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(Research Article)

Developing a Challenge-Driven Project Management Framework for Sustainable Development: An MCDM-Based Evaluation and Prioritization Approach

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Abstract

This study develops a Challenge-Driven Project Management (CDPM) framework for sustainable development by integrating two advanced Multi-Criteria Decision-Making (MCDM) methods DEMATEL and ANP to evaluate and prioritize sustainability challenges in project environments. Five sustainability criteria (economic, environmental, social, governance, and technological adaptability) and ten sub-criteria were identified through extensive literature review and expert consultation. Data collected from 20 domain experts were processed using DEMATEL to determine causal interdependencies and ANP to derive global weights. Findings reveal that Project Governance (C4) and Technological Adaptability (C5) function as dominant causal enablers influencing Environmental Sustainability, Economic Feasibility, and Social Responsibility. Among the five sustainability challenges evaluated, Budget Constraints for Green Initiatives (A2) and Limited Access to Green Technologies (A5) ranked as the most critical barriers. Based on these insights, the study proposes a CDPM framework that integrates causal relationships, priority weights, and iterative feedback mechanisms to support decision-makers in addressing systemic sustainability challenges. The framework was validated through expert review and a pilot simulation, demonstrating its applicability across construction, manufacturing, and energy sectors. The study concludes with recommendations for policy, managerial practice, and future research, emphasizing the need for adaptive governance, technological innovation, and advanced MCDM-based decision-support tools.

Keywords: Challenge-Driven Project Management; Sustainable Development; DEMATEL–ANP; Multi-Criteria Decision Making; Sustainability Challenges

1. Introduction

In an era defined by mounting environmental pressures, rapid technological change, and heightened social demands, the field of project management has increasingly recognized the need to align execution methodologies with sustainability imperatives. Projects are no longer simply assessed on the basis of cost, time, and quality; rather, their ability to contribute to sustainable development with balanced economic, environmental, and societal impacts, has become a defining criterion of success. Traditional project management frameworks often fall short in addressing these multidimensional requirements, thus motivating the evolution of sustainable project management (SPM).

At the same time, the concept of challenge-driven innovation has emerged as a powerful paradigm, whereby project efforts are oriented around well-defined societal or systemic challenges rather than purely internal objectives or incremental improvements. For example, as noted by UN-Habitat [1], challenge-driven innovation focuses on solving real problems, fostering cross-sector collaboration, and scaling solutions for cities. This shift implies that project

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management must evolve from task-oriented approaches to mission-oriented frameworks capable of addressing complex sustainability challenges. In such a context, incorporating Multi-Criteria Decision Making (MCDM) methods offers distinct advantages. MCDM approaches provide structured mechanisms to handle multiple, often conflicting criteria, such as economic cost, environmental impact, social equity, and governance; thus enabling decision-makers to prioritize alternatives in a coherent and transparent manner. As Sahoo and Goswami [2] observe, MCDM methods are increasingly adopted across domains such as renewable energy and sustainable infrastructure planning to ensure balanced decision outcomes.

The significance of this research is threefold. First, from a theoretical perspective, it extends project management literature by integrating mission-oriented (challenge-driven) thinking with sustainability and decision science. By adopting hybrid MCDM methods, such as DEMATEL and ANP, the study moves beyond simple weighting of criteria to uncover causal relationships and interdependencies among key factors, thereby enriching the decision-making model. For instance, research into sustainable engineering and management has shown that identifying interrelations among sustainability dimensions leads to more coherent strategies [3].

To summarize, this research positions itself at the intersection of challenge-driven project management, sustainability science, and decision analytics. By developing a structured MCDM-based framework, it aims to support organizations in prioritizing projects that not only meet internal targets but contribute to systemic transformation in line with the Sustainable Development Goals (SDGs). The expected contributions span improved project selection, higher system impact, more effective resource allocation, and enhanced sustainability performance.

2. Literature Review

The global imperative for sustainable development has shifted the goals of project management beyond the traditional triple constraint of cost, time and quality toward delivering social, environmental and economic value concurrently [4], [5], [6]. Early conceptual work emphasized that sustainability requires integration across the project lifecycle i.e. from initiation and design to implementation and handover and that project success metrics must be reconfigured to include environmental and social outcomes alongside financial returns [7], [8]. Silvius and Schipper (2014) argued that project managers must adopt new competencies and governance practices to embed sustainability, thus reframing the role of projects as vehicles for systemic transformation rather than isolated technical endeavors [9].

Concurrently, the challenge-driven innovation (CDI) or mission-oriented approach has gained traction among policymakers and research communities as a way to align R&D, industrial policy and programs with grand societal challenges (e.g., climate mitigation, urban resilience) [10], [11], [12]. CDI emphasizes problem framing around societal objectives, cross-sectoral collaboration, iterative experimentation, and upscaling viable solutions, features that require different project selection and management logics compared with conventional, firm-centric projects [13]. Several policy actors (e.g., Vinnova, OECD) now advocate challenge-driven programs to achieve the Sustainable Development Goals (SDGs), further motivating new governance and prioritization mechanisms at project level [14].

Because challenge-driven projects are inherently multi-dimensional and involve tradeoffs across diverse objectives, decision-support methods that explicitly handle multiple criteria are essential. Multi-Criteria Decision Making (MCDM) methods including AHP, TOPSIS, DEMATEL and ANP have been widely applied in sustainability contexts for prioritizing alternatives, weighting criteria and analyzing interactions among factors [15], [16], [17], [18], [19]. AHP (Analytic Hierarchy Process) provides a simple but rigorous way to obtain criteria weights using pairwise comparisons [20], [21], while TOPSIS ranks alternatives by closeness to ideal solutions [22], [23]. DEMATEL reveals causal relationships among criteria and identifies driving vs dependent factors which is a useful capability when intervention should target causal drivers [24]. ANP extends AHP by enabling interdependencies and feedback in the criteria network, delivering global weights through a supermatrix formulation; merges of DEMATEL to ANP are popular because they combine causal mapping with interdependency weighting [25], [26], [27], [28].

Hybrid MCDM approaches have been used successfully across domains similar to challenge-driven projects. For instance, DEMATEL–ANP hybrids are reported in sustainability performance measurement and in infrastructure prioritization, where interdependencies among environmental, social and governance factors must be accounted for [29], [30]. Researchers have demonstrated that using DEMATEL before ANP helps establish the influence structure that informs ANP's supermatrix construction, producing more realistic global weights than isolated AHP applications [25], [31]. TOPSIS is frequently used downstream to rank candidate policies or projects once weights are obtained, enabling a clear prioritization that remains interpretable to practitioners [32].

The *economic* dimension- cost effectiveness, return on investment (ROI) and resource utilization which frequently emerge as a decisive criterion in sustainable project selection [33], [34]. Studies show that when resources are constrained, economic feasibility often drives early-stage decision making, even when long-term environmental benefits are significant [35], [36]. This underscores the need for an MCDM framework that can balance short-term financial imperatives with long-term sustainability objectives, and that can be used to present tradeoffs transparently to stakeholders and funders [37], [38].

Environmental criteria- energy efficiency, emissions reduction, waste minimization, circularity are essential to evaluating the sustainability performance of projects, particularly in infrastructure, manufacturing and energy sectors [39], [40]. Empirical work has quantified how project design choices (material selection, process optimization, renewable integration) affect lifecycle emissions and operating costs, showing that multi-criteria evaluation leads to different optimal solutions than cost-only assessment [41], [42]. Consequently, advanced MCDM frameworks often include environmental sub-criteria that are measurable and comparable across alternatives [43], [44].

On the *social* dimension, stakeholder engagement, local acceptance and job creation are closely tied to project legitimacy and long-term success [45], [46]. Studies in infrastructure and energy projects document how insufficient engagement leads to delays, cost overruns and project failure, while participatory approaches improve outcomes and social value creation [47]. Challenge-driven projects, which often require community buy-in and co-creation, are particularly sensitive to social-inclusion criteria [48].

Governance factors- institutional capacity, risk management, regulatory alignment and transparency are widely recognized as enabling conditions for sustainable project delivery [49] [54]. Good governance reduces uncertainty, attracts finance, and increases scalability of innovative solutions; it also acts as a multiplier, meaning governance improvements can cause positive changes in financial, environmental and social outcomes. DEMATEL analysis in past studies frequently identifies governance or institutional coordination as a causal driver that influences other criteria [50], [51].

Technological adaptability or readiness- including digitalization, IoT-enabled monitoring, and technology innovation has been shown to increase the efficiency and scalability of sustainability interventions [52] [56]. Case studies in renewable energy, smart city pilots, and green manufacturing highlight that digital tools enable performance tracking, rapid iteration and improved stakeholder communication — all critical for scaling challenge-driven innovations [53], [57] , [58].

In summary, the literature provides robust conceptual arguments, empirical evidence, and methodological tools to justify and operationalize an MCDM-based challenge-driven project management framework [55] , [56]. The combination of DEMATEL, ANP is well supported by prior studies. Empirical guidance on expert elicitation, aggregation, consistency and sensitivity analysis will ensure the framework produces credible, actionable outputs for project managers and policymakers, particularly in resource-constrained or developing country settings where the prioritized challenges (A1–A5) are prominent.

3. Methodology

3.1. Research Design Overview

This study adopts a mixed-method quantitative approach integrating *Decision-Making Trial and Evaluation Laboratory (DEMATEL)* and *Analytic Network Process (ANP)* under a hybrid MCDM framework to identify and prioritize critical sustainability challenges in challenge-driven project management [51] ,[52]. The methodological structure follows three major stages:

- *Expert data collection* through structured questionnaires.
- *Causal interrelationship analysis* among criteria using DEMATEL; and
- *Weight determination and prioritization* of sustainability challenges using ANP.

The whole methodology process is shown in figure 1.

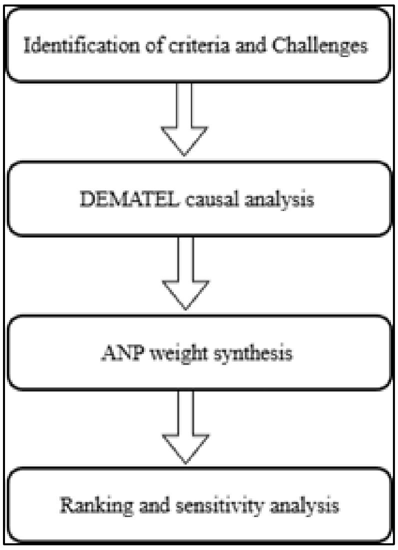

Figure 1 Research methodology steps

4. Data Analysis and Results

This chapter presents the empirical results obtained from the survey responses and subsequent MCDM-based analyses**,** specifically using the DEMATEL and ANP techniques. The objective is to identify the interrelationships among sustainability criteria, determine their relative importance, and rank the major challenges influencing the adoption of *Challenge-Driven Project Management (CDPM)* for sustainable development [54], [57].

The analysis is based on responses from 20 domain experts, including project managers, sustainability consultants, and academic researchers specializing in sustainable development, industrial engineering, and project management. The dataset was processed through Microsoft Excel 2016**,** which was equipped with automated matrix calculations and consistency validation tools.

4.1. Experts Summary

The survey comprised two sections:

- *DEMATEL Questionnaire* – evaluating interrelationships among five main criteria (C1–C5).
- *ANP Questionnaire* – performing pairwise comparisons among criteria, sub-criteria, and alternatives (A1–A5).

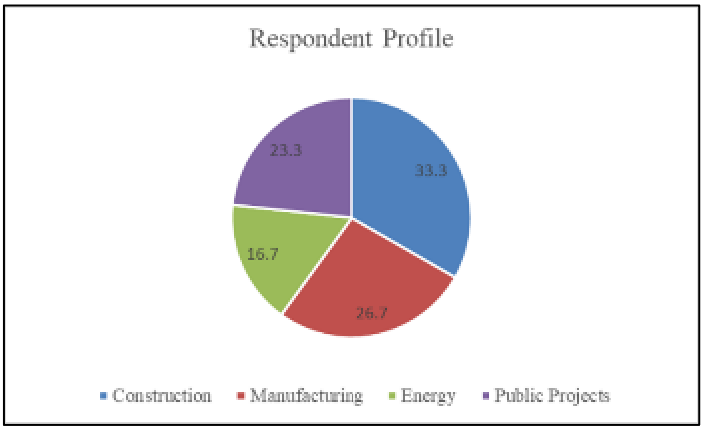

Figure 2 Expert Participation Summary

A total of 20 responses were collected. Among them, 60% were industry practitioners and 40% were academic experts. The average professional experience was 6.5 years**,** ensuring reliability and validity of expert judgments. The profile of the respondents are summarized in pie chart 2.

4.2. DEMATEL Analysis

4.2.1. Direct-Relation Matrix

Experts rated the influence of each criterion on the others on a scale of 0 (no influence) to 4 (very high influence). The average values were aggregated into a 5×5 direct-relation matrix (D), as shown in Table 1.

Table 1 Direct-relation Matrix

	C1	C2	C3	C4	C5
C1	0	1.8	2.2	2.6	1.5
C2	2.1	0	2.4	1.9	2
C3	1.5	1.7	0	2.2	1.4
C4	2.6	2.1	2.3	0	2.5
C5	2.2	2.5	2.2	2.5	0

4.2.2. Normalization Matrix

The matrix in Table 2 was normalized by dividing all elements by the maximum row sum to ensure stability of the model.

Table 2 Normalized Matrix

	C1	C2	C3	C4	C5
C1	0	0.189474	0.231579	0.273684	0.157895
C2	0.221053	0	0.252632	0.2	0.210526
C3	0.157895	0.178947	0	0.231579	0.147368
C4	0.273684	0.221053	0.242105	0	0.263158
C5	0.231579	0.263158	0.231579	0.263158	0

4.2.3. Total Matrix

The Total Relation Matrix (T) was obtained using equation (3) and presented in Table 3.

Table 3 Total Matrix

	C1	C2	C3	C4	C5
C1	1.361975	1.473146	1.642965	1.681459	1.36769
C2	1.57436	1.346878	1.693034	1.669001	1.431374
C3	1.319916	1.292887	1.263012	1.459169	1.198083
C4	1.769995	1.682591	1.855576	1.674597	1.610997
C5	1.732742	1.700942	1.838387	1.870355	1.394803

4.2.4. Causal Interpretation

Casual Interpretation provide valuable insights into the interdependencies between different sustainability factors in project management.

Table 4 Casual relationship between criterion

Criterion	D (Given)	R (Received)	Prominence (D+R)	Relation (D-R)
C1	7.527234	7.758988	15.28622	-0.23175
C2	7.714648	7.496445	15.21109	0.218203
C3	6.533067	8.292975	14.82604	-1.75991
C4	8.593758	8.354582	16.94834	0.239176
C5	8.537229	7.002946	15.54018	1.534283

From table 4 the value of Relation (D-R) is positive for C2 (Environmental Sustainability), C4 (Project Governance) and C5 (Technological Adaptability), so they are identified as the *cause group,* meaning they are the major influencers in the system. On the other hand, the negative value of C1 (Economic Feasibility) and C3 (Social Responsibility) are categorized as the effect group**,** meaning they are primarily influenced by other criteria. This means that improving governance, environmental strategies, and technological adaptability can indirectly enhance economic and social sustainability[58], [59].

Technological Adaptability ranked closely behind governance, indicating the growing importance of digitalization, data analytics, and automation in achieving project sustainability. Studies such as Brones et al. (2020) and Lu et al. (2022) similarly observed that digital tools and AI-driven monitoring significantly improve environmental and resource efficiency metrics.

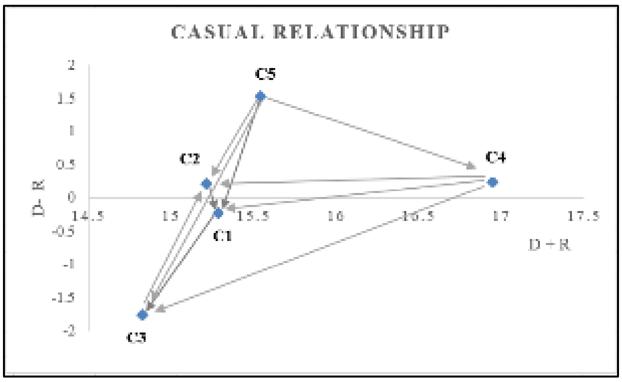

Figure 3 DEMATEL causal diagram showing cause group and effect group.

Figure 3 illustrates the causal relationships between the five criteria (C1, C2, C3, C4, and C5) based on their D + R (sum of given and received influences) and D - R (net influence) values. The x-axis represents the D + R values, indicating the overall prominence of each criterion, while the y-axis shows the D - R values, which determine whether a criterion is a net cause or effect. Arrows are used to represent the direction of influence between the criteria, with C5 being the most influential, impacting C4, C2**,** and C1, C4 also significantly influences C3**,** and C3 influences C1**,** while C1 impacts C2. The threshold value (α = 1.556) filters out criteria with weaker influences, ensuring that only those with sufficient influence (such as C5 and C4) are actively included in the network, while others like C3 and C1 have less significant effects. This graph effectively visualizes the cause-and-effect dynamics within the green project management dimensions.

5. Conclusions and Recommendations

The study concludes that the hybrid MCDM approach integrating DEMATEL and ANP is highly effective in capturing both causal relationships and interdependencies among sustainability criteria, offering a robust analytical foundation for evaluating complex project management environments. The findings reveal that governance and technological adaptability act as fundamental enablers of sustainability, supporting the theoretical underpinnings of adaptive governance and innovation-driven sustainability. Furthermore, the proposed Challenge-Driven Project Management (CDPM) framework provides a structured and iterative mechanism to identify, analyze, and mitigate sustainability challenges, enabling project decision-makers to align short-term actions with long-term sustainable development goals. However, the study acknowledges certain limitations, including the moderate expert sample size (n = 30), potential subjectivity in pairwise comparisons, and the assumption of static inter-criteria relationships that may vary across project contexts.

Based on these insights, future research is encouraged to enhance the robustness and applicability of the CDPM framework by incorporating advanced MCDM techniques such as Fuzzy DEMATEL–ANP to manage uncertainty, or by comparing results using methods like BWM, TOPSIS, and VIKOR. Cross-sectoral applications in construction, renewable energy, and manufacturing, as well as longitudinal or cross-country studies, could provide broader validation. Additionally, developing a decision-support software or dashboard would facilitate real-time challenge prioritization and managerial adoption. From a practical standpoint, project managers should integrate sustainability challenge assessments during project initiation and planning, while policymakers should promote technological innovation and transparent governance through supportive regulations. Academics, on the other hand, can adopt the CDPM framework as a teaching and research tool to advance sustainable project management education.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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