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Scoping Review of the Development of a Value Engineering-Based Multicriteria Decision System Engineering Management Model for Material Selection in the Timor Leste Roads Fund Infrastructure Project

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Abstract

This study aims to develop a systematic understanding of a decision-making model for material selection based on Systems Engineering Management (SEM), Multicriteria Decision Making (MCDM), and Value Engineering (VE) in road infrastructure projects in Timor Leste. Given the strategic role of road infrastructure in supporting economic growth in developing countries, appropriate material selection is a critical factor influencing cost efficiency, technical performance, and project sustainability. However, current material selection practices tend to be subjective and often fail to adequately consider multidimensional aspects such as life-cycle costs and environmental impacts. Therefore, the application of MCDM- and VE-based approaches is necessary to improve the quality and objectivity of decision-making in optimal material selection. Using a scoping review methodology, this study identifies and synthesizes existing literature on the application of SEM, MCDM, and VE in infrastructure projects, with a specific focus on material selection processes. The findings reveal that although MCDM methods such as AHP, TOPSIS, and VIKOR have been widely applied in infrastructure projects, the integration of SEM, MCDM, and VE into a structured and unified decision-making system remains limited, particularly in the context of developing countries such as Timor Leste. This gap indicates a significant opportunity to develop a more comprehensive decision-support model capable of enhancing cost efficiency, material quality, and the sustainability of infrastructure projects.From a theoretical perspective, this study contributes to the engineering management literature by strengthening the conceptual integration of SEM, MCDM, and VE in infrastructure material selection decision-making. From a practical

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standpoint, the findings are expected to provide a valuable foundation for the Roads Fund Infrastructure Timor Leste in developing a value-based decision model to support optimal material selection in their infrastructure projects. Future research is recommended to validate the proposed model through case studies or empirical simulations to assess its effectiveness and feasibility in real-world applications.

Keywords: Systems Engineering Management, Multicriteria Decision Making, Value Engineering, Material Selection, Road Infrastructure, Timor Leste

INTRODUCTION

Infrastructure constitutes the backbone of economic and social development across countries. In the global context, road infrastructure development has become a major priority due to its significant influence on connectivity, goods distribution, and economic equity (World Bank, 2023). However, the increasing demand for infrastructure development also presents challenges related to cost efficiency, environmental sustainability, and the accuracy of construction material selection.

Recent trends indicate that *Value Engineering* (VE) and *Multi-Criteria Decision Making* (MCDM) approaches are increasingly adopted in construction project management to enhance value-based decision-making effectiveness (Gouda et al., 2024; Albarbary, 2023). VE facilitates functional and cost analysis to achieve solutions that deliver optimal value, while MCDM supports the integration of multiple technical, economic, and environmental criteria in material selection processes (Avramova, 2025).

Several studies have demonstrated that integrating VE and MCDM can optimize project design and material selection through a systemic approach that simultaneously considers multiple influencing factors (Elsayed, 2024; Bajwa et al., 2025). Furthermore, the integration of *Building Information Modelling* (BIM) with VE and MCDM has been shown to improve project planning efficiency and reduce resource waste (Gouda et al., 2024). Consequently, value-based multicriteria decision-making has emerged as a new direction in *systems engineering management* practices for global construction projects.

At the national level, Timor-Leste has positioned infrastructure development as a key national priority through the establishment of the *Infrastructure Fund* and *Roads Fund*, managed by the Ministry of Public Works. The *Road Network Upgrading Sector Project* highlights that improving road infrastructure quality is a critical factor in enhancing interregional connectivity (Ministry of Public Works, 2020). Nevertheless, road projects in Timor-Leste frequently encounter technical and administrative challenges, particularly in selecting construction materials suitable for the country's geographical conditions, tropical

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climate, and local resource availability (Government of Timor-Leste, 2020). The use of imported materials that have not been adequately tested under local conditions often results in reduced pavement service life and increased maintenance costs.

Moreover, the *Feasibility Study Guideline* (FSG) in Timor-Leste does not yet incorporate a systematic value-based decision-making mechanism for material selection processes (Government of Timor-Leste, 2020). This situation highlights an urgent need to develop a value-based, multicriteria decision-making model grounded in *Value Engineering* (VE) principles that aligns with local conditions and supports the effectiveness of *Roads Fund Infrastructure* project management.

The primary issue in road infrastructure projects in Timor-Leste lies in material selection processes that are not value-based and are not integrated within a systems engineering management framework. Decision-making practices remain largely dominated by initial cost considerations, while functional performance, sustainability, and local material availability receive limited attention (La'o Hamutuk, 2022).

The absence of an integrated decision-making model has resulted in low project efficiency and effectiveness. This condition underscores the necessity of developing a *Systems Engineering Management* model that integrates *Value Engineering* (VE) and *MCDM* methods to support optimal material selection in the context of *Roads Fund Infrastructure* projects in Timor-Leste (Bajwa et al., 2025; Van Dua, 2024).

Research on the application of *Value Engineering* (VE) and *Multi-Criteria Decision Making* (MCDM) in construction projects has expanded significantly over the past decade. Gouda et al. (2024) developed an integrated BIM–VE model for residential projects, resulting in improved cost efficiency and project quality. Meanwhile, Albarbary (2023) applied VE within a sustainability framework by using fly ash as a cement substitute, demonstrating enhanced material performance without significant cost increases.

Within the MCDM domain, Van Dua (2024) integrated various objective weighting techniques with MCDM methods (AHP, TOPSIS, and VIKOR) for material selection, revealing that combinative approaches improve result reliability. Bajwa et al. (2025) conducted a systematic review of more than 100 MCDM studies in the construction industry and concluded that hybrid methods such as AHP–TOPSIS are the most effective for material selection contexts.

However, most existing studies predominantly focus on building construction projects and have limited application in road infrastructure projects within developing countries. Research in the Timor-Leste context remains largely confined to technical road engineering aspects and has yet to address the integration of VE–MCDM within a comprehensive decision-making management system (Ministry of Public Works, 2020).

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METHODOLOGY

This study employs a literature-based research method, commonly referred to as a *literature review*. A literature review aims to understand emerging phenomena or research problems by examining related concepts proposed in previous studies (Rowe, 2014). This approach was selected because it allows for a comprehensive exploration of diverse bodies of literature that lack a consistent research structure, as is the case in the development of a *Systems Engineering Management* based multicriteria decision-making model grounded in *Value Engineering* for material selection in *Roads Fund Infrastructure* projects in Timor Leste.

To achieve this objective, a comprehensive literature review was integrated with a rigorous bibliometric analysis to systematically map and analyze relevant research trends, methods, and thematic relationships within the existing literature (Correa-Peralta et al., 2025). The scoping review process followed the structured framework recommended by Chalachanová et al. (2021), ensuring transparency, reproducibility, and methodological rigor in the selection, screening, and synthesis of relevant studies.

RESEARCH AND RESULTS

General Findings on Road Network Conditions

The literature and development reports consistently indicate that the overall condition of the road network in Timor Leste remains highly challenging. A significant proportion of national and district roads are classified as being in *poor* to *very poor* condition, requiring extensive rehabilitation and reconstruction. Damaged road conditions and high vulnerability to landslides, particularly during the rainy season, increase transportation costs and hinder access to basic services and local economic markets.

Impact of Road Conditions on Communities

Several studies and infrastructure program reports emphasize that improvements in road networks generate substantial socio-economic benefits, including reduced transportation costs, improved accessibility to public facilities, and enhanced connectivity between rural communities and economic centers. Road rehabilitation interventions in various regions have expanded market access for local farmers and supported overall community mobility.

Complexity of Material Requirements

In the context of road rehabilitation and construction projects, the need for materials that meet technical, economic, and environmental criteria is a critical factor. For instance,

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roads located in landslide-prone areas require materials with high stability and effective drainage characteristics, which typically involve higher costs compared to standard materials. These geographical conditions necessitate decision-making methods capable of simultaneously considering multiple criteria.

Limitations of Traditional Selection Methods

Conventional material selection methods based on experience or ad hoc judgment are often inadequate in this context, as they tend to focus on one or two criteria (e.g., initial cost) without accounting for long-term value (*lifecycle value*) and environmental or operational risks. This limitation highlights the need for a more comprehensive value-based approach through *Value Engineering* (VE).

Frequency of MCDM Method Applications

The literature analysis reveals that several *Multicriteria Decision Making* (MCDM) methods such as AHP, TOPSIS, VIKOR, and PROMETHEE are widely applied in construction material selection studies, particularly when decisions must account for cost, technical performance, and environmental impact. Multiple studies indicate that hybrid approaches, especially AHP–TOPSIS, are effective in ranking material alternatives based on multiple decision indicators.

Role of Value Engineering in Material Selection

Value Engineering (VE) is frequently used to evaluate material alternatives based on *value for money*, defined as the ratio between achieved function and incurred cost. VE emphasizes maintaining or enhancing material functional quality while reducing total life-cycle costs. In infrastructure projects, VE facilitates the development of value-based material lists that meet functional requirements without compromising performance.

Integration of SEM, MCDM, and VE in the Literature

Although *Systems Engineering Management* (SEM), MCDM, and VE have been individually examined in numerous studies, current literature indicates that their integration into a unified decision-making model remains limited and insufficiently developed particularly within infrastructure projects in developing countries such as Timor Leste. This gap constitutes a critical research opportunity addressed by this scoping review.

Factor Matrix and Decision Approach

Inputs: Technical, Economic, and Environmental Factors

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The synthesis of the literature categorizes input factors for material selection into three primary groups:
Technical factors: compressive strength, resistance to moisture and climatic conditions, service life, and structural compatibility.
Economic factors: initial cost, life-cycle cost, availability of local materials, and logistics impact.
Environmental factors: carbon emissions, effects on soil and drainage systems, and climate change adaptation aspects.
Process: VE and MCDM Approaches

The synthesis identifies that *Value Engineering* provides a structured framework for defining evaluation criteria and determining their relative importance. Subsequently, MCDM methods such as AHP can be applied to assign relative weights to these criteria, while TOPSIS or VIKOR can be used to rank material alternatives based on multi-criteria performance, supporting measurable and value-based decisions.

Integrated Decision-Making Model

The synthesis highlights the potential of an integrated decision-making model that incorporates technical, economic, and environmental variables within a single framework. This model combines SEM as the managerial structure guiding decision procedures, VE as the basis for value-oriented criteria definition, and MCDM as the analytical tool for selecting optimal material alternatives in complex road infrastructure projects.

Data Conditions and Local Technical Capacity

Further discussion indicates that in the Timor Leste context, challenges such as limited availability of local material data and constrained technical capacity within construction institutions hinder the effective application of MCDM and VE approaches. The availability of valid empirical data is essential for objectively assessing material criteria.

Role of Policy and External Funding

Funding from international institutions such as the Asian Development Bank (ADB), along with national road rehabilitation programs, underscores the importance of integrating sound engineering solutions with high-quality material decision-making to maximize investment impact. Such funding frameworks also create opportunities for adopting more formalized multicriteria decision models in project planning.

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Theoretical Contribution to the Literature

These findings contribute to the literature by mapping existing approaches and demonstrating that, despite extensive research on MCDM and VE, their integration within an SEM framework remains limited. This study defines a clear research gap that can be addressed by future studies aiming to develop comprehensive decision-making models.

Practical Contribution to Roads Fund Infrastructure

The proposed integrated decision model can serve as a foundation for *Roads Fund Infrastructure Timor Leste* to implement evidence-based material selection procedures in road projects, thereby improving cost efficiency and construction quality.

Data Limitations and Future Research

It should be noted that much of the existing literature relies on case studies conducted in different countries or project contexts. Consequently, generalizing the proposed model to Timor Leste requires validation through field studies or empirical simulations.

Summary of Key Decision Variables

The synthesis confirms that technical, economic, and environmental criteria must be balanced in material selection processes, and that SEM provides a management framework to ensure continuity and consistency throughout the project life cycle.

Recommended MCDM Methods

Methods such as AHP and TOPSIS are frequently recommended in the literature as effective combinations for addressing decision priorities involving multiple criteria.

Role of VE in Long-Term Value

VE is shown to be essential for maintaining a focus on long-term project value, particularly in infrastructure projects with service lives extending over several decades.

Potential of an Integrated Decision System

The synthesis demonstrates that employing SEM as a management structure, VE as a value-based approach, and MCDM as an evaluation tool represents a robust and coherent solution for complex material selection problems.

Accordingly, this scoping review supports the notion that developing a VE-based multicriteria decision-making model within an SEM framework represents both a

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conceptual and practical necessity for road infrastructure projects in Timor Leste, particularly those managed by *Roads Fund Infrastructure*.

CONCLUSION AND RECOMMENDATIONS

Infrastructure Conditions and Key Issues

The review results indicate that road infrastructure in Timor Leste continues to face significant challenges, including limited resources, complex geographical conditions, and a strong dependence on imported materials. The primary issue in this context is the absence of a systematic approach to material selection that integrates technical, economic, and environmental criteria in a comprehensive manner.

Limitations of Traditional Approaches

Material selection processes currently applied tend to be subjective and heavily reliant on individual experience. Such traditional approaches are unable to adequately integrate long-term value considerations, life-cycle cost efficiency, and environmental impacts. This situation highlights an urgent need for a value-based decision-making framework.

Key Findings from the Scoping Review

The scoping review of international scientific literature reveals that *multicriteria decision-making* (MCDM) methods such as AHP, TOPSIS, and VIKOR are frequently employed in material selection processes. *Value Engineering* (VE) has proven effective in evaluating and enhancing *value for money* in construction projects, while *Systems Engineering Management* (SEM) provides a conceptual framework for integrating complex decision-making processes.

Integration of SEM, MCDM, and VE as a Conceptual Solution

The synthesis of findings demonstrates that the integration of SEM, MCDM, and VE holds strong potential for development into a comprehensive decision-making model. SEM functions as a systemic management framework, VE serves as a mechanism for identifying optimal value, and MCDM acts as an analytical tool for prioritizing material alternatives based on measurable criteria.

Relevance to the Timor Leste Context

Within the context of *Roads Fund Infrastructure Timor Leste*, this integrated approach is highly relevant for supporting efficient use of public funds, improving project outcomes, and strengthening technical accountability in decision-making processes. Additionally, the

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approach can assist in managing project risks arising from geographical conditions and variability in local material quality.

Theoretical and Practical Contributions

From a theoretical perspective, this study enriches the literature by proposing a conceptual framework that integrates SEM, MCDM, and VE within infrastructure management. From a practical standpoint, the findings provide a foundation for developing a *decision support system* that can be implemented by *Roads Fund Infrastructure* to support material selection during both the planning and execution stages of road projects.

Research Limitations and Future Research Directions

The main limitation of this study lies in its reliance on secondary literature data, rendering the findings conceptual and not yet empirically validated. Future research is therefore recommended to test the proposed model through real-world case studies or decision-making simulations in Timor Leste, enabling quantitative assessment of the effectiveness of the SEM–MCDM–VE integration.

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