



# Discovering the underlying relationships among assembly-phase risk factors in MiC projects

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## ABSTRACT

Modular Integrated Construction (MiC) has emerged as a promising approach to address growing urban housing demands, offering advantages in construction speed, cost efficiency, and quality control. Despite increasing global interest, research specifically examining risks during the assembly phase of MiC projects in developing countries remains limited. Existing studies tend to focus on the overall project lifecycle and predominantly reflect conditions in developed markets, leaving a significant gap in understanding how assembly-phase risks are structured in emerging economies such as Vietnam. This study aims to uncover the latent relationships among assembly-phase risk factors in MiC projects within the Vietnamese construction industry. A three-stage methodology was adopted, combining a systematic literature review, structured expert consultation with senior MiC practitioners, and a quantitative questionnaire survey targeting construction professionals from leading firms with direct MiC experience. Exploratory factor analysis with Varimax rotation was applied to identify the underlying structure of the risk factors. The analysis revealed seven distinct risk components. External factors emerged as the most dominant group, driven primarily by material price volatility, environmental impacts of construction activities, and government policy changes. This was followed by risks related to construction materials, machinery, and equipment, with lifting equipment installation identified as a key concern. Management and planning risks ranked third, centered on inappropriate construction methods and inadequate scheduling. The remaining components encompassed risks from component manufacturing and transportation, stakeholder capacity limitations, delays attributable to project participants, and coordination difficulties among parties. A notable finding is that external institutional factors, rather than technical risks, constitute the dominant risk dimension in Vietnam's MiC context. This contrasts with patterns observed in developed markets and reflects the heightened influence of policy uncertainty, market volatility, and infrastructure constraints in emerging economies. The seven-factor framework developed in this study extends existing risk management theory to better accommodate emerging market conditions and provides industry practitioners with a structured basis for prioritizing risk mitigation efforts. For policymakers, the results highlight the importance of regulatory stability and institutional support in enabling sustainable MiC growth in Vietnam.

**Key words:** Modular Integrated Construction (MiC), risk management, assembly phase, Construction Risks

## INTRODUCTION

Vietnam's rapid urbanization has created unprecedented demand for housing and infrastructure, with urban population expected to reach 45% by 2030, requiring approximately 70 million square meters of additional urban housing annually (10). This surge in demand, coupled with increasing foreign direct investment in construction and real estate sectors, has necessitated innovative construction methods to meet tight schedules and cost requirements. MiC has emerged as a viable alternative to traditional construction methods, offering advantages such as reduced construction time, improved quality control, and better cost efficiency (13). This method involves producing building components in factory-controlled

environments before transporting them to construction sites for assembly (2). The assembly phase represents a critical stage in MiC projects, involving the transportation and installation of prefabricated components at construction sites. This phase requires complex coordination between multiple stakeholders, including manufacturers, transporters, and construction teams, making effective risk management essential for project success. Existing research has examined various risk factors in MiC projects through different methodological approaches. Li et al. (2013) utilized fuzzy analytic hierarchy process to identify and assess MiC risks (8). Lee and Kim (2017) analyzed cost-increasing risk factors in Korea using failure mode and effects analysis (6). Li et al. (2017) de-

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veloped schedule risk models for prefabrication housing production using system dynamics and Monte Carlo simulation (7). More comprehensive reviews by Wuni et al. (2019) and Khan et al. (2022) have systematically identified critical risk factors across different project phases (5,12).

Despite the growing number of studies on risk factors in MiC projects, several important research gaps remain unaddressed. Most studies adopt a broad project lifecycle perspective, with limited attention specifically given to risks during the assembly phase. In addition, few studies provide a comprehensive structure for categorizing risk factors into meaningful groups to support effective risk management. Moreover, there is a lack of context-specific research in Vietnam, where industry conditions and practices may differ significantly from those in other countries. Specifically, this study addresses the following research questions: (1) What are the key risk factors affecting the assembly phase of MiC projects in Vietnam? (2) What underlying relationships exist among these assembly-phase risk factors? (3) How do these risk factor relationships differ from patterns observed in developed markets? To address these gaps, this study investigates risk factors specific to the assembly phase of MiC projects in Vietnam. By applying factor analysis to survey data collected from industry professionals, this research aims to uncover the underlying relationships among assembly-phase risk factors and provide insights for improving risk management practices in Vietnam's MiC sector.

## LITERATURE REVIEW

Risk management has long been recognized as a fundamental component of successful construction project delivery, with extensive research emphasizing its critical role in achieving project objectives related to time, cost, quality, and safety (4). Traditional risk management frameworks typically encompass risk identification, analysis, evaluation, and response planning, evolving from qualitative assessments to sophisticated quantitative approaches incorporating probabilistic models and simulation techniques. MiC represents a significant departure from traditional on-site construction methods, introducing new risk dimensions while potentially mitigating others. This method involves several distinct phases including design, manufacturing, transportation, and assembly, each presenting unique risk characteristics (11). The assembly phase is particularly critical as it involves the convergence of off-site manufacturing processes with on-site construction activities.

Several pioneering studies have attempted to identify and categorize risks in MiC projects. Li et al. (2013) applied fuzzy analytic hierarchy process to MiC risk assessment, identifying 15 major risk factors including design errors, manufacturing defects, transportation damage, and assembly complications (8). Lee and Kim (2017) analyzed cost-increasing risk factors in Korean MiC projects, identifying 12 critical risk factors and recommending strategies to minimize costs through improved installation and logistics (6). Li et al. (2017) focused on schedule risks in prefabrication housing, identifying 4 key risk factors affecting project timelines: information flow deficiency between enterprise systems, logistical information handling issues, environmental monitoring concerns, and information gaps between design and manufacturing (7). More comprehensive reviews have emerged recently. Wuni et al. (2019) conducted a systematic review identifying 29 critical risk factors, with the five most significant being stakeholder fragmentation, high initial costs, poor supply chain integration, component delivery delays, and inadequate government support (13). Khan et al. (2021) reviewed 52 studies, categorizing risks by project phases and noting that assembly phase risks are often underrepresented compared to design and manufacturing phases (5). Wuni et al. (2022) used principal component analysis to group 29 risk factors into four categories: stakeholder and supply chain risks, design and capability risks, financial risks, and regulatory risks (12). Wuni and Shen (2020) evaluated 28 risk events across the MiC supply chain, identifying on-site assembly as particularly high-risk, with concerns including misalignment, weather issues, workspace conflicts, and skilled labor shortages (11).

Recent research from emerging markets reveals distinct risk patterns compared to developed countries. In Malaysia, Hassan et al. (2024) found that external institutional factors pose greater risks than technical aspects in MiC implementation (1), while Ismail and Adnan (2016) identified regulatory inconsistency and skilled labor shortages as major barriers to MiC adoption in Malaysia (9). Studies on modular construction in Brazil also indicate that infrastructure constraints and complex regulatory approval processes significantly hinder the adoption of MiC (14). Comparative analysis of Southeast Asian markets, including Thailand, Indonesia, and Malaysia, reveals persistent challenges in transportation logistics and institutional support, indicating that emerging markets face fundamentally distinct risk structures compared to developed economies (3).

Although many studies have contributed to understanding risks in MiC projects, several issues remain underexplored. Most existing research examines the entire project lifecycle, with limited focus on the specific challenges involved in the assembly phase. In addition, there is a lack of research in developing countries like Vietnam, where regulations, technologies, and market conditions may differ from those in more established markets. Few studies have grouped assembly-phase risk factors into categories that can support effective risk management. Therefore, this study aims to address the identified gaps by focusing on risk factors specific to the assembly phase of MiC projects.

## METHODOLOGY

This study was approached with three basic stages shown in the flowchart in Figure 1, aiming to identify and analyse risk factors in the assembly phase of MiC projects in Vietnam. The research methodology combines expert qualitative assessment with factor analysis to ensure comprehensive identification of risk factors. The first stage focused on risk identification through a literature review of publications related to modular construction risks, supplemented by expert consultation. Articles, reports, and academic works published in the last 15 years were reviewed to identify potential risk factors relevant to the assembly phase. This literature search resulted in 35 preliminary risk factors, which were then refined through consultation with five experts selected based on specific criteria: minimum 15 years of construction experience, direct involvement in at least three MiC projects in Vietnam, and current senior positions (project directors, construction managers, or principal engineers). The consultation employed a two-round process where experts independently assessed each risk factor's relevance using a 5-point scale, achieving consensus when  $\geq 80\%$  agreement was reached, ultimately confirming 32 risk factors from the initial 35. These experts assessed the relevance and applicability of each risk factor in the Vietnamese construction context, ultimately confirming 32 risk factors (Table 1). After identifying the risk factors, the next stage involved data collection through a structured questionnaire survey. The questionnaire used a five-point Likert scale to assess both the likelihood of occurrence and the level of impact of each identified risk factor. Survey participants were selected through a convenience sampling method from leading construction companies in Vietnam. Convenience sampling was chosen due to the specialized nature of MiC experience in Vietnam, where only a

limited number of construction companies have implemented modular projects. This approach enabled access to practitioners with relevant MiC experience, though it may limit the generalizability of findings to the broader construction industry.

The survey distribution targeted construction practitioners with direct experience of modular construction, ensuring the quality and relevance of the data. The data collection process generated 172 initial responses, of which 14 incomplete or inconsistent questionnaires were discarded, resulting in 158 valid responses for analysis. The sample size of 158 respondents satisfies the minimum requirements for factor analysis. With 32 variables, the participant-to-variable ratio is 4.94:1, which exceeds the minimum threshold of 4:1 recommended by Tabachnick and Fidell (2019) and approaches the preferred 5:1 ratio. Furthermore, the Kaiser-Meyer-Olkin (KMO) value of 0.812 confirms sample adequacy as "meritorious" according to Kaiser's (1974) classification, indicating that the sample size is sufficient for reliable factor extraction. The final sample included project managers (34%), site engineers (38%), project directors (15%), and other construction professionals (13%). The experience levels of the participants ranged from less than 5 years (24%) to more than 20 years (7%), while the project sizes ranged from less than VND50 billion to more than VND trillion, ensuring broad representation across project sizes and experience levels. The study scope is limited to assembly-phase risks in MiC projects within Vietnam's construction industry. Data limitations include the focus on practitioner perceptions rather than objective risk measurements, reliance on self-reported experience levels, and potential response bias inherent in survey methodologies. The temporal scope covers current industry conditions and may not reflect future changes in technology or regulatory frameworks. In the final stage, the study included a comprehensive data analysis that began with a reliability assessment using Cronbach's alpha to verify internal consistency within risk factors. The reliability analysis revealed satisfactory internal consistency across factor groups, with Cronbach's alpha values ranging from 0.693 to 0.851. Six of seven factors exceeded the recommended 0.7 threshold (Nunnally, 1978): Risks related to external factors ( $\alpha = 0.833$ ), Risks related to management and planning ( $\alpha = 0.851$ ), Risks arising from component production and transportation ( $\alpha = 0.768$ ), Risks related to the capabilities of project stakeholders ( $\alpha = 0.779$ ), Risks related to construction materials, machinery, and equipment ( $\alpha = 0.732$ ), and Risks related to delays caused by project participants ( $\alpha = 0.715$ ). Risks

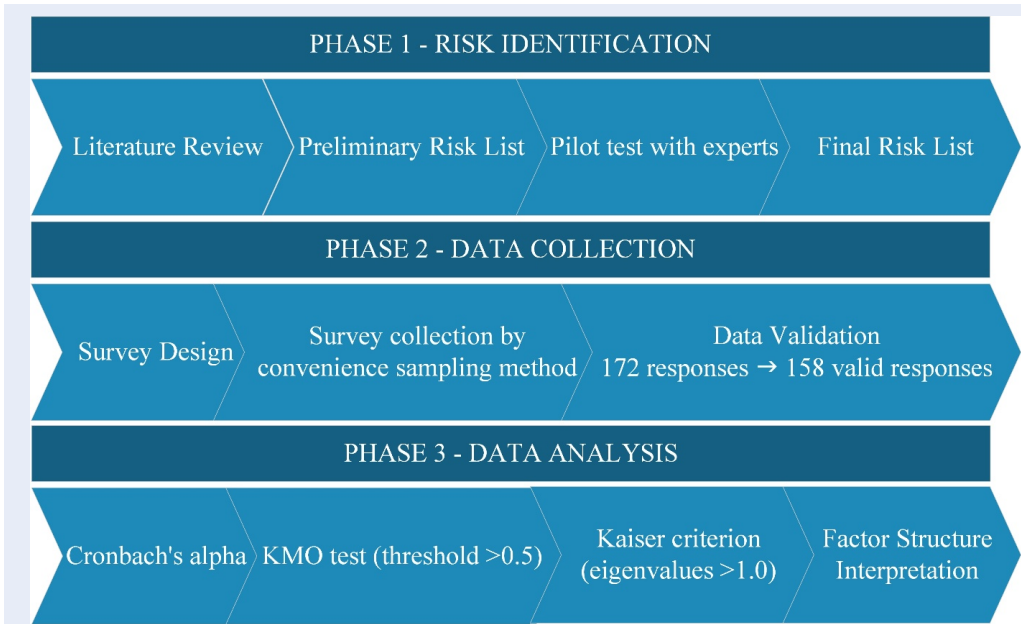


Figure 1: Research framework. Source: Authors own work

related to the coordination among project participants ( $\alpha = 0.693$ ) approached the acceptable threshold, which is reasonable given its smaller number of items. Factor analysis was then conducted to determine the underlying relationships of the assembly risk factors. The Kaiser-Meyer-Olkin (KMO) test was used to assess the adequacy of the sample, with values above 0.5 considered acceptable for factor analysis. Bartlett's sphericity test was also performed to confirm the suitability of the correlation matrix for factor extraction. According to the Kaiser criterion, components with eigenvalues greater than 1.0 were retained for interpretation. Varimax rotation was applied to enhance the interpretability of the resulting factor solution, ensuring a clearer factor structure and more meaningful clustering of variables. Factor loadings above 0.5 were considered meaningful for interpretation, with variables assigned to factors based on their highest loading values. The analysis examined the cumulative variance explained by the extracted factors to ensure adequate representation of the original risk variables.

DATA ANALYSIS

Factor analysis successfully identified seven distinct risk components that collectively explain 63.388% of the total variance in the dataset. The Kaiser-Meyer-Olkin (KMO) measure was 0.812, exceeding the recommended threshold of 0.5, while Bartlett's test of

sphericity was statistically significant ( $p < 0.001$ ), confirming the data's suitability for factor analysis. Factor analysis successfully identified seven distinct risk components, as shown in Table 1. "Risks related to external factors" is the most influential dimension, accounting for 10.833% of the total explained variance. This factor consists of six risk variables with loadings ranging from 0.687 to 0.765, led by "Unexpected fluctuations in material prices" (0.765), "Construction works affecting nearby housing and the environment" (0.762) and "Changes or updates in government policies" (0.751); force majeure events (0.742), inflation and market volatility (0.716) and weather disruptions (0.687) complete the set. "Risks related to construction materials, machinery and equipment" explains 10.235% of the variance. Its top five indicators are "Risks during installation or dismantling of lifting equipment" (0.806), followed by "Inadequate allocation of construction materials, tools and equipment" (0.770), with both "Tower crane incidents" (0.765) and "Ineffective layout planning for lifting equipment" (0.765) following closely behind. "Risks related to management and planning" contributes 9.896% of the variance through four variables. The largest loading is "Ineffective or inappropriate construction methods" (0.890), followed by "Incorrect construction plans and schedules" (0.853), "Ineffective component assembly sequences" (0.785), and "Production plans inconsistent with actual site

**Table 1** Factor analysis of risk factors. Source: Authors own work

| Factors in the respective risk group                                  |                                                                                                                                                  | Factor loading | Varianced explained(%) |
|-----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|----------------|------------------------|
| A - Risks related to external factors                                 |                                                                                                                                                  |                | 10.833                 |
| A1                                                                    | Unexpected fluctuations of material price                                                                                                        | 0.765          |                        |
| A2                                                                    | Construction work affects nearby houses and the environment                                                                                      | 0.762          |                        |
| A3                                                                    | Changes or updates to Government policy or related departments' laws leading to project delay                                                    | 0.751          |                        |
| A4                                                                    | Force majeure: disease, war, disaster, ...                                                                                                       | 0.742          |                        |
| A5                                                                    | Inflation, fluctuations in loan interest rates or market prices                                                                                  | 0.716          |                        |
| A6                                                                    | Weather disruptions (wind, rain, temperature,...)                                                                                                | 0.687          |                        |
| B - Risks related to construction materials, machinery, and equipment |                                                                                                                                                  |                | 10.235                 |
| B1                                                                    | Risk in installing or dismantling lifting equipment                                                                                              | 0.806          |                        |
| B2                                                                    | Insufficient allocation of construction materials, tools, and equipment.                                                                         | 0.77           |                        |
| B3                                                                    | Inefficient layout planning for lifting equipment                                                                                                | 0.765          |                        |
| B4                                                                    | Tower crane breakdown, malfunction, or maintenance                                                                                               | 0.765          |                        |
| B5                                                                    | Improper lifting equipment selection on the construction site                                                                                    | 0.71           |                        |
| C - Risks related to management and planning                          |                                                                                                                                                  |                | 9.896                  |
| C1                                                                    | Ineffective or inappropriate construction methods                                                                                                | 0.89           |                        |
| C2                                                                    | Construction plans and schedules are inaccurate or ineffective                                                                                   | 0.853          |                        |
| C3                                                                    | Inefficient or unsuitable sequencing of component assembly and installation.                                                                     | 0.785          |                        |
| C4                                                                    | Production plan not aligned with actual site conditions                                                                                          | 0.774          |                        |
| D - Risks arising from component production and transportation        |                                                                                                                                                  |                | 8.751                  |
| D1                                                                    | The dimensional error of the module exceeds the allowable limit                                                                                  | 0.835          |                        |
| D2                                                                    | Distance between the site and the module production factory                                                                                      | 0.72           |                        |
| D3                                                                    | Connection errors between factory-produced components during assembly, or between factory-produced components and cast-in-place elements on site | 0.717          |                        |
| D4                                                                    | Unclear verification of modular components due to missing or incorrect labeling information                                                      | 0.661          |                        |
| D5                                                                    | Components are deformed, warped, or damaged during transport and lifting.                                                                        | 0.597          |                        |
| E - Risks related to the capabilities of project stakeholders         |                                                                                                                                                  |                | 8.709                  |
| E1                                                                    | Inaccurate cost estimation                                                                                                                       | 0.832          |                        |
| E2                                                                    | Safety accident because of operating lift equipment or worker's action                                                                           | 0.826          |                        |
| E3                                                                    | Lack of skilled workers for installing modular components                                                                                        | 0.695          |                        |
| E4                                                                    | Owner's or contractor's poor financial capacity                                                                                                  | 0.643          |                        |
| E5                                                                    | The contractor lacks experience with modular construction projects                                                                               | 0.569          |                        |
| F - Risks related to delays caused by project participants            |                                                                                                                                                  |                | 8.054                  |
| F1                                                                    | Delay in the approval document of Consultant, Management, Owner                                                                                  | 0.826          |                        |
| F2                                                                    | Slow or redundant acceptance process for the quality of incoming components                                                                      | 0.792          |                        |
| F3                                                                    | Delay in construction schedule due to legal matter of owner                                                                                      | 0.751          |                        |
| F4                                                                    | Delays in transporting components to the site or incorrect delivery information.                                                                 | 0.736          |                        |
| G - Risks related to the coordination among project participants      |                                                                                                                                                  |                | 6.911                  |
| G1                                                                    | Overlap of the installation work area with other construction activities                                                                         | 0.869          |                        |
| G2                                                                    | Change of project design or scope                                                                                                                | 0.785          |                        |
| G3                                                                    | Poor cooperation and communication among project participants                                                                                    | 0.841          |                        |
|                                                                       |                                                                                                                                                  |                | Total:                 |
|                                                                       |                                                                                                                                                  |                | 63.388                 |

conditions" (0.774). "Risks arising from component manufacturing and transportation" accounted for 8.751% of the variance, mainly due to "Module size error exceeding the allowable limit" (0.835); the distance between the construction site and the factory (0.720), connection errors (0.717), verification problems (0.661), and component damage during transportation (0.597) were also loaded here. "Risks related to stakeholder capacity" explained 8.709% of the variance, led by "Inaccurate cost estimates" (0.832) and "Safety accidents due to equipment operation" (0.826), followed by "Lack of skilled workers" (0.695), "Poor financial capacity" (0.643), and "Contractor lack of experience in MiC" (0.569). "Risks related to delays due to project participants" accounted for 8.054% of the variance: delays in document approval (0.826), slow acceptance process (0.792), legal delays (0.751), and shipping delays (0.736). Finally, "Risks related to coordination between project participants" contributed 6.911% of the variance, anchored by overlapping work areas (0.869), poor collaboration and communication (0.841), and design changes (0.785). The hierarchy placed external impacts first, equipment and material issues second, and management deficiencies third. High loadings (mostly above 0.7) confirm strong factor-target relationships and the factors together account for 63.388% of the total variance, indicating comprehensive coverage of the identified risk landscape.

## DISCUSSION AND IMPLICATIONS

The factor analysis results reveal seven distinct risk components explaining 63.388% of the total variance, providing valuable insights into the risk structure of MiC assembly in Vietnam. The dominance of "Risks related to external factors" (10.833% of variance) challenges conventional risk management frameworks that typically emphasize technical and operational aspects. The strong loadings for material price fluctuations (0.765) and environmental impact concerns (0.762) reflect unique characteristics of the Vietnamese construction market, highlighting the critical importance of external environmental management in emerging markets.

From a theoretical perspective, this finding aligns with institutional theory, suggesting that external environmental pressures fundamentally shape project outcomes. Unlike developed markets where technical risks often dominate, Vietnamese MiC projects face greater institutional instability and policy uncertainties, as evidenced by the high loading for government policy changes (0.751). This reframes established risk management frameworks by demonstrat-

ing how contextual factors can reshape risk hierarchies based on market characteristics. The prominence of "Risks related to construction materials, machinery, and equipment" (10.235% of variance) supports resource-based view theory, particularly regarding the critical role of lifting equipment capabilities (0.806). This finding indicates that specialized equipment represents a crucial competitive advantage in the Vietnamese MiC context, where resource scarcity is more pronounced than in developed markets. Management and planning risks (9.896% of variance) validate contingency theory's emphasis on situational factors, with construction methods showing exceptional importance (0.890). This reinforces that MiC projects require specialized management approaches distinct from traditional construction methods, particularly in emerging markets where experience with modular techniques remains limited.

Practically, these findings offer crucial guidance for industry stakeholders. The external risk dominance necessitates robust environmental scanning capabilities and stakeholder management strategies. Companies should establish dedicated functions for monitoring policy changes and managing community relations. The high impact of material price fluctuations suggests implementing innovative contracting mechanisms such as price escalation clauses or long-term supply agreements. Equipment and material risks require immediate attention through specialized training programs for MiC-specific operations and government support for equipment leasing initiatives. The critical importance of lifting equipment suggests developing comprehensive certification programs and technology transfer partnerships with experienced international firms. For production and transportation risks (8.751% of variance), the significance of dimensional errors (0.835) emphasizes the need for precision manufacturing and quality control systems. The factory-to-site distance impact (0.720) suggests that distributed manufacturing strategies may be more viable than centralized production in Vietnam's geographic context. Stakeholder capability concerns (8.709% of variance) highlight critical human capital development needs. High loadings for cost estimation errors (0.832) and safety issues (0.826) reveal fundamental capacity gaps requiring comprehensive training programs and professional certification schemes. The delay-related risks (8.054% of variance) point to systemic inefficiencies in approval processes, with administrative delays showing strong impact (0.826). This suggests prioritizing regulatory reform initiatives to streamline procedures for MiC projects. Quality inspection delays

(0.792) indicate the need for standardized inspection protocols specifically designed for modular components. Coordination risks (6.911% of variance) emphasize workspace management challenges (0.869), suggesting investments in specialized project management systems and collaborative platforms to enhance multi-party coordination.

These findings collectively indicate that successful MiC adoption in Vietnam requires addressing external environmental management, technical capability development, and institutional reform simultaneously. The identified risk structure provides a framework for prioritizing investments and developing targeted interventions. For policymakers, results suggest that supportive regulatory frameworks, infrastructure investments, and capacity building initiatives are essential for realizing the potential benefits of modular construction in addressing Vietnam's rapid urbanization challenges.

The study's theoretical contribution lies in demonstrating how market context fundamentally shapes risk structures, extending existing frameworks to accommodate emerging market characteristics. Practically, the risk prioritization framework enables targeted resource allocation for risk mitigation strategies, supporting the sustainable development of Vietnam's MiC sector.

## CONCLUSION

This study successfully identified and analyzed the risk factor structure in the assembly phase of MiC projects in Vietnam through factor analysis. The research extracted seven distinct risk components that collectively explain 63.388% of the total variance, providing a robust framework for understanding and managing risks in Vietnamese MiC assembly operations.

The findings reveal that external factors represent the most critical risk components, challenging conventional risk management approaches. The prominence of material price fluctuations, environmental impact concerns, and government policy changes demonstrates the unique risk profile of emerging markets where institutional pressures significantly influence project outcomes. Construction materials, machinery, and equipment risks emerged as the second most significant dimension, with lifting equipment installation risks showing particularly high importance. Management and planning risks validated the crucial importance of appropriate construction methods and accurate planning processes.

Theoretically, this study extends existing risk management frameworks by demonstrating how market

context fundamentally shapes risk hierarchies, with external institutional factors becoming dominant in emerging markets.

Practically, the identified risk structure provides a prioritization framework for resource allocation and risk mitigation strategies tailored to the Vietnamese construction industry. For industry practitioners, successful MiC implementation requires simultaneous attention to external environmental management, technical capability development, and institutional coordination. Companies should invest in environmental scanning capabilities, specialized equipment training, and stakeholder relationship management to address the identified risk priorities. Policymakers should focus on regulatory streamlining, infrastructure development, and capacity building initiatives to support MiC sector growth. Addressing systemic issues such as approval delays and quality inspection inefficiencies could significantly improve MiC project outcomes.

The current study employed exploratory factor analysis to establish the foundational risk structure for MiC assembly phase in Vietnam. Future research should validate these findings through confirmatory factor analysis (CFA) using independent samples to establish construct validity and assess model fit indices. Cross-validation techniques, such as split-sample validation, would further strengthen the robustness of the seven-factor structure identified. Additionally, structural equation modeling could examine causal relationships among the risk factors and their impact on project outcomes. Advanced methodologies such as Monte Carlo simulation could provide probabilistic risk assessments for complex scenarios. Furthermore, future studies should investigate Vietnam-specific risk factors that emerged from industry development, particularly infrastructure constraints when dealing with oversized prefabricated components that challenge existing transportation networks and lifting capacities at construction sites.

This study provides a solid foundation for future studies on MiC risk management in emerging markets and offers practical guidance for industry stakeholders navigating the complexities of modular construction adoption in Vietnam. The identified risk structure serves as a benchmark for developing comprehensive risk management strategies that address the unique challenges of implementing advanced construction technologies in developing economies.

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## ABBREVIATIONS

MiC: Modular Integrated Construction; EFA: Exploratory Factor Analysis; KMO: Kaiser-Meyer-Olkin; AHP: Analytic Hierarchy Process; FMEA: Failure Mode and Effects Analysis.

## CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest. / Nhóm tác giả xin cam đoan rằng không có bất kỳ xung đột lợi ích nào trong công bố bài báo này.

## AUTHOR CONTRIBUTIONS

Do Tien Sy: Literature review, data collection.

Nguyen Thai Tan: Writing original draft, figures and tables preparation, writing review and editing.

Nguyen Thanh Viet: Supervision, writing review and editing.

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# Khám phá các mối quan hệ tiềm ẩn giữa các yếu tố rủi ro trong giai đoạn lắp đặt của dự án Xây dựng Mô-đun Tích hợp (MiC)

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## Bản quyền

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## TÓM TẮT

Xây dựng Mô-đun Tích hợp (MiC) nổi lên như một phương pháp tiềm năng đáp ứng nhu cầu nhà ở đô thị ngày càng tăng, với ưu điểm về tốc độ thi công, hiệu quả chi phí và kiểm soát chất lượng. Dù được quan tâm ngày càng nhiều trên toàn cầu, các nghiên cứu tập trung vào rủi ro trong giai đoạn lắp đặt tại các nước đang phát triển vẫn còn rất hạn chế. Phần lớn nghiên cứu hiện có tiếp cận từ góc độ toàn bộ vòng đời dự án và chủ yếu phản ánh bối cảnh các thị trường phát triển, tạo ra khoảng trống đáng kể trong hiểu biết về cấu trúc rủi ro giai đoạn lắp đặt tại các nền kinh tế mới nổi như Việt Nam. Nghiên cứu này nhằm khám phá các mối quan hệ tiềm ẩn giữa các yếu tố rủi ro giai đoạn lắp đặt trong dự án MiC tại Việt Nam. Phương pháp ba giai đoạn được áp dụng, kết hợp tổng quan tài liệu có hệ thống, tham vấn chuyên gia MiC cấp cao và khảo sát định lượng với các chuyên gia xây dựng tại các doanh nghiệp có kinh nghiệm trực tiếp về MiC. Phân tích nhân tố khám phá với phép xoay Varimax được áp dụng để xác định cấu trúc tiềm ẩn của các yếu tố rủi ro. Kết quả phân tích cho thấy bảy nhóm rủi ro riêng biệt. Nhóm yếu tố bên ngoài chiếm ưu thế, chủ yếu bởi biến động giá vật liệu, ảnh hưởng môi trường của hoạt động thi công và thay đổi chính sách nhà nước. Tiếp theo là rủi ro liên quan đến vật liệu, máy móc và thiết bị xây dựng, với rủi ro lắp dựng thiết bị cầu nâng được xác định là mối quan ngại trọng yếu. Rủi ro quản lý và lập kế hoạch xếp thứ ba, tập trung vào phương pháp thi công không phù hợp và lập tiến độ thiếu chặt chẽ. Bốn nhóm còn lại bao gồm rủi ro từ sản xuất và vận chuyển cấu kiện, hạn chế năng lực các bên tham gia, chậm trễ do các bên và khó khăn phối hợp giữa các bên. Phát hiện nổi bật là các yếu tố thể chế bên ngoài, thay vì rủi ro kỹ thuật, là nhóm chiếm ưu thế trong bối cảnh MiC tại Việt Nam. Điều này khác biệt so với các thị trường phát triển và phản ánh tác động mạnh của bất ổn chính sách, biến động thị trường và hạn chế hạ tầng tại các nền kinh tế mới nổi. Khung bảy nhân tố được phát triển trong nghiên cứu này mở rộng lý thuyết quản lý rủi ro sang bối cảnh thị trường mới nổi, cung cấp cơ sở ưu tiên can thiệp rủi ro cho doanh nghiệp và nhấn mạnh tầm quan trọng của ổn định thể chế đối với sự phát triển bền vững của MiC tại Việt Nam.

**Từ khóa:** Xây dựng tích hợp theo mô-đun (MiC), quản lý rủi ro, giai đoạn lắp ráp, rủi ro xây dựng

**Trích dẫn bài báo này:** Sỹ D T, Việt N T, Tân N T. Khám phá các mối quan hệ tiềm ẩn giữa các yếu tố rủi ro trong giai đoạn lắp đặt của dự án Xây dựng Mô-đun Tích hợp (MiC). VNUHCM J. Econ. Bus. Law 2026; 10(3): 7015-7023.