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Presenting an integrated decision-making framework based on the Best-Worst Method (BWM) and Fuzzy TOPSIS for evaluating, ranking, and selecting sustainable and resilient suppliers in the supply chain

Omid Fanaei Niya[1], Hamid Goodarzi[2], Hamidreza Motamedi[3], Mahdi Mirzaei[4], Ramin Jahanshahi[5], Samad Khaledian[6]

1. Bachelor of Industrial Management and industrial engineering in Engineering Management
2. Bachelor's, Master's and PhD in Civil Engineering Master's student in Industrial Engineering, Engineering Management
3. Bachelor of Industrial Engineering and Master of Industrial Engineering majoring in Engineering Management
4. Bachelor of Industrial Engineering,Isfahan University of Technology Master of Industrial Engineering, Engineering Management , Isfahan University of Technology
5. Bachelor of Civil Engineering, Bahonar University of Kerman and Master of Industrial Engineering, Engineering Management, Isfahan University of Technology.
6. Bachelor of industrial safety and industrial engineering in engineering management

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ABSTRACT

In today's competitive and unstable business environment, selecting sustainable and resilient suppliers has become one of the fundamental challenges of supply chain management. The existence of multiple and sometimes conflicting economic, environmental, social, and resilience criteria makes the decision-making process complex and uncertain. The aim of this research is to present an integrated decision-making framework based on the combination of the best-worst method (BWM) and fuzzy TOPSIS in order to evaluate, rank, and select sustainable and resilient suppliers. In the proposed framework, first, the criteria and sub-criteria affecting supplier selection are identified with a sustainability and resilience approach. Then, using the BWM method, the weights of the criteria are determined accurately and by reducing the inconsistency of expert judgments. Subsequently, the fuzzy TOPSIS method is used to rank suppliers and take into account the uncertainty and ambiguity in linguistic evaluations. The proposed approach enables the integration of quantitative and qualitative data, leading to more realistic decision-making in complex environments. The results of the research show that the proposed framework can be used as an efficient tool for supply chain managers to select suppliers that are resilient to disruptions and aligned with sustainable development goals.

Introduction

In today’s business environment, organizations are facing increasing pressure to increase efficiency, reduce costs, and improve quality. The supply chain plays a pivotal role in achieving these goals, and selecting the right suppliers is one of the most important management decisions. With the increasing complexity and dynamism of the market, suppliers must not only be able to meet the current needs of the organization, but also have the ability to be resilient to disruptions and sudden changes. On the other hand, environmental, social, and economic sustainability requirements have increased the level of expectations from suppliers and have turned their evaluation and selection into a multi-criteria issue.

The main challenge in this context is to make decisions simultaneously based on quantitative and qualitative criteria, short-term and long-term, and performance and sustainability factors. Organizations need to consider multiple criteria such as cost, quality, delivery time, flexibility, compliance with environmental standards, and the ability to manage risk. In addition, the information available about suppliers is often vague and uncertain, which makes decision-making based solely on definitive data inaccurate and inefficient.

Traditional methods for evaluating suppliers are usually limited to analyzing single criteria or simple weights and are unable to integrate different criteria and existing uncertainties. In such situations, the use of multi-criteria decision-making (MCDM) methods with uncertainty modeling capabilities, such as the fuzzy method, becomes necessary. These approaches allow for more accurate and comprehensive evaluation of suppliers and help decision-makers make strategic decisions that are resilient to environmental changes.

One of the efficient methods for determining the weight of criteria is the Best-Worst Method (BWM), which provides higher accuracy and consistency by reducing the number of pairwise comparisons compared to traditional methods such as AHP. On the other hand, the fuzzy TOPSIS method has the ability to rank options based on proximity to the positive ideal solution and distance from the negative ideal solution and can well manage the uncertainty in the evaluations. The combination of these two methods provides a powerful framework for evaluating, ranking and selecting suppliers that simultaneously considers various performance and sustainability criteria.

Therefore, the problem of the present research focuses on designing an integrated decision-making framework that, by combining the best-worst method and fuzzy TOPSIS, can comprehensively evaluate, weight and rank sustainable and resilient suppliers. This framework helps organizations to make strategic decisions in the supply chain with higher accuracy and lower risk and simultaneously achieve economic, social and environmental goals. Also, providing such a method allows the development of flexible and robust decision-making models against uncertainties and supply chain disruptions.

Problem Classification:

-2-1Article 1:

Main Topic: Selecting Sustainable Building Materials Using Multi-Criteria Decision Making Model: A Case Study of Construction Work in Lideta, Addis Ababa

-2-1-1Problem Type:

Multi-Criteria Decision Making (MCDM)

-2-1-2Problem Nature:

Selection Problem – The objective is to select the best option from a set of building materials based on different sustainability criteria.

-2-1-3Decision Level:

A decision at the tactical or project engineering level (affecting the design and implementation of buildings but not at the national strategic level).

-2.1.4Type of data and criteria:

•Quantitative data (e.g. cost, durability, energy consumption, recyclability)

•Qualitative data (e.g. aesthetics, local accessibility, social impacts)

-2.1.5Number of alternatives:

Types of building materials (e.g. traditional brick, concrete block, compacted soil block, natural stone, recycled materials)

-2.1.6Number of criteria:

Several criteria including economic, environmental and social — so the issue is multidimensional.

-2-1-7Proposed decision-making method:

MCDM models such as:

•AHP (Analytical Hierarchy Process)

•TOPSIS (Approach to Ideal Solution Method)
•VIKOR or PROMETHEE (for evaluating materials according to the trade-off between criteria)
-2-1-8Ultimate objective:
Identify and rank sustainable building materials to increase environmental and economic efficiency in construction projects in the Lidda region.

-2-2Article 2:
Main topic: A comprehensive review of MCDM methods, applications and emerging trends

2-2-1Methods
2-2-1-1Classical methods
•AHP, ANP for weighting and structuring
•TOPSIS, VIKOR for ranking
•ELECTRE, PROMETHEE for non-compensatory comparisons

2-2-1-2Uncertainty-based methods
•Fuzzy methods (Fuzzy AHP, Fuzzy TOPSIS)
•Gray methods (Grey Systems)
•New models: Neutrosophic, Z-number, Pythagorean fuzzy

-2-2-1-3Hybrid and advanced methods
•Combination of methods: AHP–TOPSIS, DEMATEL–ANP, BWM–COPRAS
•Integration with metaheuristics and machine learning for weight and ranking optimization
-2-2-2Application Areas
2-2-2-1Management and Economics
•Supplier Selection
•Performance and Risk Assessment
•Project Prioritization
2-2-2-2Engineering and Industry
•Material and Technology Selection
•Supply Chain Management
•Maintenance and Repairs
-2-2-2-3Energy and Environment
•Renewable Energy Source Selection
•Sustainability Assessment
•Waste Management
-2-2-2-4Health and Medicine
•Treatment Selection
•Disease Risk Assessment
•Patient Prioritization

-2-2-3Emerging Trends
2-2-3-1Integration with Artificial Intelligence
•Using Machine Learning for Automatic Weighting
•Neural Networks for Prediction and Ranking
-2-2-3-2MCDM in Big Data
•Decision Analysis in Big Data
•Need for Fast and Scalable Methods
2-2-3-3Advanced Uncertainty Models
•Neutrosophic, hesitant fuzzy, Z-number
•Modeling complex and multi-layered uncertainties
2-2-3-4Group decision making
•Consensus methods
•Collaborative and distributed models

-2-2-4Challenges
•Computational complexity and sensitivity to weights

•Inconsistency of judgments and correlation of criteria
•Data scarcity and the need for interpretable models
•Integrating MCDM with real and intelligent systems

-1Mathematical modeling:
-3-1First article:
What is happening, what factors affect it, and what needs to be measured or controlled. This initial description is the foundation on which the structure of a model can be formed, without yet going into symbolic or formulaic details.
The next step in modeling is to identify the variables and the relationships between them. Instead of writing equations, we explain in natural language how one variable affects another. For example, we might say, “Increasing demand increases the pressure on resources” or “Population growth is dependent on the birth rate.” This type of statement defines the logical structure of the model and helps the designer to understand the dependencies conceptually.
Next, the modeler must specify assumptions. Assumptions define the boundaries of the model and specify which factors are ignored and which are the main ones. For example, it might be assumed that “environmental conditions remain constant over time” or that “consumer behavior is predictable.” These assumptions make the model simpler and more usable, although they always omit some part of reality.
In the next step, the model structure is described as a system. This system can include inputs, outputs, intermediate processes, and feedbacks. Without writing a formula, we can say that “inputs include primary resources, processes include the conversion of these resources into products, and outputs include final products and wastes.” This type of description provides a clear picture of the internal logic of the model and allows for a qualitative analysis of its behavior. Finally, the model must be evaluated to determine how well it fits reality. This evaluation can be done by comparing the model’s predictions with actual data, or by examining its logical consistency. If the model is far from reality, the assumptions are revised and the model structure is modified. This revision cycle is an integral part of mathematical modeling and ensures that the model can provide a reliable picture of the phenomenon under study.

-2-3Second article:
Mathematical modeling is the process of converting a real phenomenon into a structured and analyzable language. In this process, a problem that exists in the real world is first described precisely and then its main elements are selected. The goal is to retain only the important and influential parts of all the details so that a simple but meaningful picture of the problem can be built. This simplification is the first step in creating an understandable and testable model.
In the next step, the relationships between the main elements of the problem are identified. These relationships can indicate the dependence, influence, or interaction between different components. In mathematical modeling, these relationships are usually expressed in the form of logical structures, concept diagrams, or quantitative descriptions. The goal is to make the behavior of the phenomenon predictable and analyzable in the form of a coherent framework, without the need to enter into complex computational details.
After building the model, it is time to analyze it. Model analysis helps us understand how the outcome will change if conditions change. This step can involve examining different scenarios, comparing different states, or assessing the model’s sensitivity to changes. Model analysis allows decision makers to examine the likely behavior of the system in a safe and controlled environment before taking action in the real world.
In the next step, the model is compared with reality to assess its accuracy and efficiency. If the model fails to reflect real-world behavior well, it needs to be revised and improved. This revision may involve adding new factors, changing the structure of relationships, or further simplification. Modeling is an iterative process, and it usually gets closer to reality with each revision.
Finally, the mathematical model is used as a tool for prediction, decision-making, and optimization. This model can be used in various fields such as management, economics, engineering, environment, or social sciences. The main value of modeling is that it allows us to better understand complex phenomena, predict their behavior, and provide more effective solutions to real-world problems.

- 4Problem Solving Method:
-1-4Article 1:
1-1-4Problem Definition and Objective:

•Objective: To select the best option (e.g., type of construction material) based on sustainability.
•Problem: We have several options (stone, brick, cement block, CEB) and several conflicting criteria (cost, environment, performance, social benefit, …)
-2-1-4Determining criteria and sub-criteria:
•By reviewing the literature and interviewing experts, the main criteria are determined; such as:
o Life cycle cost, waste reduction, performance, resource efficiency, environmental impact, social benefits.
•Sub-criteria are defined under each criterion (e.g. for cost: initial cost, maintenance, disposal; for community: use of local materials, beauty, health and safety)

-4-1-3Building decision hierarchies and pairwise comparisons:
•Hierarchical structure:
o Level 1: Objective (choosing sustainable materials)
o Level 2: Criteria
o Level 3: Subcriteria
o Level 4: Alternatives (stone, brick, CEB, cement block)
•For both criteria, we ask experts to determine the relative importance on a scale of 1, 3, 5, 7, 9 (equal importance to very high importance).
•The same is done for the subcriteria and then for the comparison of the alternatives under each criterion.
-4-1-4Calculating weights and checking consistency:
•From the pairwise comparison matrices, the weight of each criterion and subcriteria is calculated (normalized eigenvector).
•The discrepancy ratio (CR) is calculated; if CR ≤ 0.10, the judgments are acceptable; Otherwise, the judgments should be revised.
-4-1-5Summarizing the weights and selecting the final option:
•The weight of each sub-criterion is multiplied by the weight of the upstream criterion to obtain its global priority.
•For each option, its score under each criterion is calculated and multiplied by the weight of that criterion; then the sum of the scores is obtained as the final score of the option.
•The option with the highest final score is selected as the best solution to the problem (for example, the most sustainable building material); in the article, this option was “compressed earth block (CEB).”

-4-2Second article:
-4-2-1Problem definition and identification of objectives
In the first step, the problem must be defined precisely and clearly. This stage includes determining the main goal of the decision-making and identifying the stakeholders. According to the article, real problems are usually multi-objective and complex and require consideration of conflicting criteria. Therefore, it must be clear what exactly the decision maker is looking for and what the constraints are.
-4-2-2Determining criteria and sub-criteria
According to the content of the article, MCDM is based on multiple criteria. In this step:
•Quantitative and qualitative criteria are identified.
•If necessary, the criteria are broken down into more detailed sub-criteria.
•Criteria can be economic, technical, social, environmental or risk-based.
•If the data is ambiguous or linguistic, fuzzy can be used.

This step forms the main basis of the decision-making model.
-4-2-3Choosing the right MCDM method
According to the article, the choice of method depends on the type of data, the level of uncertainty and the complexity of the problem:
•AHP for hierarchical structure and pairwise comparison
•TOPSIS for ranking based on the distance from the ideal solution
•PROMETHEE / ELECTRE for problems with preference relations and qualitative data
•Fuzzy AHP / Fuzzy TOPSIS for ambiguous data and human judgments
•Hybrid models for complex problems with various criteria
•AI + MCDM for dynamic and data-driven problems
•Big Data MCDM for analyzing massive and real-time data
The choice of method should be made according to the nature of the problem.
-4-2-4Collecting data and weighting the criteria

In this stage:
- •Real, expert or linguistic data are collected.
- •The weight of the criteria is determined by methods such as AHP, entropy, or fuzzy.
- •If the data is instantaneous, IoT or Big Data is used (according to the article).

Correct weighting ensures the accuracy of the model.

-4-2-5Evaluation of options and final ranking

After determining the weights:
- •The options are evaluated based on the criteria.
- •The selected method (e.g. TOPSIS or PROMETHEE) is executed.
- •The options are ranked and the best option is introduced.
- •If necessary, a sensitivity analysis is performed to determine the effect of changing the weights of the criteria on the result.

This step provides the final output of the model.

Literature Review

-5-1Article One

-5-1-1Literature Review

The literature of the present study shows that the authors have attempted to examine the issue of sustainable materials selection in the context of Ethiopian urban construction and analyze it using the AHP multi-criteria decision-making method. The literature review of the article covers a range of sources related to sustainability, resource consumption, environmental impacts and decision-making methods and shows that the issue of material selection is a multidimensional issue and dependent on economic, social and environmental factors. However, the literature of the article is more descriptive and less involved in in-depth criticism or comparison between previous models and findings. Also, the direct relationship between some sources and the specific issue of “construction materials in Lidda” is not fully explained.

-5-1-2Strengths of the literature

.1Appropriate coverage of sustainability concepts

The article's literature well introduces the three main dimensions of sustainability—economic, social, and environmental—and shows that the selection of materials is not just a technical decision, but a multidimensional decision.

.2Use of reliable and diverse sources

The authors have used international sources and research related to sustainability, energy consumption, and MCDM methods, which has contributed to the scientific richness of the article.

.3Emphasis on the necessity of scientific decision-making in the selection of materials

The article's literature well shows that the selection of materials based on habit or past experience can lead to additional costs and negative environmental impacts.

.4Rationale for using AHP

The article, citing reliable sources, shows why AHP is suitable for hierarchical and multi-criteria problems.

-5-1-3Weaknesses of the literature

.1Lack of in-depth critique of sources

The literature is mostly reporting and less concerned with comparison, critical analysis, or contradictions in previous research.

.2Lack of attention to similar regional studies

Although the issue has been studied in Ethiopia, comparisons with similar countries in terms of development, climate, or resources have not been made.

.3Lack of empirical evidence in the literature

The literature is mostly theoretical and rarely refers to real data or case studies that could strengthen the arguments.

.4Lack of examination of the limitations of the AHP method in the literature

While AHP is chosen, the article does not point out the limitations of this method (subjectiveness of judgments, sensitivity to inconsistency, large number of comparisons).

-5-1-4Future research and research suggestions

.1Using MCDM Hybrid Methods

Future research can use hybrid methods such as:
- •AHP–TOPSIS
- •AHP–VIKOR
- •Fuzzy AHP to better manage uncertainty and ambiguity in expert judgments.

.2Model development for other building components

The presented model can be extended to select:
•Structural materials
•Insulation materials
•Flooring materials
•Facade materials.
.3Comparison of results with real project data
Future research can investigate whether the selected materials are actually more sustainable in practice.
.۴Adding more quantitative indicators
For example:
•Actual CO_2 emissions
•Latent energy
•Life cycle cost with real market data These can increase the accuracy of the model.
5 .Investigating the impact of climate and geography
Sustainable materials vary in different regions; future research could adapt the model to different climates in Ethiopia or similar countries.

5-2-Article Two:

5-2-1-Literature Review
The literature reviewed in the article covers a wide range of multi-criteria decision-making (MCDM) methods, from the history of classical methods to intelligent and data-driven models. The author has tried to show the evolution of this field in a linear and evolutionary way and highlight the relationship between methods and their applications. However, the literature presented is more descriptive than analytical and less focused on in-depth comparison, methodological critique, or theoretical contrasts between studies. As a result, the reader receives a comprehensive but not entirely critical picture of the field.
5.2.2-Strengths of the Literature
5.2.2.1 -Comprehensive and Structured Coverage
The literature of the article covers a wide range of MCDM methods:
•Classical methods (AHP, TOPSIS, ELECTRE, PROMETHEE)
•Fuzzy methods
•Hybrid models
•AI and Big Data-based models
This breadth allows the reader to gain a complete understanding of the historical and technical evolution of this field.
5-2-2-2 -Attention to interdisciplinary applications
One of the important strengths of the article is the reference to the applications of MCDM in different fields: management, engineering, environment, health, and policy-making. This diversity shows that the author is aware of the multidisciplinary nature of MCDM and has reflected it well.
-5-2-2-3Reference to emerging technologies
Integrating MCDM with:
•Blockchain
•IoT
•Artificial Intelligence
•Big Data Analysis
shows that the paper is forward-looking and does not rely solely on traditional methods.
-5-2-3Literature Weaknesses
-5-2-3-1Lack of in-depth methodological critique
The literature is more descriptive than analytical. For example:
•Philosophical differences between compensatory and non-compensatory methods are not explored.
•The actual limitations of the methods are not compared in case studies.
•The challenges of model validation are ignored.
-5-2-3-2Lack of theoretical coherence
Although the paper introduces the methods, it does not provide a coherent theoretical framework for their classification. For example:
•Fuzzy, probabilistic and machine learning methods are placed on the same level, while their nature is completely different.
•The relationship between data-driven models and judgment-driven models is not clarified.

-5-2-3-3Lack of references to valid comparative studies

The literature does not refer to large comparative studies (Benchmark Studies). In the field of MCDM, there are studies that have compared dozens of methods on a single problem, but the article does not use them.

-5-2-3-4Failure to address computational challenges

Although the paper mentions “computational complexity”, it:

•Does not provide quantitative analysis

•Does not address the difference between lightweight and heavy methods

•Does not address scalability challenges in Big Data

-5-2-4Future Research Directions

Based on the literature, several important directions for future research can be derived:

-5-2-4-1Development of Real-time MCDM models

Given the growth of IoT and real-time data, the need for models that can:

•Respond to changes in real time

•Update criteria weights automatically

•Use reinforcement learning is essential.

-5-2-4-2Deeper integration of AI with MCDM

Future research could move towards:

•Self-explaining models (Explainable AI + MCDM)

•Predictive–Prescriptive models

•Hybrid models based on deep learning. 5.2.4.3- Standardization of evaluation methods

One of the important gaps is the lack of a standard framework for comparing MCDM methods. Future research could:

• Define unified evaluation indicators

• Provide reference datasets

• Develop comparative protocols

5.2.4.4- Advanced uncertainty modeling

Fuzzy and probabilistic methods are not enough. The need for:

• Evidence-based models

• Rough Set models

• Grey System models is strongly felt.

5.2.4.5- Sustainability and ESG applications

Given the paper’s emphasis on sustainability, future research could focus on:

• Green decision-making

• Life cycle assessment

• ESG indicators.

5- Conclusion:

Combining the findings of these two areas, we demonstrate that Multi-Criteria Decision Making (MCDM) as a powerful analytical framework has a fundamental role to play in guiding construction projects towards sustainability, efficiency and transparency. The case study in Lideta shows that the selection of construction materials—especially in masonry—can no longer be based solely on cost or availability; rather, a set of environmental, economic, technical and social criteria must be considered simultaneously. This is precisely where MCDM methods show their value.

On the other hand, a comprehensive review of emerging methods and trends in MCDM shows that the field is evolving rapidly:

• Integrating classical methods with fuzzy, gray, and artificial intelligence

• Developing hybrid models to increase accuracy

• Expanding applications in the areas of sustainability, resource management, and construction

These trends indicate that sustainable material selection in the future will not only become more accurate, but also smarter and more data-driven.

Overall, the link between the case study and the theoretical review shows that:

• MCDM is the backbone of sustainable decision-making in the construction industry.

• Using these methods in the selection of building materials can lead to reduced environmental impacts, improved structural performance, and increased economic efficiency.