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A review of studies on construction investment project risk management using sem model

Do Van Thuan[1], Nguyen Thi Tuyet Dung[2], Dinh Dang Quang[3], Hoang Thi Hang Nga[2], Nguyen Thi Phuong[4]*

[1] Institute of Transport Administration and Management Cadres, Co Nhue Ward, Tu Liem District, Hanoi

[2] Urban Management Faculty, Hanoi Architectural University

[3] Faculty of Construction Economics and Management, Hanoi University of Civil Engineering

[4] PhD student Hanoi Architectural University

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ABSTRACT

Construction investment activities involve numerous risks, both during construction and operation phase Some risks recur frequently across multiple projects, while others have a lower probability of occurrence SEM is one of the optimal methods for assessing a project's performance under risk conditions. Globally there are numerous studies on construction investment project risk management using SEM. In Vietnam while SEM has been applied in fields such as biology, sociology, psychology, medicine, business, an education, its application in the construction sector remains limited. This paper reviews scientific studies o construction investment project risk management using SEM both domestically and internationally identifies limitations in the application of this model in Vietnam, and aims to provide managers with comprehensive overview of this modern multivariate analysis technique.

1. Introduction

Construction project risk management is a process of identifying, assessing, and ranking project risks, and then developing effective measures and necessary resources to monitor, mitigate, and control their occurrence and/or impacts [1]. This issue has always been of interest to both managers and researchers. However, studies using existing tools for risk identification and assessment have not been able to fully capture the interdependent nature, continuous feedback processes, and nonlinear relationships among risks, especially in complex projects. Therefore, there is a need for innovation in methodology, approach, and the search for modern tools to assess the interrelationships among risks in practice..

Structural equation modeling (SEM) is a statistical technique characterized by its ability to analyze multivariate relationships among multiple variables and to accommodate latent variables. It is widely used for: testing research model theories; assessing the fit and impact of variables within a model; and testing hypotheses among variables. SEM has been extensively applied in various research fields such as psychology (Anderson & Gerbing, 1988; Hansell & White, 1991), sociology (Lavee, 1988; Lorence & Mortimer, 1985), child development (Anderson, 1987; Biddle & Marlin, 1987), management (Tharenou, Latimer & Conroy, 1994), mobile telecommunications services in Korea (M.-K. Kim et al., 2004), and customer loyalty in Vietnam's mobile telecommunications services (Pham Duc Ky, Bui Nguyen Hung, 2007).

The application of SEM in construction project risk management enables the precise identification of the number of potential risks that can impact the overall project objectives. SEM provides a comprehensive assessment of overall risks and project feasibility when subjected to multiple factors. Traditional statistical methods are limited to a certain number of variables and cannot address complex theories. Using a small number of variables to understand complex phenomena is very restrictive. In contrast, SEM can model and test these complex phenomena, allowing for the simultaneous testing of a set of regression equations. SEM integrates techniques such as factor analysis, multiple regression, and correlation analysis..

2. Research methodology

To achieve the research objectives, this study employs common methods such as synthesis, induction, deduction, and comparison to analyze and clarify the contents related to construction investment project risk management using SEM.

Secondary data was collected from various sources. All data was verified, cross-referenced, and compared to ensure consistency and reliability, with clear citations.

3. Research on construction investment project risk management utilizing SEM

3.1. Global studies

*Corresponding author: phuong.phamminhvu@gmail.com

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A review of international studies on construction investment project risk management utilizing Structural Equation Modeling (SEM) reveals that:

Mukhtar A. Kassem's study [2] asserts that oil and gas construction projects often face chronic risks leading to time and cost overruns and poor quality, thereby jeopardizing project success. This study focuses on identifying, categorizing, and modeling risk factors that negatively impact the success of construction projects in Yemen. The research identified 51 risk factors, categorized into two groups: internal factors (client risks, feasibility and design risks, bidding risks, resource risks, contractor risks, and consultancy risks) and external factors (domestic economic risks, political risks, local community risks, environmental and safety risks, security risks, and force majeure risks). The study employed Partial Least Squares Structural Equation Modeling (PLS-SEM) to analyze data collected from a questionnaire survey of 314 participants, including clients, contractors, and consultants working on oil and gas construction projects. The analysis results showed a model fit index of 0.638, a determination coefficient (R^2) of 0.720, and the most significant impact of internal risks with factor loadings greater than 0.7. Based on the analysis, the authors emphasize that stakeholders in oil and gas construction projects should utilize risk mitigation techniques and share responsibilities to minimize hazards. Due to the potential impacts throughout the project lifecycle, oil companies should establish a project monitoring plan from the feasibility and design stages to the bidding and contracting stages.

Shahid Hussain and colleagues [3] in their study on social infrastructure construction projects asserted that quality is a critical measure of project sustainability. To investigate the factors influencing project quality, the authors employed various techniques and methodologies and explained the relationships between specific variables. The authors collected 451 valid questionnaires from construction experts and applied the Structural Equation Modeling (SEM) technique. The authors developed a quantitative approach using Smart-PLS version 3.2.7. The research findings revealed that quality in a social infrastructure project in Pakistan is influenced by five factors: (1) construction factors; (2) stakeholder factors; (3) design factors; (4) material factors; and (5) external factors. The findings from this study can support decision-making for project stakeholders and policymakers (government) by enhancing their understanding of the critical factors affecting construction quality. Additionally, the research indicates that appropriate quality management plans and methods can be designed and implemented to ensure the quality of social infrastructure projects.

Study [4] assessed the impact of risk factors on the success of higher education construction projects using Structural Equation Modeling (SEM). Data was collected through a questionnaire survey of 452 respondents, including clients, consultants, and contractors involved in higher education construction projects at 5 public universities in Ondo State, Nigeria. Of the 452 questionnaires, 279 were usable for analysis, indicating a response rate of 61.73%. Cronbach's alpha and average variance extracted values demonstrated the high reliability and internal consistency of the data collection instrument. Furthermore, the study employed percentile, mean, correlation, regression analysis, and SEM to analyze the data. The analysis results indicated that among the six criteria for measuring project success, three were significantly influenced by risk factors: completion time was significantly affected by environmental risk factors; safety performance was significantly affected by logistics, environmental, and legal risk factors; and logistics, design, and environmental risks significantly impacted profitability. The study found that cost performance, standards/quality, and end-user satisfaction were not significantly affected by risk factors in higher education construction projects.

Authors [5] presented the development of a multidimensional contract administration performance model (CAPM) for construction projects. CAPM was proposed to provide stakeholders in the industry with a tool to measure construction contract administration (CCA) performance and identify the strengths and weaknesses of the CCA system for ongoing or completed projects. In the study, the authors employed a sequential mixed methods approach of collecting and analyzing qualitative and quantitative data. In the initial phase, contract management indicators were collected from relevant literature. In the second phase, data was collected through questionnaires and analyzed using Structural Equation Modeling (SEM). The model comprises 93 CCA performance indicators, categorized into 11 groups, namely: project administration and initiation; team management; communication and relationship management; quality and acceptance management; performance monitoring and reporting management; document and record management; financial management; change and control management; claims and dispute resolution management; contract risk management; and contract closure management. The results showed that communication and relationship management, performance monitoring and reporting management, and document and record management were the most critical constructs reflecting CCA performance. The study recommends that construction project management should focus on key indicators such as allocating contract risk responsibilities, supporting the client on design risks, reviewing project closure documents, verifying actual work upon completion, reporting work progress, evaluating payment applications, processing final accounts, auditing contractor's health, safety, and security, handling change orders, and utilizing information technology (SFL 50.805). The proposed CAPM aims to support the contract management team with a quantifiable multidimensional measurement tool for planning, monitoring, and controlling CCA performance. Moreover, CCA companies, employers, and contractors involved in multiple projects will be able to compare and benchmark the CCA performance of different projects.

Azariy Lapidus and colleagues [6] investigated the destabilizing factors that affect the sustainability performance indicators of construction companies, specifically project duration. To identify and assess the impact of these time-destabilizing factors, the study surveyed clients, consultants, and contractors. Structural Equation Modeling (SEM) was employed to analyze the data and group the destabilizing factors. The study identified the primary causes of the average increase (20%-50%) in project duration, leading to cost overruns and increased negative impacts on the overall utilization of resources: the lack of a suitable material procurement program; ineffective planning by contractors and instability in construction production; and untimely information processing and decision-making. Additionally, the study highlighted other significant destabilizing factors affecting the efficiency and sustainability of construction companies, such as government policies, cost additions, awareness, labor and technical factors, stakeholder pressures, local environment, and social issues.

SEM has been widely applied in cost management. Ali Foroutan Mirhosseini and colleagues [7] investigated the impacts of various factors on the costs of large-scale road projects in Norway, during both the planning and construction phases. Data was collected through questionnaires, and factors in both phases were ranked according to their importance. A comprehensive cost overrun model was developed using the PLS-SEM method. The model was categorized into four main constructs: (i) External—factors beyond the project organization's complete control, such as the impact of adverse weather and market conditions; (ii) Pre-construction—factors primarily related to the planning process but whose effects are manifested during the construction phase and affect project cost performance; (iii) Project management and contractual relationships—human-related factors that can hinder the project execution process; (iv) Contractor’s site management—challenges related to finance, scheduling, supervision, or emerging issues. The results obtained from PLS-SEM showed that external-related factors had the most significant impact on cost overruns during the construction phase. Additionally, Dedong Wang and colleagues [8] affirmed that large-scale construction project management is an evolutionary process characterized by high transaction costs and complex interrelationships. Based on transaction cost theory, relational contract theory, and evolutionary management theory, the study explored the impact of project management on project performance by examining the overall mediating effect of transaction costs and the moderating effect of relational contracts. In the study, SEM was used to test the hypotheses based on data collected from 176 respondents. The results showed that reducing transaction costs improves project performance and it is a significant mediating variable between project management and project performance. Furthermore, the paper by Aftab Hameed Memon and colleagues [9] thoroughly examined and identified the relationships between factors causing cost overruns in the Pakistani construction industry using PLS-SEM. Six constructs were used to categorize the factors, including: (1) client responsibility; (2) contract management; (3) design and project management; (4) information and communication; (5) resource management; (6) site management. The analysis results showed that resource management significantly impacted project costs in the Pakistani construction sector. Project costs were also significantly affected by contract management. Based on these results, the study suggested establishing a contractual management between stakeholders throughout the design and supervision process.

In addition, Yaser Gamil [10] Studied the relationship between causes and effects of poor communication in construction projects using a PLS-SEM approach. The model explains the level of relationship between the causes and effects in construction projects. Notably, the model was subsequently validated by involving 14 construction experts to confirm its applicability in the construction project context..

Study [11] indicated that the tendering process is highly dependent on the exchange rate, interest rates, and inflation costs of equipment and labor. Projects are likely to fail if economic considerations are not adhered to for effective risk management in construction. The research framework is based on the Organizational Control Theory and focuses on the PLS-SEM method, addressing the impact of economic factors on the government's management in Saudi Arabia. The model is constructed with three factor groups: (1) Economic factors significantly related to risk management among Saudi contractors; (2) Government laws, regulations, and policies significantly related to risk management among Saudi contractors; (3) Government laws, regulations, and policies that regulate economic factors and risk management among Saudi contractors. The results of the model analysis show that both economic factors and government management procedures have a positive impact on risk management in the construction industry. Additionally, the regulation of government management procedures has a positive correlation with risk management in the Saudi Arabian construction industry.

Therefore, SEM has been widely used worldwide to identify, analyze, and evaluate risks in a detailed, specific, and quantifiable manner, aiming to uncover common risks in construction investment projects and subsequently propose solutions for managing these risks.

3.2. Domestic studies

Currently, in Vietnam, SEM has been widely applied in various fields. However, the utilization of SEM in construction and construction risk management is still uncommon and limited, especially in-depth studies. Moreover, most existing studies only utilize a portion of SEM. Studies in construction and construction risk management using SEM in Vietnam are specifically:

Nguyen Thanh Liem and Nguyen Thanh Thao Vy [12] constructed a theoretical model of the spreading impact of the construction industry from components such as: (1) economic impact;

(2) technological impact; (3) social impact; (4) environmental impact. The research was conducted through two steps: qualitative research and quantitative research. Qualitative research was mainly conducted through interviews with experts and consultations with construction managers in Soc Trang province. Quantitative research was conducted through the SEM model with a sample size of 310 observations. The scale has 66 degrees of freedom, showing that this model is suitable for market data. The research contributes to the theoretical system on the development of the construction industry in Vietnam, as well as Soc Trang province.

Tran Quang Truong and Do Tien Sy [13] collected and compiled data on risks affecting the finishing construction phase of projects in Ho Chi Minh City. The authors conducted a survey and then used several statistical analyses: reliability testing, exploratory factor analysis (EFA), hypothesis model building, and confirmatory factor analysis (CFA) to identify latent factors based on the initial theoretical model, thereby testing the compatibility of these factors with the hypothesized model and building a SEM model. The results of the SEM model testing showed that the risk group related to contractors, including: inappropriate project organization structure, incomplete or poor project planning and budgeting, or poor contractor management ability, was assessed as having a significant impact on the finishing construction process of high-rise buildings in Vietnam.

Hoang Van Phuong and Truong Duc Long [14] conducted a study on building a System Dynamics support model and risk management in the preparation phase of high-rise building projects for investors in Ho Chi Minh City. The authors identified 26 factors from five main groups: (1) Finance and economics; (2) Policies and laws; (3) Technology and engineering; (4) Organization and management; (5) Environment and society. From there, they determined the weights, correlations between risk groups, and built a System Dynamics support model to quantify and evaluate risks. Through a risk management method based on the Probability and Impact matrix, the authors have made a basic assessment of risks, thereby proposing measures and management procedures for investors in high-rise building projects in Ho Chi Minh City.

Lê Anh Minh Trang and colleagues [15] investigated the factors affecting the delay in capital disbursement for projects in Can Tho city. Based on previous research and expert interviews, eight factors were identified for inclusion in the research model: (1) Human factors; (2) Investor/Project Management Board; (3) Contractor; (4) Consultant; (5) Policies and laws; (6) Readiness of investment capital; (7) Capacity of participating parties; (8) External environment. The results of the SEM model estimation showed that the model achieved a good fit with market data: Chi-square = 464.068, P-value = 0.000; Chisquare/df = 1.694 < 2; TLI = 0.947 (>=0.9); CFI = 0.955 (>=0.9); RMSEA = 0.048 (<0.05). Among the eight factors included in the model, six factors had a positive correlation with the delay in capital disbursement, including: (i) Investor/Project Management Board; (ii) Policies and laws; (iii) Consultant; (iv) Contractor; (v) Readiness of investment capital; (vi) External environment..

Study [16] assessed the impact of design risks on the effectiveness of design-build projects in Vietnam. The authors used 21 risk factors in design-build projects, classified into five groups: (1) Risks of inaccurate or inconsistent design information; (2) Risks of inappropriate design; (3) Risks of inadequate designer capacity; (4) Risks of inadequate contractor design capacity; (5) Risks of unclear project scope and objectives. From these factors, the authors developed a questionnaire and conducted a survey. After completing the survey and data collection, the authors used the SEM model for analysis. The results showed that inappropriate design risks, inadequate designer capacity risks, and unclear project scope and objectives had a significant and negative impact on project effectiveness. These findings have enhanced the understanding of design-build contractors to achieve better project outcomes through improved design risk management.

Phạm Hồng Luân and Phạm Văn Linh [17] analyzed the relationship between factors affecting the project appraisal and post-design process of construction regulatory agencies. The authors developed a survey questionnaire and sent it to experienced experts in the construction industry and applied statistical analysis methods including exploratory factor analysis (EFA), confirmatory factor analysis (CFA), and structural equation modeling (SEM) to identify six groups of factors that were assessed as having an impact on the project appraisal and post-design process of construction regulatory agencies, including: (1) Construction capacity of participating entities; (2) Errors in the design process; (3) Errors in documents related to the appraisal process; (4) Coordination process; (5) Related mechanisms and legal regulations; (6) Finance, market, and force majeure. Through the analysis results, the project appraisal and post-design process at the construction regulatory agency is one of the important steps, having a great impact on the project's progress and effectiveness. Therefore, to improve project efficiency, project participants need to pay special attention to coordination, interaction, and task allocation among participating components, always ensure timely information updates with the appraisal agency and timely correction of documents, grasp and comply with legal regulations, and minimize risks arising during the appraisal process.

4. Discussion

4.1. Discussion of studies on construction project risk management using SEM models worldwide.

Through studies on construction project risk management using SEM models, the following issues can be summarized:

(1) Numerous studies on construction project risk management using Structural Equation Modeling (SEM) have been conducted worldwide. These studies have been carried out on various types of projects, project levels, scales, and investment forms.

(2) Research has been conducted to generalize the entire risk management process or to focus on clarifying a specific issue or stage in the risk management process, such as risk assessment and analysis, risk allocation, and risk management techniques. All of these studies form a scientific foundation for risk and risk management using SEM models.

(3) To classify and assess risks, studies have gone beyond the use of traditional qualitative methods, employing a variety of modern risk management techniques widely used worldwide, especially the combination of these techniques with SEM models to assess the priority level of risks for all three project criteria (cost, quality, and time) based on the interaction between criteria and risks.

(4) Risks and risk management have been studied from various perspectives of project stakeholders. Studies have presented the interaction and influence of project stakeholders. At the same time, risks have also been considered in terms of their reciprocal relationships.

(5) Many studies have demonstrated the advantages of using SEM in construction project risk management, such as accurately identifying the number of risks that can affect the overall project objectives; the relationship between construction, stakeholders, materials, design, and external factors, and how these relate to project quality.

4.2. Discussion of studies on construction project risk management using SEM models in Vietnam.

In Vietnam, studies on the use of SEM models in construction and risk management are still limited. The following issues can be summarized:

(1) Vietnamese studies have significantly benefited from the global body of research on risk and risk management using SEM. This is evident in the adoption of research methodologies, risk management solutions, and risk management software that have been successfully implemented worldwide.

(2) Most risk management studies in Vietnam currently focus on assessing the impact of risks on individual project objectives. There are very few studies that comprehensively assess the impact of risks on multiple project objectives, including cost, time, and quality.

(3) Studies often examine the impact of risks independently on project objectives with little consideration of the interactions between objectives or the interactions between risks. This approach is inadequate as these factors should be viewed as a system with many interrelated relationships.

(4) The positive aspect (opportunity risk) in risk management has not been mentioned or researched in most domestic research topics.

(5) The application of SEM in Vietnamese studies has often been partial, with limited utilization of the model's full capabilities. Furthermore, inconsistent risk classification criteria in some studies have resulted in double-counting of risks, hindering a clear and accurate assessment of the current state of risk management.

(6) The research method is conducted in two steps: qualitative research and quantitative research. Qualitative research is mainly conducted through interviews with experts, project managers, and construction enterprises. Quantitative research is conducted through the SEM model.

5. Conclusion

Construction project risk management is a critical process that can be supported by various tools, techniques, and standards to maximize project efficiency. Structural Equation Modeling (SEM) is a multivariate statistical technique for estimating structures and evaluating hypotheses. Researchers worldwide have achieved significant success in applying SEM to project management to assess overall project risks and performance under the influence of risks. This can be applied throughout the entire project lifecycle (project preparation, construction, and operation). In Vietnam, research on construction project risk management using SEM has begun to receive attention, with a few studies conducted. This paper summarizes research on construction project risk management using SEM worldwide and in Vietnam to provide managers with a comprehensive overview and step-by-step guidance on using SEM to assess overall project risks and performance.

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