It has also been used in areas such as resource allocation, project portfolio selection, and supply chain optimization. , As the construction industry continues to evolve, the use of TOPSIS and other advanced decision-making tools will become increasingly important in ensuring the efficient and effective management of construction projects.

**Application of TOPSIS in Environmental engineering**

Environmental engineering is a vital field that encompasses various aspects of preserving and protecting the natural environment, including waste management, sustainable design, and resource conservation. In the context of environmental engineering, TOPSIS can be a valuable tool for decision-making processes, such as evaluating waste management strategies, sustainable design options, or resource allocation.

For instance, TOPSIS can be used to assess different waste management alternatives, taking into account factors such as environmental impact, cost, and social acceptability. By comparing the relative performance of the alternatives, decision-makers can identify the most suitable option that balances various considerations.

Moreover, TOPSIS can be employed in the development of sustainable design frameworks for environmental engineering projects. By incorporating multiple criteria, such as energy efficiency, material use, and environmental impact, TOPSIS can help identify the most sustainable design alternative from a set of options.

➢ **Application of TOPSIS in Water Resources Engineering**

TOPSIS is a widely used multi-criteria decision-making method that has found numerous applications in the field of water resources management. The use of TOPSIS in water resources management is well-documented in the literature. For example, TOPSIS has been used to evaluate the performance of different water supply systems, taking into account criteria such as cost, reliability, and environmental impact.Furthermore, the technique has been extended to group decision-making environments, where it can be used to incorporate the preferences of multiple stakeholders in the decision-making process(Fox & Everton, 2013).

In the context of reservoir operation, TOPSIS can be used to determine optimal release strategies that balance competing objectives, such as water supply, flood control, and hydropower generation. The method can also be applied to the evaluation of alternative water management policies, allowing decision-makers to identify the most suitable course of action.

The application of TOPSIS in water resources management has several advantages. The technique is relatively straightforward to implement, making it accessible to a wide range of decision-makers. Additionally, the method provides a transparent and logical approach to decision-making, which can be useful in gaining stakeholder buy-in and ensuring the accountability of the decision-making process(Yadav et al., 2018).

## IV. Recent developments and modifications

The field of multi-criteria decision-making has witnessed a remarkable evolution in recent years, with the introduction of innovative approaches to address the complexities inherent in real-world decision-making problems. One such notable development is the TOPSIS, which has gained significant attention due to its ability to effectively handle uncertain and ambiguous data(Krohling & Campanharo, 2011).

The conventional TOPSIS method, although widely applied, has been recognized as limited in its capacity to address the inherent vagueness and imprecision often present in decision- making scenarios. To address this limitation, researchers have proposed the Fuzzy TOPSIS approach, which integrates the principles of fuzzy set theory with the TOPSIS methodology.

The integration of fuzzy logic into the TOPSIS framework allows for the effective handling of linguistic variables and subjective judgments, which are commonly encountered in decision-making processes. This enhances the decision-maker's ability to capture the nuances of the problem and make more informed and reliable decisions.

In recent years, several studies have focused on the development and modification of the Fuzzy TOPSIS method to further enhance its applicability and robustness. For instance, a study by introduced a novel decision-making strategy, the OOPCS, which incorporates modifications to the traditional TOPSIS approach for handling fuzzy hypersoft sets in interval settings. Another study by proposed a Fuzzy TOPSIS for group decision-making, which

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considers the weight of each decision-maker to mitigate the impact of errors and inconsistencies(Gitinavard et al., 2017).

Furthermore, the work by explored the use of hesitant fuzzy information in a hierarchical multi-criteria group decision-making context, utilizing the Fuzzy TOPSIS methodology. These advancements demonstrate the ongoing efforts to refine and adapt the Fuzzy TOPSIS approach to tackle increasingly complex decision-making problems.

The evolution of Fuzzy TOPSIS has been driven by the need to address the inherent uncertainties and subjectivities inherent in real-world decision-making scenarios. The integration of fuzzy set theory has enabled the decision-makers to incorporate linguistic variables and subjective judgments, leading to more accurate and reliable decision-making processes.

## V. Current Limitations in Civil Engineering Applications of TOPSIS

The Technique for Order of Preference by Similarity to Ideal Solution is a widely-adopted multi-criteria decision-making method that has found numerous applications in the field of civil engineering, where decision-makers are often faced with complex problems involving the evaluation and selection of alternatives based on a set of conflicting criteria(Frija et al., 2021). While TOPSIS has been successfully utilized in various civil engineering domains, such as water resources management, renewable energy, and infrastructure planning, the method is not without its limitations, which merit further investigation and discussion.

## VI. Potential areas for improvement and expansion of TOPSIS

TOPSIS is a widely adopted multi-criteria decision-making method that has been extensively utilized across various fields, from engineering and management to social sciences and public policy. While the technique has demonstrated its effectiveness, there are opportunities for further enhancement and expansion to address emerging challenges and user needs.

One potential area for improvement is the normalization of the decision matrix. The choice of normalization technique can impact the final ranking of alternatives, and more research is needed to offer conclusive recommendations on suitable benefit/cost criteria-based normalization methods. Additionally, extending TOPSIS to a group decision-making environment could enhance its applicability in real-world scenarios where multiple stakeholders are involved in the decision-making process(Shih et al., 2007).

## VII. Summary of TOPSIS effectiveness in civil engineering decision-making

The Technique for Order Preference by Similarity to Ideal Solution has emerged as a widely adopted multi-criteria decision-making approach in various industries, including civil engineering. The method's ability to identify the optimal alternative by considering both the positive-ideal and negative-ideal solutions has made it a popular choice for solving complex decision-making problems.

In the field of civil engineering, TOPSIS has been successfully applied to a diverse range of applications, such as water resources management, renewable energy, and manufacturing. The technique's straightforward approach and suitability for handling a large number of criteria and alternatives make it an attractive option for civil engineers tasked with evaluating and prioritizing different design, construction, or infrastructure options(Frija et al., 2021).

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One of the key advantages of TOPSIS in civil engineering decision-making is its ability to quantify the relative performance of alternatives based on their proximity to the ideal solution. By ranking the alternatives, civil engineers can make informed decisions that optimize for multiple, often conflicting, criteria such as cost, environmental impact, safety, and feasibility.

The application of TOPSIS in civil engineering has been particularly beneficial in situations where the decision-making process involves a large number of stakeholders with varying preferences and priorities. The method's flexibility in accommodating group decision-making enhances its suitability for complex civil engineering projects that require consensus-building among diverse stakeholders.

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