FACTORS INFLUENCING THE LEVEL OF CIRCULAR ECONOMY PARTICIPATION ACROSS TRANSPORTATION PROJECTS WITH DIFFERENT PROFITABILITY LEVELS THROUGH EFA ANALYSIS

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Abstract: ***This study examines the factors influencing implementation of the circular economy (CE) in transportation infrastructure projects (ICE-TIP) with different profitability levels in Vietnam. Using survey data from 312 professionals involved in infrastructure projects during 2020–2024, the study applies Exploratory Factor Analysis (EFA) to identify key factor structures associated with CE implementation. Projects are classified into two groups based on the Internal Rate of Return (IRR): high-profitability (IRR ≥ 11%) and low-profitability (IRR < 11%). The results show that high-profitability projects exhibit a coherent four-factor structure including management policy, internal capabilities, technology adoption, and supply chain integration. In contrast, low-profitability projects display a more fragmented structure with weaker institutional and organizational elements. The findings highlight the need for differentiated policy approaches to promote CE adoption across projects with varying financial capacities.***

• Keywords: *circular economy, transportation infrastructure, profitability, policy difference.*

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1. Introduction

In the context of climate change, resource depletion, and increasing pressure for sus-tainable development, the circular economy (CE) model has emerged as a compre-hensive approach to restructuring production and consumption patterns particularly in resource-intensive sectors such as transportation infrastructure construction (Abdulai et al., 2024).

In the field of transportation infrastructure construction, the adoption of CE principles such as modular design, use of recycled materials, lifecycle digitalization, and predictive maintenance is receiving growing attention (Awad et al., 2024).

However, practical implementation in Vietnam reveals that CE participation levels in transportation projects remain limited and uneven across project types. One of the key factors influencing CE engagement is project profitability levels (Tô & Bùi, 2025; Trần et al., 2022). Highly profitable projects are more likely to access advanced technologies and invest in digital and sustainable solutions, whereas low-profit projects are often constrained by costs, limited financial capacity, and a lack of prioritization for non-financial sustainability goals.

This raises a critical question: Are projects with different profitability levels select-ing different CE solution groups? And if so, how do the factor structures influencing CE participation differ between groups? Understanding these differences forms the basis for designing tailored support policies that enable less profitable projects to still access and benefit from CE practices, while encouraging financially capable projects to take on leadership roles.

This study aims to develop and analyze a model of factors affecting CE participa-tion in transportation infrastructure construction projects (ICE-TIP) and to compare factor structure differences between high-profitability and low-profitability project groups using Exploratory Factor Analysis (EFA). The research provides clear quantitative evidence on the differences in CE drivers and barriers across project types and offers policy recommendations to promote the wider adoption of the circular economy model across the entire transportation sector.

2. Literature Review

2.1. Policy and Regulatory Foundations for Circular Economy Implementation

In the field of transportation infrastructure construction, governmental policies and

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regulations play a pivotal role in establishing a conducive legal environment for pro-jects to adopt circular economy (CE) practices. Several international studies have demonstrated that the presence of incentive frameworks such as tax relief, green fi-nance, and mandatory material reuse regulations can significantly promote CE adop-tion in the construction sector (Khan & Mahajan, 2023).

In Vietnam, although the orientation toward CE has been embedded in various national strategies, studies reveal that implementation guidelines remain fragmented, non-binding, and especially vague in the context of transportation infrastructure (Tô & Bùi, 2025; Trần et al., 2022; Vietnam, 2016). The lack of clear technical standards for material reuse and waste management often leads to passive adoption and neglect of CE practices among projects. Furthermore, studies emphasize that policy clarity, transparency, and effective enforcement mechanisms are critical in building trust and incentivizing sustainable investments (Fathalizadeh et al., 2019; Kahupi et al., 2024).

Based on these findings, management policy is considered a key factor influencing the level of circular economy participation in transportation infrastructure projects, including aspects such as regulatory clarity, financial incentives, and monitoring mechanisms.

2.2. Internal Resources Driving Circular Implementation

According to the dynamic capabilities theory, innovation capacity and organizational adaptability are key to navigating transitions such as CE transformation (Teece et al., 1997). In large-scale infrastructure construction, CE implementation requires in-depth technical understanding, integrated planning capacity, and a corporate culture aligned with sustainability goals. Brglez et al. found that projects with top-level management committed to sustainability are more likely to invest in recycled materials, lifecycle assessment (LCA) tools, and resource-efficient processes (Brglez et al., 2025). In contrast, projects with limited internal capabilities and lacking CE as a strategic priority often implement circular measures superficially (Wang & Levinson, 2023). In Vietnam, Tô and Bùi pointed out that a lack of green project management skills, absence of dedicated CE departments, and weak innovation culture remain major barriers in the transportation construction sector (Tô & Bùi, 2025).

Therefore, internal capabilities are expected to play an important role in shaping CE participation, particularly through leadership commitment, implementation capacity, and organizational culture.

2.3. Technological Foundations Enhancing Circular Implementation

In the construction sector, technologies such as Building Information Modeling (BIM), lifecycle assessment (LCA), and material passports are essential tools to enable circularity (Bonifazi et al., 2025; Verma et al., 2025). These digital tools help projects identify reuse potential, optimize construction processes, and minimize emissions across the asset lifecycle.

In Vietnam, however, the readiness to adopt such CE technologies in transportation infrastructure projects remains low due to limited technological capabilities, lack of investment funding, and absence of integrated data systems (Ngô et al., 2020). Therefore, technology readiness is considered a critical differentiator between pioneering and lagging projects.

Thus, technology adoption is considered another major factor affecting CE participation, including the application of digital construction technologies, information systems for resource management, and technologies for recycled materials.

2.4. Collaborative Conditions for Circular Implementation

CE in construction cannot be realized in isolation; it demands coordinated efforts among main contractors, material suppliers, recycling units, monitoring agencies, and investors (Arabpour & Silvius, 2023; Kahupi et al., 2024). The ability to share lifecycle data across the supply chain is essential to CE success in transportation construction projects. However, Trần et al. found that Vietnam's construction supply chain remains fragmented, lacks standardized green contracting practices, and does not yet have technical platforms for data integration among stakeholders hindering traceability, material reuse, and circular design implementation (Trần et al., 2022).

Accordingly, supply chain integration is identified as another critical factor influencing CE participation, particularly through supplier linkage, lifecycle data sharing, and the adoption of green contract models.

Based on the literature review, four conceptual factor groups were identified: management policy, internal capabilities, technology adoption, and supply chain integration. These factors were later examined using exploratory factor analysis (EFA).

3. Data and research methodology

3.1. Research data

The data were collected from technical staff, consultants, and project managers with experience in transportation infrastructure construction projects in Vietnam during the period 2020–2024. A total of 400 survey questionnaires were distributed, of which 312 valid responses were used for analysis.

The questionnaire was designed using a 5-point Likert scale (ranging from 1 – Strongly disagree to 5 – Strongly agree) to measure the influence of various factor groups on the implementation of circular economy (CE) practices.

To clarify the relationship between financial efficiency and CE participation, the projects were classified into two groups based on the "Internal Rate of Return (IRR)" indicator:

- High-IRR group: projects with an estimated IRR ≥ 11%, based on respondents' assessments or related financial reports.

- Low-IRR group: projects with IRR < 11%, assessed as having modest financial performance, longer payback periods, or high cash flow risks.

This classification is informed by the Asian Development Bank's (ADB) benchmark, where projects with an Economic IRR (EIRR) above 12% are typically approved, while those below 10% are often rejected (Wang & Levinson, 2023).

3.2. Analytical method

Following the methodological frameworks of Soewin & Chinda (2018) and Van Tam (2025), this study employs Exploratory Factor Analysis (EFA) to identify the underlying structures influencing Circular Economy (CE) engagement in transportation infrastructure projects.

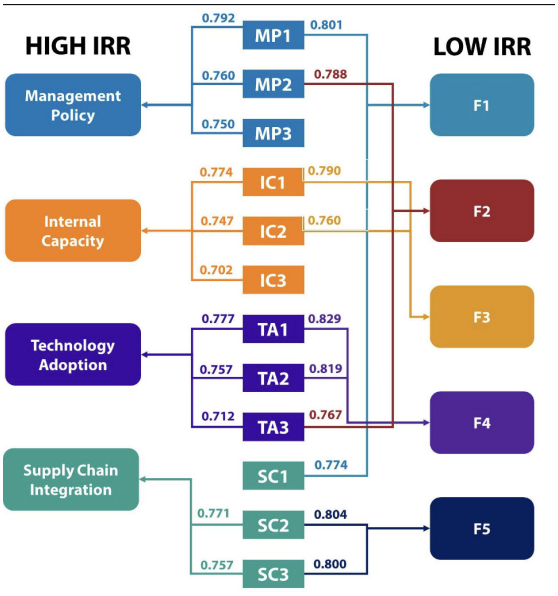
Table 1. Key Factors and Variables Influencing Circular Economy Implementation in Transportation Infrastructure Projects

Factors	Variable	Content	Related researches
Factor 1: Management Policy	MP1	Clear and coherent CE legislation	(Fathalizadeh et al., 2019)
	MP2	Green financial incentives	(Khan & Mahajan, 2023; Tô & Bùi, 2025)
	MP3	Monitoring and sanction mechanism	(Fathalizadeh et al., 2019)
Factor 2: Internal Capacity	IC1	Leadership commitment	(Tô & Bùi, 2025)
	IC2	Implementation capability	(Brglez et al., 2025; Tô & Bùi, 2025)
	IC3	Organizational culture	(Wang & Levinson, 2023)
Factor 3: Technology Adoption	TA1	Application of digital technologies in sustainable construction	(Ngô et al., 2020; Verma et al., 2025)
	TA2	Information system for resources and waste	(Ngô et al., 2020)
	TA3	Technology for recycled materials and construction	(Bonifazi et al., 2025)
Factor 4: Supply Chain Integration	SC1	Supplier linkage	(Arabpour & Silvius, 2023)
	SC2	Data sharing	(Kahupi et al., 2024)
	SC3	Green contract model	(Arabpour & Silvius, 2023)

4. EFA results

The EFA results are presented in the following Figure:

Fig. 1. Factor Structures (Loading factor and groups)



Source: Designed by the author

The EFA results for high-profitability projects (KMO = 0.663) identify four core factors Management Policy, Internal Capacity, Technology Adoption, and Supply Chain Integration explaining 60.37% of the total

variance with acceptable reliability (Cronbach's alpha: 0.554–0.681). In contrast, low-profitability projects (KMO = 0.508) exhibit a more fragmented five-factor structure despite explaining 72.14% of the variance, with lower internal consistency (alpha: 0.514–0.557). In the low-IRR subgroup, the analysis yielded a marginal KMO of 0.508 and Cronbach's Alpha coefficients ranging from 0.514 to 0.557. These relatively low reliability indices suggest a nascent stage of Circular Economy (CE) adoption and a lack of consensus in perception among the surveyed firms. Consequently, these findings are presented as exploratory evidence, serving as a preliminary baseline rather than establishing definitive structural paths

Among projects with high profitability (IRR ≥ 11%), the factor analysis results reveal a clear and theoretically consistent structure. The factors influencing circular economy (CE) implementation are grouped into four distinct categories: policy, internal capacity, technology, and supply chain. Each factor cluster comprises observed variables with high loadings and no significant cross-loadings, indicating that the factors exert distinct and consistent effects on the actual implementation of CE practices in these projects. In other words, when financial conditions are favorable, projects possess sufficient resources to methodically engage with and operate various components of the CE framework from leveraging policy incentives and enhancing internal capabilities to adopting technologies and establishing green supply chain linkages. As such, the influence of each factor group is reflected independently, systematically, and in line with the original theoretical assumptions.

In contrast, the factor structure for projects with lower profitability (IRR < 11%) presents a markedly different picture. Instead of the four theoretically derived categories (policy, internal capacity, technology, supply chain), the actual analysis yields five distinct factors. A new factor emerges, combining two variables originally assigned to separate theoretical groups: MP1 (policy transparency) and SC1 (supplier linkage).

The simultaneous emergence of these two variables in one factor suggests a tightly intertwined and conditionally dependent relationship between policy and supply chain mechanisms in the practical implementation of low-efficiency projects. Specifically, in these cases, project developers often lack the resources to independently engage with policy frameworks or establish a robust partner network. When policies are vague, lack clear technical standards, or fail to signal long-term stability, suppliers tend to remain passive reluctant to invest in recycling technologies, green materials, or long-term collaborative commitments. Conversely, if the partner network is weak, lacking capacity or innovation drive, even well-formulated policies face difficulties in real-world execution due to the absence of capable stakeholders.

As a result, in financially constrained contexts where every decision must account for short-term risks and limited cash flow the relationship between policy and supply chain is no longer structured along separate axes but becomes a tightly bound and inseparable unit of mutual influence. This explains why, in the factor analysis, MP1 and SC1 no longer load independently onto distinct factors (as seen in the high-efficiency group), but instead converge on an integrated factor.

Moreover, other factor clusters in the low-IRR group reflect the specific characteristics of these projects. For example, financial incentives (MP2) and recycled materials (TA3) appear within the same factor, suggesting that concern for recycled materials is only activated when direct financial support is available a common trait among financially limited projects. In contrast, internal capacity (IC1, IC2), digital technology (TA1, TA2), and supply chain coordination (SC2, SC3) still form separate groups, but operate within a fragmented environment, lacking holistic integration, which diminishes the effectiveness of CE implementation.

Notably, the factor analysis for the low-IRR group shows the complete absence of two key variables: MP3 (sanction mechanism) and IC3 (organizational culture). This reflects the practical reality that foundational and long-term elements such as strict enforcement mechanisms or a well-established internal culture are not perceived by these projects as directly influencing CE adoption decisions. On one hand, enforcement mechanisms may be too vague, lacking deterrent power, or inconsistently applied, preventing projects from perceiving any real compliance pressure. On the other hand, organizational culture evolves over time and requires sustained leadership commitment and internal consensus conditions

that financially struggling or short-term-oriented projects often lack the capacity to maintain.

In summary, the differences in factor structure between the two project groups stem from fundamentally distinct implementation environments. High-profitability projects typically benefit from consistent support across policy, partnerships, and internal capacity, allowing influencing factors to operate independently and as theoretically expected. In contrast, low-profitability projects suffer from the lack of such coordination, causing formerly independent factors to become interdependent and overlapping resulting in a fragmented, under-resourced, and poorly coordinated CE implementation landscape. This significantly hinders the realization of sustainable development goals aligned with circular economy principles.

5. Conclusion and Recommendations

Based on the Exploratory Factor Analysis (EFA), this study identifies a clear structural divergence in the factors influencing Circular Economy (CE) implementation between high-profitability and low-profitability transportation infrastructure projects. For high-return projects, factors are structured in a stable and logical manner, reflecting a comprehensive integration of institutional frameworks, technology adoption, and organizational capacity. In contrast, low-profitability projects exhibit fragmented strategies and unstable awareness, where policy, technology, and operational variables often overlap, leading to diminished economic and environmental outcomes.

The study advocates for a stratified policy framework rather than a "one-size-fits-all" approach. For high-capacity projects, the focus should be on scaling innovation through Life Cycle Management (LCM), BIM/LCA integration, and the formation of industry-wide circular alliances. These projects should be incentivized through green certifications and preferential bidding eligibility for public infrastructure tenders that prioritize sustainability criteria. Such a top-down innovation model ensures that leading projects drive the industry's technological frontier.

Conversely, for low-capacity projects, policy support must prioritize institutional risk mitigation and foundational capacity building. Complex legal frameworks should be translated into practical, sector-specific technical toolkits with visual aids and on-site training. CE adoption in this group should start with small-scale, low-risk recycling models such as using waste concrete for subbase layers supported by simplified access to green credit and regional circular construction labs for technology transfer.

At the macro level, inter-sectoral coordination is essential to synchronize CE deployment across regions. Future research should focus on validating these factor structures using Confirmatory Factor Analysis (CFA) and Structural Equation Modeling (SEM). Quantifying the impact of each factor group on the triple-bottom-line (financial, environmental, and social outcomes) will provide a more robust scientific foundation for long-term sustainable transportation development.

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