The Eurasia Proceedings of Science, Technology, Engineering and Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering and Mathematics (EPSTEM), 2026

Volume 40, Pages 341-349

ICBAST 2026: International Conference on Basic Sciences and Technology

ERP Strategic Framework for Vietnam's Precision Mechanical Engineering: A Hybrid MCDM Approach to Digital Transformation

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Abstract: For precision mechanical engineering firms in emerging economies, adopting an Enterprise Resource Planning (ERP) system presents a distinct challenge. Decision-makers frequently struggle to reconcile complex technical operational requirements with strict economic limitations. This research navigates this tension by developing a contextualized, mixed-methods evaluation framework for Vietnamese Small and Medium Enterprises (SMEs). Integrating qualitative expert consultation with a combined Best-Worst Method (BWM) and VIKOR analytical model, the study offers a rigorous, data-driven pathway to selecting the most viable ERP system. Applying BWM, the results indicate that Technical Capability emerges as the dominant evaluation criterion, substantially outweighing both Economic Feasibility and Organizational Readiness. The subsequent VIKOR compromise ranking further confirms Epicor Kinetic as the most suitable solution, as it provides the strongest overall performance (i.e., maximized group utility) while maintaining low individual regret—particularly in relation to complex requirements such as multi-level Bill of Materials (BOM) integration and Make-to-Order (MTO) synchronization. By contrast, alternatives emphasizing high modularity and lower upfront cost were ranked least favorable, primarily because they entail considerable operational risk in engineering-intensive settings. Taken together, these findings challenge conventional cost-led adoption logics and suggest an evidence-based implication for practice: decision-makers should prioritize foundational technical alignment over initial capital savings to enable a more resilient and sustainable digital transformation.

Keywords: Enterprise Resource Planning (ERP); Multi-Criteria Decision-Making (MCDM); Best-Worst method (BWM); VIKOR; Precision mechanical engineering.

Introduction

The global manufacturing landscape has been shifting in significant ways in recent years, with Vietnam increasingly positioned as a key node in the China-plus-one diversification strategy and a growing contributor to international supply chain networks (Basu & Ray, 2022). Within this evolution, the precision mechanical engineering sector stands as a cornerstone of the nation's industrial modernization. Unlike general manufacturing, this sector is defined by high-complexity environments—characterized by multi-level Bills of Materials (BOM), stringent quality tolerances, and a predominant Make-to-Order (MTO) production model. (Soeiro et al., 2025; Sun & Zhu, 2026). As these firms strive to integrate into global value chains, the transition toward Industry 4.0 is no longer optional; it is a strategic imperative for survival.

At the heart of this digital transformation lies Enterprise Resource Planning (ERP). For precision engineering firms, an ERP system serves as the digital nervous system, synchronizing shop-floor data with high-level administrative functions. However, the path to implementation is fraught with challenges. Statistics globally suggest that ERP implementation failure rates remain high, but the risk is amplified for Small and Medium Enterprises (SMEs) in emerging economies like Vietnam (Madathala et al., 2025). These firms often face a double bind: the technical necessity for sophisticated, real-time data integration versus the harsh realities of limited capital, legacy infrastructure, and a shortage of digital expertise.

The existing literature frequently discusses ERP adoption in broad manufacturing contexts, yet there remains a significant gap in research tailored to the high-precision demands of the Vietnamese mechanical sector (Hing, 2025). Generic ERP solutions often fail to account for the nuances of local tax compliance, localized technical support needs, and the specific synchronization required between the shop floor and the warehouse in an MTO environment (Tran et al., 2026). While the potential of Artificial Intelligence (AI) for predictive maintenance and scheduling is widely recognized, its integration into the ERP ecosystems of Vietnamese SMEs remains underexplored (Hoang et al., 2025).

To address these gaps, this study proposes an integrated strategic framework for cloud-based ERP system selection and implementation. Drawing on a hybrid Multi-Criteria Decision-Making (MCDM) approach, the research identifies the critical success factors that separate a costly digital misstep from a meaningful operational transformation. The findings, informed by semi-structured interviews and supported by quantitative analysis, offer a contextually grounded roadmap aimed at helping Vietnamese supporting industries reduce lead times, improve supply chain transparency, and pursue a scalable, structured path through the broader complexities of digital transformation.

Literature Review

The successful deployment of Enterprise Resource Planning (ERP) in specialized industrial contexts requires a multidimensional understanding of technical capabilities, localized socio-economic barriers, and robust decision-science methodologies. (Akbari et al., 2024). This section synthesizes current academic discourse across three critical pillars to establish the theoretical foundation for the proposed framework.

Pillar 1: ERP in High-Precision Manufacturing

In the realm of precision mechanical engineering, ERP systems transcend basic administrative functions, acting instead as the primary engine for operational precision. Unlike mass production, precision engineering is characterized by Make-to-Order (MTO) strategies and extremely complex Bills of Materials (BOM) that require granular tracking.

Quality and Traceability: Research by Raiput et al. emphasizes that for high-precision sectors, ERP must support rigorous quality tolerances and "digital birth certificates" for components (Raiput et al., 2024). Compliance with ISO 9001 and IATF 16949 standards necessitates real-time traceability from raw material batch numbers to the final CNC machining parameters. (Razali et al., 2022).

Shop-Floor Synchronization: The integration of ERP with Manufacturing Execution Systems (MES) is a recurring theme in Industry 4.0 literature. Modern ERPs are expected to facilitate a "digital twin" environment where machine-level data—such as spindle hours or tool wear—is fed directly into the planning module to optimize production scheduling and minimize idle time. (Saenz de Ugarte et al., 2009; Vogel, 2026).

Material Complexity: Scholars argue that the primary failure point in engineering ERPs is the inability to manage engineering change orders (ECOs). A robust system must handle dynamic BOMs, with design modifications instantly reflected in procurement and floor-level instructions. (Bantwal & Fatahi Valilai, 2026).

The Digital Literacy Gap: Bilal et al. note that "technical debt" in Vietnam extends beyond old hardware to include human capital. There is a documented scarcity of personnel who possess both deep mechanical engineering knowledge and the digital fluency required to manage integrated systems (Bilal et al., 2026).

Legacy Reliance and Cultural Resistance: A significant proportion of Vietnamese enterprises continue to operate within fragmented "islands of information," characterized by a persistent reliance on disparate Excel-based tracking systems and siloed accounting software. Empirical evidence from recent industrial surveys indicates that cultural resistance—particularly the absence of a data-driven orientation among middle management—constitutes a more formidable barrier to digital transformation than the software's inherent technical complexities. (Nguyen et al., 2026; Nguyen & Kend, 2026).

Pillar 2: MCDM in System Selection: Beyond Financial Metrics

Selecting an appropriate ERP system is inherently complex, as it involves balancing a wide range of criteria that are often qualitative and often in tension with one another. In this regard, traditional Return on Investment (ROI) metrics have come to be seen as increasingly limited in their ability to capture long-term strategic value. A straightforward financial analysis, for instance, tends to overlook intangible yet consequential benefits—such as greater organizational transparency or stronger supplier relationships—that do not translate neatly into monetary terms. As a result, scholarly consensus has gradually shifted toward MCDM frameworks, which offer a more comprehensive and nuanced basis for evaluation.(Modi, 2026; Vo et al., 2023a).

Superiority of Hybrid Models: Hybrid MCDM models—such as those combining AHP with TOPSIS, or BWM with VIKOR—are particularly well-suited for navigating the inherent ambiguity that characterizes human judgment in complex decision-making contexts. The Best-Worst Method (BWM), for example, provides a structured mechanism for assigning relative weights to competing criteria, such as Local Vendor Support versus System Flexibility, in a way that is both systematic and cognitively manageable. Complementing this, the VIKOR method is designed to identify a compromise solution—one that performs reasonably well across all criteria—in situations where no single software alternative can simultaneously satisfy all requirements. Together, these approaches offer a more balanced and defensible basis for ERP selection than any single method could provide (Tang et al., 2026; Triantafyllidou & Vagiona, 2026).

Localized Weighting: A growing body of research suggests that when applying MCDM frameworks in emerging market contexts, localization criteria warrant considerably more attention than they typically receive in Western-oriented selection models. Factors such as compatibility with Vietnamese Accounting Standards (VAS) and the availability of native language support are not merely operational conveniences—they are foundational requirements that can significantly shape both adoption outcomes and long-term system usability. Yet these dimensions are frequently underweighted or overlooked in frameworks designed for more mature, Western institutional environments, highlighting a significant gap between existing models and the practical realities facing organizations in markets like Vietnam (Vo et al., 2023b; Wang et al., 2024).

Synthesis of Research Gaps

While the literature provides a clear view of ERP's technical requirements and the general hurdles in Vietnam, there is a notable absence of an integrated roadmap that specifically links MCDM-based selection to the MTO-specific workflows of precision engineering. Existing research is often siloed into either purely technical discussions or broad economic analyses. This study bridges these gaps by proposing a localized framework that harmonizes the technical demands of Industry 4.0 with the practical resource constraints of the Vietnamese mechanical sector.

Method

This research adopts a mixed-methods design, synthesizing qualitative expert heuristics with quantitative decision-analytic modeling to formulate a contextualized ERP implementation framework for the precision mechanical engineering sector. The methodological architecture is partitioned into three discrete phases: (1) Criteria Identification and Alternative Selection: This initial stage involves the identification of critical evaluative criteria through expert consultation, coupled with the preliminary selection of ERP alternatives specifically tailored to the requirements of high-precision manufacturing. (2) Hybrid MCDM Modeling: This phase leverages hybrid MCDM modeling to establish a systematic weighting of criteria, ensuring that the evaluation transcends purely financial metrics. (3) Alternative Ranking: The final phase focuses on the execution of a compromise ranking of the selected alternatives to determine the optimal solution for the target industrial environment.

Phase I: Criteria Identification and Alternative Selection

To understand the unique operational realities of high-precision engineering, the first phase of this study involved semi-structured interviews with five industry experts. Drawing on their localized experience, this consultative approach helped identify four core evaluative criteria specifically suited to the Vietnamese manufacturing sector. By bringing together academic theory and practical, on-the-ground insights, the resulting framework bridges a critical gap: it balances the strict technical demands of complex manufacturing—such as multi-level BOM synchronization—with the financial realities and organizational readiness of domestic Small and Medium Enterprises (SMEs). Ultimately, these four criteria serve as the foundation for the hybrid BWM-VIKOR decision-

making model, ensuring the system evaluation goes beyond basic cost analysis to capture what these firms genuinely need to succeed:

(C1) Technical Capability: This dimension prioritizes the synchronization of multi-level Bills of Materials (BOM), which is essential for managing the high-complexity Make-to-Order (MTO) workflows inherent in precision machining (Soeiro et al., 2025; Sun & Zhu, 2026).

(C2) Economic Feasibility: Evaluation focuses on the comprehensive Total Cost of Ownership (TCO), accounting for both direct capital expenditures and hidden implementation costs (Nguyen et al., 2025). **(C3)**

Vendor Reliability: This criterion emphasizes the necessity of localized technical infrastructure and support ecosystems to ensure system stability within the Vietnamese regulatory environment (Tran et al., 2026). **(C4)**

Organizational Readiness: This final dimension assesses the digital maturity and analytical capacity of the human capital, addressing the critical "digital literacy gap" that often moderates implementation success (Adel, 2024; Huynh et al., 2025).

Phase II: Expert-Driven Evaluative Scaling and Empirical Validation

Unlike the traditional Analytic Hierarchy Process (AHP), which necessitates pairwise comparisons, the BWM optimizes the process by requiring only $\frac{n(n-1)}{2}$ comparisons. Decision-makers are tasked with identifying the "Best" (most significant) and "Worst" (least significant) criteria, subsequently comparing all other attributes against these two reference points. This approach substantially mitigates cognitive load and the potential for human error—critical factors when eliciting data from high-level manufacturing executives in a time-constrained industrial environment (Bhattacharjee et al., 2022; Khokhar et al., 2020). The final phase of this research involves empirically validating the proposed framework through a structured expert evaluation process. To ensure rigorous assessment of the Multi-Criteria Decision-Making (MCDM) outputs, a panel of experts from the surveyed precision engineering firms was tasked with providing evaluations on a standardized 9-point scale. This 9-point scale facilitates the translation of qualitative linguistic judgments into precise numerical values, with 1 indicating "Equal Importance/Effectiveness" and 9 "Extreme Importance/Effectiveness" (Rezaei, 2015).

Phase III: Alternative Ranking

After establishing the criteria weights, the VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) method is used to rank ERP solutions. VIKOR is particularly robust for this study as it determines a "compromise solution" by maximizing group utility (overall system performance) while simultaneously minimizing individual regret (ensuring that non-negotiable requirements, such as localized tax compliance, are satisfied) (Chiu et al., 2013; Titiyal et al., 2019).

Results and Discussion

Enhanced Operational Transparency and Lead Time Reduction

Table 1. Fundamental scale of importance for MCDM evaluation

Rating	Linguistic Definition / Meaning
1	Equal importance
2	Somewhat between Equal and Moderate
3	Moderately more important than
4	Somewhat between Moderate and Strong
5	Strongly more important than
6	Somewhat between Strong and Very strong
7	Very strongly important than
8	Somewhat between Very strong and Absolute
9	Absolutely more important than

To systematically translate qualitative expert judgments into a quantifiable format for mathematical modeling, this study utilizes a standardized 9-point fundamental scale. This scale acts as a vital bridge between subjective linguistic preferences and objective numerical data. By doing so, it enables a precise calculation of each criterion's relative importance within the hybrid MCDM framework. *Table 1* delineates the numerical ratings and their corresponding linguistic definitions, providing the methodological basis for the criteria weighting and alternative ranking processes executed in the BWM and VIKOR phases.

Following the synthesis of expert judgments and the subsequent mathematical derivation of criteria weights, a distinct hierarchical prioritization emerged among the four primary dimensions of the strategic framework. Technical Capability was identified as the most critical determinant, with a significant weight of 0.4286, underscoring the sector's paramount need for multi-level BOM synchronization and MTO workflow management in high-precision environments. Economic Feasibility and Vendor Reliability were of equal secondary importance, each assigned a weight of 0.2571, reflecting a balanced strategic focus between managing total cost of ownership and ensuring robust, localized technical support. Conversely, Organizational Readiness was determined to be the least influential factor, yielding a weight of 0.0571, suggesting that while the digital maturity of human capital is essential for implementation, it is perceived as a subordinate priority relative to the system's core functional and economic viability during the initial selection phase. These calculated weight distributions are graphically represented in *Figure 1*.

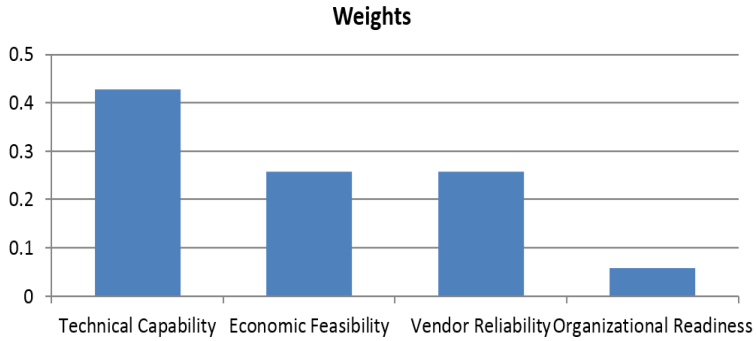

Figure 1. Distribution of calculated weights for ERP selection criteria

Table 2 presents the consolidated decision matrix, which synthesizes the expert panel's qualitative assessments across the four primary evaluative dimensions. Using the 1–9 fundamental scale, these linguistic judgments were converted to precise numerical values to facilitate the subsequent VIKOR-based compromise ranking analysis. This matrix provides the quantitative basis for evaluating each ERP alternative against the sector-specific requirements of Vietnamese precision engineering firms.

Table 2. Consolidated expert decision matrix

Alternative	C1	C2	C3	C4
A1: SAP S/4HANA	8.8	3.2	8.5	4.5
A2: Oracle NetSuite	7.5	5.8	7.8	6.2
A3: Epicor Kinetic	8.2	4.5	7.2	5.5
A4: Odoo	5.5	8.6	6.5	8.4
A5: Infor SyteLine	7.8	5.2	7.5	6.0

Table 3 demonstrates that the final computational phase of the VIKOR methodology yields the indices for maximum group utility (S), minimum individual regret (R), and the comprehensive compromise ranking measure (Q) for each ERP alternative. As evidenced by the calculated results, Alternative A3 (Epicor Kinetic) clearly emerges as the optimal compromise, achieving the lowest possible Q value of 0. This definitive ranking is fundamentally driven by its simultaneous minimization of both the S index (0.300182) and the R index (0.095455).

In decision-science terms, this indicates that A3 successfully maximizes the overall operational utility for the majority of the criteria while rigorously minimizing the regret associated with individual criterion underperformance. Alternative A5 (Infor SyteLine) secures second place with a Q value of 0.239055, further underscoring the sector's strategic preference for systems inherently specialized in complex engineering and BOM workflows. Conversely, Alternative A4 (Odoo), despite its initial appeal on economic feasibility, ranks lowest with a Q value of 1. This reflects a significantly higher degree of implementation risk and system inadequacy when evaluated against the stringent technical demands of the precision mechanical environment.

Table 3. Final VIKOR evaluation metrics and compromise ranking results

Alternative	S	R	Q
A1	0.363636	0.272727	0.424883
A2	0.511077	0.177273	0.466204
A3	0.300182	0.095455	0
A4	0.636364	0.363636	1
A5	0.409632	0.136364	0.239055

The VIKOR indices visually reinforce the hierarchical standing of the evaluated ERP systems. As depicted, Alternative A3 demonstrates unambiguous superiority by minimizing both the maximum group utility distance (S) and the individual regret metric (R), converging on the optimal Q value of 0. *Figure 2* disparity underscores A3's balanced capability to satisfy the aggregated criteria while effectively mitigating specific operational risks. In stark contrast, Alternative A4 exhibits the greatest deviation from the ideal solutions across all parameters, solidifying its position as the least viable option for this high-precision industrial context. Furthermore, the chart clearly shows that Alternative A5 is the most competitive runner-up, with comparatively low indices for both individual regret (R) and the final compromise measure (Q).

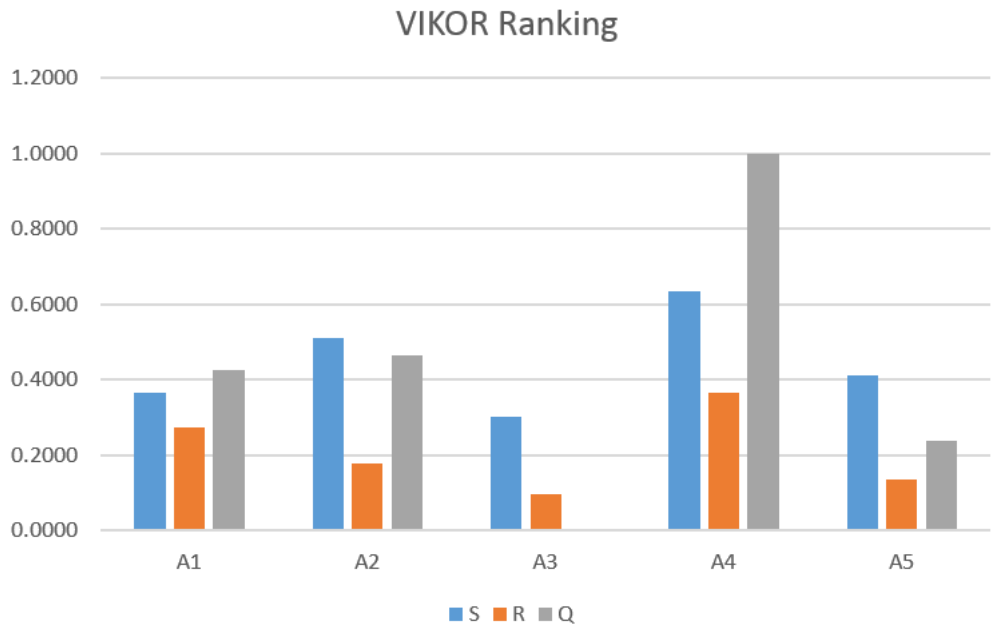

Figure 2. Final compromise ranking results of ERP alternatives

Discussion

The empirical results of this study illuminate the complex trade-offs inherent in selecting an Enterprise Resource Planning (ERP) system for the precision mechanical engineering sector. The criteria weighting derived from the Best-Worst Method (BWM) establishes that Technical Capability (0.4286) is the paramount concern for industry experts. This heavy prioritization validates the hypothesis that high-tolerance manufacturing environments cannot compromise on core operational functionalities, specifically multi-level Bill of Materials (BOM) synchronization and Make-to-Order (MTO) workflow management. The VIKOR compromise ranking provides critical insights into the viability of market-leading ERP solutions within this specific industrial context. Alternative A3 (Epicor Kinetic) emerged as the unequivocal optimal solution (Q = 0). Its success is fundamentally due to its ability to meet the stringent technical requirements of the sector while maintaining an acceptable threshold for Economic Feasibility and Vendor Reliability. In contrast, Alternative A4 (Odoo), which often appeals to Small and Medium Enterprises (SMEs) due to its superior Economic Feasibility and Organizational Readiness, ranked as the least viable option (Q = 1). This dichotomy highlights a critical industry reality: cost-efficiency and user-friendly interfaces cannot compensate for foundational inadequacies in handling complex engineering data. The high individual regret metric (R) associated with Odoo suggests that adopting a generic, modular system poses significant operational risks in high-precision environments.

Similarly, while Alternative A1 (SAP S/4HANA) possesses robust technical capabilities, its lower overall ranking compared to A3 and A5 (Infor SyteLine) reflects the inhibiting nature of its high Total Cost of Ownership (TCO) and potential localized support challenges. Therefore, the VIKOR analysis demonstrates that the optimal ERP for this sector is not necessarily the most technologically advanced or the most affordable, but rather the one that offers the best balance between rigorous technical alignment and systemic feasibility.

Conclusion

This research successfully developed a localized, data-driven ERP selection framework tailored specifically for the precision mechanical engineering sector. By transitioning away from heuristic, intuition-based decision-making, the study employed a robust mixed-methods design integrating qualitative expert consultation with quantitative decision-science modeling.

The application of the BWM optimized the criteria weighting process, significantly reducing the cognitive load on subject matter experts while accurately capturing the sector's operational priorities. The subsequent VIKOR analysis provided a rigorous mathematical validation of the alternatives, ultimately identifying Epicor Kinetic (A3) as the optimal compromise solution, closely followed by Infor SyteLine (A5). The study concludes that for precision manufacturing firms, the successful adoption of Industry 4.0 technologies hinges primarily on a system's technical capability to manage complex, customized production workflows, rather than on upfront capital savings. Ultimately, this framework bridges the gap between legacy operational paradigms and digital transformation, offering a highly contextualized roadmap for Vietnamese SMEs navigating complex software investments.

Recommendations

Based on the synthesized findings and the hierarchical ranking of the evaluative criteria, several strategic recommendations are proposed for industry stakeholders and the academic community. For manufacturing executives and practitioners, it is imperative to prioritize technical alignment over initial cost savings. Decision-makers must actively avoid the cost trap of low-cost, generic ERP systems and strictly anchor their selection in a system's inherent capacity to manage high-complexity MTO workflows and intricate BOMs. Furthermore, firms should transition away from ad hoc software selection processes and adopt structured MCDM frameworks, such as the BWM-VIKOR model, to objectively navigate conflicting operational, economic, and human capital variables. For ERP vendors and integrators, enhancing localized ecosystems is paramount. Given the significant weight (0.2571) assigned to Vendor Reliability, global providers must invest heavily in localized technical infrastructure, as ensuring seamless compliance with regional requirements—such as Vietnamese Accounting Standards (VAS)—constitutes a critical competitive advantage. Additionally, vendors of high-tier, technically robust systems like SAP or Epicor should explore modular, Cloud-based SaaS architectures to lower the upfront Capital Expenditure (CAPEX) barriers for high-growth SMEs. Finally, to advance future research, subsequent studies should consider methodological expansions by integrating Fuzzy Logic or Neutrosophic sets into the existing BWM-VIKOR framework to better capture and quantify the inherent ambiguity and uncertainty in expert linguistic evaluations. Moreover, while this study focuses primarily on the selection phase, future inquiries must conduct longitudinal post-implementation analyses on the recommended systems to empirically validate the projected improvements in lead time reduction and operational transparency.

Scientific Ethics Declaration

* The author declares that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the author.

Conflict of Interest

* The author declares that there is no conflict of interest

Funding

* This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Basic Sciences and Technology (www.icbast.net) held in Konya/Türkiye on April 02-05, 2026.

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To cite this article:

Vo, T. M. N. (2026). ERP strategic framework for Vietnam's precision mechanical engineering: A hybrid MCDM approach to digital transformation. *The Eurasia Proceedings of Science, Technology, Engineering and Mathematics (EPSTEM), 40,* 341-349.