TOWARDS SUSTAINABLE HEALTHCARE: SURGICAL SET SELECTION USING SPHERICAL FUZZY AHP

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Highlights

- Spherical Fuzzy AHP addresses uncertainty in material selection decisions.
- Key criteria include durability, quality, reusability, and cost considerations.
- Framework supports sustainable and high-quality material choices in healthcare.

ABSTRACT

Selecting materials for the operating room is a critical decision-making process that significantly impacts patient safety, operational success, and cost efficiency. Ensuring that surgical sets are made from high-quality, durable, and reusable materials is essential, as this not only reduces the risk of complications but also enhances overall patient outcomes. However, the selection process is complex, involving numerous criteria that must be carefully evaluated to meet stringent quality standards while considering cost constraints and reusability.
To address these challenges, this study proposes a multi-criteria decision-making (MCDM) framework utilizing the Spherical Fuzzy Analytic Hierarchy Process (AHP), which is particularly suited for handling the uncertainty and vagueness often present in expert evaluations. Spherical Fuzzy AHP allows for a detailed assessment of the various factors influencing material selection—such as durability, quality, cost, and reusability—by incorporating fuzzy logic to account for the subjective and imprecise nature of human judgment. This approach provides a structured methodology for weighting and ranking each criterion, facilitating a comprehensive analysis that supports decision-makers in selecting the optimal materials for operating room use. The proposed framework not only ensures that the selected materials align with clinical and operational needs but also promotes cost-effective choices that contribute to long-term sustainability. A case study with a private hospital in Istanbul was conducted to demonstrate the effectiveness of the proposed approach.

Keywords: Healthcare, Operating Room, Surgical Sets, Fuzzy MCDM, Spherical Fuzzy AHP

1. Introduction

The selection of surgical sets is a critical decision in healthcare, directly impacting patient safety, operational success, and cost efficiency. This study focuses on identifying the best surgical set supplier among three alternatives—X, Y, and Z—by employing the Spherical Fuzzy Analytic Hierarchy Process (AHP). This advanced methodology accounts for uncertainty in expert evaluations, enabling a more precise and reliable assessment. The findings aim to support healthcare decision-makers by promoting cost-effective, high-quality, and sustainable choices that align with clinical needs, ultimately enhancing patient outcomes and operational efficiency.
The significance of this study lies in its potential to improve decision-making processes in healthcare procurement, particularly in the context of surgical materials. By identifying the optimal supplier, this research not only aims to enhance patient safety and operational efficiency but also to promote cost-effective and sustainable choices that align with clinical needs. The findings of this study will serve as a valuable reference for hospital administrators and decision-makers in similar contexts.

2. Literature Review

The application of multi-criteria decision-making (MCDM) methods in healthcare is well-documented, with various studies highlighting their relevance to critical decision-making processes. For instance, Sağlam et al. (2020) explored performance indicator selection for operating room supply chains using the Analytic Network Process (ANP), emphasizing the importance of structured frameworks for evaluating supply chain efficiency. Another study by Çetin et al. (2018) introduced a multifaceted approach to medical equipment management through multicriteria decision analysis, showcasing the complexities involved in selecting suitable materials.

Beyond healthcare, the interval-valued spherical fuzzy AHP method has been successfully applied to other fields. For example, Kara et al. (2019) utilized this approach for aircraft selection, demonstrating its robustness in handling uncertainty and vagueness in decision-making processes. Similarly, Demir et al. (2021) combined spherical fuzzy AHP and TOPSIS methodologies for selecting emergency hospital locations, addressing complex criteria within disaster management scenarios.

Despite these advancements, a significant gap remains in the literature regarding operating room material selection that incorporates the insights of frontline healthcare professionals, such as nurses. This study aims to fill this gap by combining qualitative evaluations from experienced operating room nurses with the computational strength of spherical fuzzy AHP, thereby introducing a novel methodology tailored to the healthcare sector.

3. Hypotheses/Objectives

The primary objective of this study is to develop a structured decision-making model tailored to the selection of surgical sets for operating rooms, incorporating both qualitative and quantitative evaluations. By utilizing the Spherical Fuzzy Analytic Hierarchy Process (AHP), the study aims to address the inherent uncertainty in expert judgments and provide a systematic framework for evaluating multiple criteria, including durability, quality, flexibility, and cost. The hypothesis underlying this research is that integrating subjective insights from experienced operating room nurses with a robust computational methodology will lead to a more accurate and practical decision-making process. This approach not only ensures the alignment of material selection with clinical and operational requirements but also facilitates cost-effective and sustainable procurement strategies.

4. Research Design/Methodology

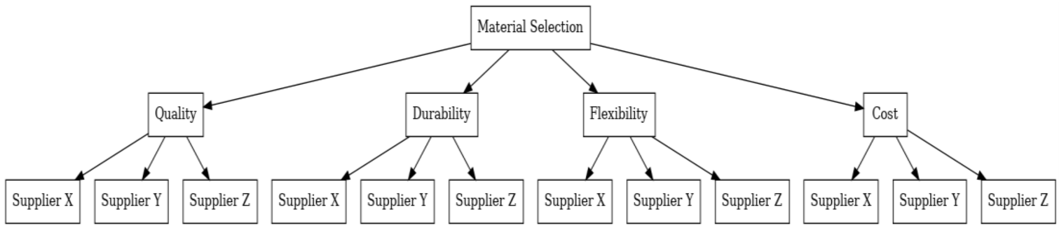

Figure 1. Hierarchical Structure for Material Selection

Model Development:

Data Sources: The model was built based on judgments obtained from three decision-makers (DM 1, DM 2, DM 3), all of whom are experienced operating room nurses.
Criteria Definition: Based on a literature review and expert opinions, the criteria—Quality, Durability, Flexibility, and Cost—were defined.
Matrix Construction: Pairwise comparison matrices for each decision-maker were created, and the Consistency Ratios (CR) were calculated to ensure that all CR values were below 0.10.

Weight Calculation:
The pairwise matrices for each decision-maker were aggregated using the geometric mean method, normalized, and the final weights of the criteria were calculated.

Criteria (C)	Weights (w)
Quality	0,06
Durability	0,11
Flexibility	0,24
Cost	0,59

Table 1. Criteria Weights

The pairwise comparison matrices were aggregated using the geometric mean method to determine the final weights of the criteria. The results indicated that the Cost criterion holds the highest weight (0.59), emphasizing its importance in the decision-making process. This was followed by Flexibility (0.24), Durability (0.11), and Quality (0.06). The direct involvement of the nurses in procurement decisions influenced their judgments and made cost a more prominent factor in the decision-making process.

The weight calculations and alternative evaluations in this study are based on a structured approach that combines fuzzy geometric mean and normalization methods. Initially, fuzzy pairwise comparison matrices provided by the decision-makers were aggregated to ensure a robust and comprehensive analysis. The geometric mean formula was used to derive the relative importance of each criterion and alternative.

$$r^i = \left(\prod_{\{j=1\}}^{n} r_{\{ij\}} \right)^{\frac{1}{n}}$$

Following the aggregation, membership functions were converted into numerical values using the formula.

$$F(A_s) = \mu \cdot (1 - \nu) \cdot (1 - \pi)$$

The normalized priority vector for each criterion was calculated using,

$$w_i = \frac{F(r^i)}{\sum_{i=1}^{n} F(r^i)}$$

The final ranking was achieved through a weighted sum approach,

$$W_i = \sum w_{\{ij\}} \cdot w_j$$

5. Results/Model Analysis

The results of this study revealed that Z Supplier is the optimal choice among the evaluated alternatives, achieving the highest aggregated score of 0.230, followed by X Supplier (0.111) and Y Supplier (0.101). Z Supplier demonstrated exceptional performance across all criteria, particularly excelling in the Cost (K4) criterion, which holds the highest weight at 59%. This highlights the critical role of cost in the decision-making process, reflecting the procurement priorities of the operating room. The other alternatives, while performing well in specific areas, were unable to achieve the same balanced and strong performance as Z Supplier.

	C1	C2	C3	C4	
w	0,06	0,11	0,24	0,59	W
X Alternative	0,016	0,149	0,067	0,131	0,111
Y Alternative	0,074	0,205	0,134	0,071	0,101
Z Alternative	0,027	0,227	0,154	0,286	0,230

Table 2. Weighted Scores of Alternatives Based on Criteria

The calculated scores effectively reflect the relative performance of each supplier in meeting the requirements of operating room material selection. The findings confirm the robustness and reliability of the proposed model, offering decision-makers a transparent and structured evaluation process.

6. Conclusions

The findings contribute to both theory and practice by demonstrating the effectiveness of the Spherical Fuzzy AHP method in addressing uncertainties and integrating subjective judgments. This structured approach not only ensures reliable and consistent decision-making but also provides a scalable model for similar evaluations in healthcare and other industries. Future research could incorporate additional criteria, such as sustainability, and explore comparative analyses with other MCDM methods to further enhance the model's applicability and robustness.

The analysis confirms that Z Supplier is the most suitable option, showcasing balanced performance across the criteria and excelling in the Cost criterion (K4), which decision-makers prioritized due to their procurement-related responsibilities. This result underscores the practical applicability of the proposed methodology in aligning clinical and operational objectives.

7. Limitations

Including additional decision-makers, such as surgeons or procurement officers, could provide a broader perspective and enhance the model's robustness. Additionally, the study evaluated only four criteria—Quality, Durability, Flexibility, and Cost—leaving out other potentially influential factors such as environmental sustainability or supply chain reliability.

8. Key References

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