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The structural equation model of risk factors influencing government irrigation project

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Abstract: This research aimed to study the impact of risk factors on the success of irrigation projects in Thailand. Data were collected using questionnaires at irrigation agencies in various projects. A structural equation model (SEM) was then developed, and the risks of various factors affecting the irrigation project were analysed. The study results found that the risk factors affecting the construction process were as follows: The study results found that the risk factors affecting the construction process were as follows: In terms of work control, the presence of multiple chains of command led to delays in decision-making. This was followed by delays caused by the employer's material approval process, the lack of clear and detailed construction project planning by the employer, and delays resulting from the performance of subcontractors. The factors mentioned above resulted in the highest score of all 56 factors. The findings of this study showed factors that affected the project, causing project managers, related agencies, or stakeholders to know and find a way for problem solution. The results of this study have found that the SEM values of risk management affecting the construction irrigation project have passed the criteria and have caused the relationship. Those values consist of significance chi-square (*p*-value = 0.799), chi-square relation value at 0.413, normal fit index (NFI) value at 0.999, goodness of fit index (GFI) value at 0.999, CFI value at 0.999, standardised root mean square residual (RMR) value at 0.029, and root mean square error of approximation (RMSEA) value at 0.001.

Keywords: risk management, structural equation model, construction irrigation project, project management, factor analysis, government project, Influencing risk factor

1 Introduction

The construction industry is characterised by its distinctiveness, complexity, and differentiation from other sectors. It operates under a multitude of challenging conditions, including outdoor work environments, strict project deadlines, and unpredictable weather conditions (Pétursson 2015; Suárez et al. 2021). Furthermore, the involvement of diverse stakeholders such as project owners, architects, construction project supervisors, and contractors, each with specific roles and responsibilities (Osei-Asibey et al. 2021), creates a dynamic that is prone to conflicts and disputes (Kilag et al. 2024). These factors collectively contribute to the high-risk nature of the industry in terms of potential disagreements and legal challenges.

A construction project has a clear scope of operations as defined by the agreement and conditions of stakeholders (Jaffar et al. 2011; PMI 2013; San 2013; Pétursson 2015). The success of a construction project relies on effective cost management, time management, and quality management. Additionally, risk analysis is a critical knowledge area in construction management, influencing both time and cost of a project. Furthermore, conflicts within a project are also considered risk factors that can impact project outcomes. To mitigate such risks, appropriate conflict management tools are utilised to analyse and address risks in construction projects (Ghorbani 2023).

The researchers have noted that construction projects have two distinctive phases: the preconstruction phase (starting with project initiation, feasibility studies, and engineering design through the awarding of works contracts) and the construction phase (from awarding of works

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contracts to handing over completed works to the client). They observed that delays and cost overruns occurred in both phases but noted that project overruns were more frequent in the construction phase (Frimpong et al. 2003; Suárez et al. 2021). On the contrary, they have identified challenges in project construction such as extended construction times, loss of both capital and revenue, increasing market risk, material costs, delays in production, and low efficiency. The timely completion of a project means more profit, growth in the market, increased client trust, and increased stakeholder confidence. Due to the above facts, Shubham (2013) recorded that irrigation construction projects are commonly undertaken by government agencies because they are of national interest.

Currently, risk factors in construction projects are being studied to facilitate their identification and mitigation. The top five risk factors affecting project duration, ranked based on their relative importance index, are (1) inadequate project management, (2) delayed funding, (3) rework due to errors, (4) late material delivery and (5) shortages of skilled labour. In terms of cost, the top five risk factors include (1) rework due to errors, (2) underestimation of project completion time, (3) poor site management, (4) underestimation of project costs and (5) fluctuations in material prices. Regarding quality, the most significant risk factors are poor supervision, defective materials supplied by vendors, lack of consultant experience, unclear quality definitions and low bidding practices. Additionally, financial risks, particularly inflation in construction material prices, pose a major challenge to the construction industry, as highlighted in studies by Kamal et al. (2022) and Shibani et al. (2024).

To enhance knowledge of conflict management in construction projects, this study focuses on developing a structural equation model (SEM) of conflict management that affects a construction project. Furthermore, the model aims to improve the ability of project administration, especially in budget and time management. After all, this can be a guideline in construction management development everywhere.

2 Materials and methods

2.1 Construction project management

Project management is the application of knowledge, skills, tools and various techniques to process project activities. Furthermore, to succeed in the proposal of a project, there are 10 pieces of project management knowledge. The 10-project management knowledge has consistent data integration, and project cost management is one important process. In addition, project cost management consists of four processes: cost management planning, cost estimation, budgeting and cost control. In planning such a working process, it requires well-prepared and well-managed cost management of a project, together with project scope and execution strategy development, schedule planning and development, quality planning, resource planning, risk management, procurement planning and stakeholder planning (Hollmann 2006; Al Shami 2018).

2.2 Risk management

Project managers will recognise the classic systems methodology of input, process, output and feedback loop outlined above, which is vital to the effective control of a project; however, the risk is somehow different. It has to do with uncertainty, probability or unpredictability, and contingency planning according to the project management body of knowledge (PMBOK). Additionally, a project manager must be managing various risks, from the less complicated to the most complicated. Conflicts are common in construction projects. When each party has different motivations, attitudes, and opinions, it is possible to have conflicts. Therefore, project management must fix the problem as soon as possible; otherwise, other issues, such as an employee's absence or resignation, may occur (Burke 2013). Risk management can reduce adverse effects in four ways: avoid, transfer, mitigate and accept (Lester 2007).

2.3 Irrigation construction projects

Irrigation is one of the crucial inputs to agricultural production, raising crop yields and increasing crop varieties in the region. The construction of irrigation schemes has also contributed to an increase in crop variety in the region. In consequence, the economic well-being of rural people is increased, and migration to big cities decreases. The overall level of spending on water-related infrastructure in developing countries amounts to about US$65 billion per year, with irrigation and drainage accounting for about US$25 billion (Briscoe 1999). The first irrigation scheme in Turkey was built in the Konya Plain by the Ottoman Empire between 1903 and 1913. Large-scale construction of irrigation and drainage schemes started with the foundation law numbered 6200 of the General Directorate of State Hydraulic Works (DSI). Classical open-channel irrigation schemes were built until 1950–1965. Since then, Western countries, especially Italy, have applied the flume (canalette), which is a type of prefabricated material. Sloped terrain requires a considerable number of drop-type constructions, needs to overcome water distribution problems during the operation phase, and needs close examination of low-pressure pipe schemes. In the 1980s, low-pressure concrete pipes were used. However, population growth in Turkey, together with the increase in rural to urban migration, brought an increase in water demand. As a result, in Turkey, since 1990, developing pipe production and water-saving tube technology, which allow usage of the optimum level of water resources, has started in high-pressure pipe schemes and sprinkler systems (Koç 2011).

Irrigation construction projects play a critical role in agricultural development by building infrastructure such as dams, canals, reservoirs and pipelines to manage and distribute water effectively. These projects are especially important in regions with inadequate rainfall, helping to enhance agricultural productivity, ensure food security, and support local economies. Additionally, irrigation projects are among the top three budget priorities in Thailand's construction sector, as defined by the government. This prioritisation is due to the country's predominantly agricultural economy, where a significant portion of the population consists of farmers. Additionally, most irrigation projects aim to mitigate flood risks and improve drainage infrastructure, which are critical concerns in Thailand. However, they often face significant challenges due to various risk factors that can disrupt progress and inflate costs (Abdaljader and Günal 2024).

Management-related risks are among the most impactful, including poor project planning, ineffective communication among stakeholders and delays in decision-making. These issues can lead to misaligned objectives and prolonged timelines. Financial risks are another critical concern, often stemming from budget constraints, delayed payments or inaccurate cost estimations, which can hinder progress and strain project resources. Material-related risks, such as shortages, delivery delays, and the use of substandard supplies, further exacerbate challenges during construction (Bahamid et al. 2020; Abdaljader and Günal 2024).

Labour and equipment issues also pose considerable risks. These include shortages of skilled workers, low productivity and equipment breakdowns or inefficiencies, all of which can disrupt workflows. Design risks, such as incomplete or unclear project plans, frequent changes or insufficient surveys conducted before construction, can lead to rework and delays. External risks, including adverse weather conditions, regulatory hurdles and shifts in government policies, add further complexity to these large-scale projects (McDermot et al. 2022; Abdaljader and Günal 2024).

Mitigating these risks requires comprehensive planning and effective collaboration among all stakeholders, including clients, contractors and consultants. This involves clear communication, accurate cost and resource estimations, timely procurement of materials, and robust risk assessment processes. By addressing these challenges proactively, irrigation construction projects can achieve their objectives, delivering sustainable water management solutions that benefit agriculture and local communities. Effective risk management is essential to ensuring that these projects are completed on time, within budget, and to the required standards (Abdaljader and Günal 2024; Adedokun and Egbelakin 2024).

2.4 Risk factors for construction project

An overview of risk factors in construction projects reveals several key issues identified in previous studies that stakeholders should be aware of. Many studies have categorised the group of risk factors that affect construction projects such as grouping of environmental, physical, logistic, legal, political, construction, design, financial and management (Bahamid et al. 2020). In the other hand, several researchers define eight components of risk factors: cost, construction knowledge, design, economic, estimator, resource, geographic and project-related (Ekung et al. 2021). Specifically in irrigation projects, five groups of risk factors identified through a relative importance index analysis include management, design, finance, materials, labor and equipment, and external factors.

Construction risk is the umbrella term for all possible losses that could occur during a construction project. Construction risk can be caused by various factors, including the environment, project delays, safety concerns and other challenges. Throughout the entire building process, risk is an unavoidable component, according to the PMBOK. Table 1 lists the 56 criteria that were compiled from the literature evaluation process and used in this investigation. Many risk factors are used in this study, and they focus only on risk factors that relate to construction projects, infrastructure projects and irrigation projects.

2.5 Conceptual framework

The conceptual framework in this study is a structural framework built from the relationship between risk

Tab. 1: Risk factors at a sublevel that affect the construction of an irrigation project

Risk ID.	Descriptive	Reference
I1	Delays caused by the approval – details of the construction plan (Shop drawing) of the employers	E, T, O, Q, S
I2	Delay factors caused by the approval-material of the employers	E, T, O, S
I3	Lack of a good coordination system between parties involved with each other	F, T, O, S, P
I4	The factor of the employer planning the construction project is not detailed (not clear)	G, T, Q, S
I5	Mistakes against employer's strike order	H, R, T
I6	The contractor lacks knowledge and experience in construction techniques	F, T, S, P
I7	The contractor does not pay attention to construction safety	I, T, Q, P
I8	Accidents caused by the contractor's construction, such as falls from heights, impacts, etc.	I, Q, S, P
I9	The employers lack control and inspection of the income-expensing accounting system of the construction project	J, Q, S, P
I10	Delays in recognising and solving problems between the individuals involved	J, O, S
I11	Mistake of communication	F,T, O, Q
I12	The contractor breaches the terms of the contract	J, O, P
I13	The text of the contract is unclear in terms of meaning, responsibility, or contract details	J, Q
I14	Continuity in construction work	F, R, O, P
I15	Availability of labour in terms of number and skill.	J, O, P
I16	Coordination between parties involved in the project	F, Q, P
I17	Project management and site supervision	F, R, S
I18	Financial liquidity of construction projects	J, R, S, P
I19	Period for disbursing money from project owners and contractors	J, Q, S, P
I20	Accuracy and suitability of design data	J, Q, S
I21	The perfection of the design and the details of the design.	K, Q, S
I22	Project planning and budgeting	J, R, O, Q
I23	Delivery of the construction site	J, R, O, Q
I24	Competence and compliance of subcontractors	J, S, P
I25	Personnel competence	L, T, S
I26	Personnel commitment	L, T, P
I27	Communication and coordination	J, Q, S, P
I28	Financial management	J, R, O, P
I29	Surveillance and monitoring of performance	J, P
I30	Late approval of the construction of drawings (Shop Drawing)	J, T, O
I31	The delay from the owner of the project in answering questions from the contractor	J, S
I32	Installation payments are not as scheduled	J, R, Q, S, P
I33	Deficiencies and unclear construction contracts	J, R, Q, S, P
I34	Details of designs used in construction	K, Q, S, P
I35	Interference with the contractor from the owner	J, Q
I36	Interfering with the contractor's work by other contractors or other owners.	J, S
I37	Lack of expertise in the work of supervisors	F, O, S, P
I38	The number of supervisors is insufficient	J, S
I39	Supervisors have multiple chains of command, resulting in delayed decision-making	J, T, S
I40	Failure to take ownership of the construction site and the use of rights on route to the construction site	J, T
I41	Discovery of antiquities or ancient civilisation sites in construction sites	J, S
I42	Obstruction of buildings, restricted trees and utilities of other agencies	J
I43	The problem of working space conditions has changed from the counterparty contract model	J, R, S
I44	Problems with the condition of the work site. Hard stones are obstructed, causing the need to use tools. special in destruction	J, S
I45	The delay in submitting the construction drawing (Shop Drawing) is delayed	J, R, Q, S
I46	The delay in submitting construction drawings (As build Drawing) is delayed	E,R, Q
I47	the lack of experience of personnel and expertise in operations or construction planning	J, R, Q, S, P
I48	Delays caused by subcontractor work	E, T, P
I49	The building does not comply with the contract without matching the specifications or construction drawings	J, Q
I50	Failure to comply with the request of the owner of the work that the contractor has agreed to according to that request	J, Q, S

(*Continued*)

Tab. 1: Continued

Risk ID.	Descriptive	Reference
I51	Deficiencies in tracking tasks and adjusting work plans	J, Q, S
I52	Disorders in coordination on site	N, U, Q, S
I53	Lack of management and coordination within the contractor's organisation	J,T, O, P
I54	Delay in procurement of equipment or construction materials	J, T, Q, S, P
I55	Using construction tools or equipment that do not meet the requirements	H, T, Q, S, P
I56	Lack of financial liquidity of contractors	M, O, S
Y1	Duration	D
Y2	Budget	D
Y3	Quality	D

D: PMBOK; E: (Assaf and Al-Hejji 2006); F: (Odeh and Battaineh 2002); G: (Jaffar et al. 2011); H: (Kaliba et al. 2009); I: (Tam et al. 2004); J: (Saram and Ahmed 2001); K: (Abowitz and Toole 2010); L: (Lytvyn 2017); M: (Haupt and Padayachee 2016); N: (Ajayi et al. 2015); O: (Ekung et al. 2021); P: (Cevikbas et al. 2024); Q: (Gajera 2024); R: (Bahamid et al. 2020); S: (Adedokun and Egbelakin 2024); T: (McDermot et al. 2022); U: (Suárez et al. 2021).
PMBOK, project management body of knowledge.

factors affecting cost management, time management and quality management. The factors will be analysed before developing the structural model that could be identified by exploratory factor analysis, as shown in Figure 1. With assumption 1 (H1), the risk factors affecting construction irrigation project management are related to three main aspects of project management.

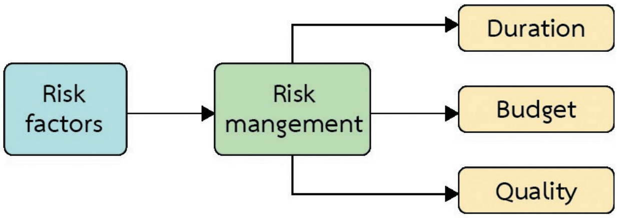

Fig. 1: Conceptual framework in this study.

3 Research methodology

The study of the conditions of the contract for architects and supervisors in the government construction project is quantitative research. The process of this study is divided into the following steps.

3.1 Population and *s*ample

Since the entire population of the irrigation work group in Thailand is unknown, Cochran's formula was used, calculated at a confidence level of 95%, a tolerance of 5%, and a proportion of the characteristic of interest in the population of 0.5. The required population size was 384 units (Burrows 1953), and the researcher allowed 50% (Chaitongrat et al. 2021), totalling 576 units in determining the sample size, which is consistent with the concept of Pallant (2020) that specified the acceptable size to be more than 150 samples and 460 responses and complete sets, which is a small proportion because most construction companies are not convenient to provide information. The response rate of the questionnaire (Respond Rate) of more than 20% is considered acceptable (Ehrlinger and Wöß 2022).

The sample for this research comprised 460 irrigation construction projects funded by government departments, classified as a type of public construction project under the Government Procurement and Supplies Management Act B.E. 2560 (2017), within the 2024 fiscal year. In addition, the representatives of each construction project were engineers who were experienced in construction management and supervision.

3.2 Research instrument

A questionnaire was used as a tool in the research. In addition, the questionnaire was divided into two parts: (1) participants' general information and (2) issues about problems and conditions of the contract for architects and construction supervisors. Both parts were a closed-end questionnaire with five rating scales to evaluate the chance of having risk factors. Moreover, the research instrument employed in this study underwent rigorous validity and reliability testing to ensure its effectiveness. The validity test was conducted by three experts in construction management and government project supervision, following the methodology described by

Kangpheng et al. (2016). As a result, this process identified and refined the final set of 56 factors used in the study. Additionally, the instrument's reliability was evaluated through a try-out method involving 30 individuals who possessed similar characteristics to the sample population but were not included in the actual sample group. The tool achieved a Cronbach's α value of 0.95, which significantly exceeds the standard reliability threshold of 0.75, as outlined by Vorakitkasemsakul (2011). Consequently, the questionnaire was deemed both valid and reliable, making it suitable for data collection from the study's target sample.

3.3 Data analysis

3.3.1 Exploratory factor analysis

Factor analysis was employed to group the risk factors that contribute to construction project failure. Two indicators were used to validate the results: the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity (Thorndike, 1936; Ostle, 1963).

3.3.2 SEM

Computer packages SPSS25 and AMOS2 were used to assess the concordance between the model and empirical information by considering statistical chi-square, adjusted goodness of fit index (AGFI) and root mean square residual (RMR). Data analysis was divided into two phases: (1) results of information analysis correlation between factors and (2) results of relation conflict management in the government construction project fit of the model as per seven assessment criteria, which consisted of *p*-value or χ^2, χ^2/df, normal fit index (NFI), goodness of fit index (GFI), fit index (CFI), standardised RMR and root mean square error of approximation (RMSEA) (Pallant 2020).

4 Results and discussion

This research has investigated the relationship between risk factors that affect construction irrigation project management by analysing and building a structural model. In addition, the results of this study have been divided into three parts: general information about participants, exploratory factor analysis and the results of building the structural model of conflict management.

4.1 General information of participants

The analysis of the general data from the questionnaire and the evaluation of the research instruments revealed that the sample group comprised 70.87% male and 29.13% female participants. Most respondents were aged between 31 years and 50 years (48.48%), followed by those <30 years (38.91%) and >50 years (12.61%). In terms of educational background, the largest proportion held a bachelor's degree (42.83%), while 36.74% had completed a higher vocational certificate, 17.39% had a vocational certificate, and 3.04% held a master's degree or higher.

Regarding work experience, 32.39% of respondents had <5 years of experience, 30.65% had 5–10 years, 31.52% had 11–30 years, and 5.43% had >30 years of experience. Most participants worked in the private sector (74.13%), while 25.87% were employed in government organisations. In terms of job position, 26.30% of respondents were engineers, 11.52% were officers, and 6.30% were managers. A significant portion, 51.96%, held other roles such as supervisors or subcontractors, while 3.91% were directors, as summarised in Table 2.

Tab. 2: Overview of participant

Category	Component	Amount	Percentage (%)
Sex	Male	326	70.87
	Female	135	29.13
Age (years)	<30	179	38.91
	31–50	223	48.48
	>50	58	12.61
Education	Vocational	80	17.39
	Higher vocational	169	36.74
	Bachelor	197	42.83
	Master or higher	14	3.04
Experience (years)	<5	149	32.39
	5–10	141	30.65
	11–30	145	31.52
	>30	25	5.43
Organisation	Government	119	25.87
	Private company	341	74.13
Position	Director	18	3.91
	Engineer	121	26.30
	Manager	29	6.30
	Officer	53	11.52
	Other (supervisor or subcontractor)	239	51.96

One limitation of this study is the private-sector sample bias, with 74.13% of the respondents representing private construction firms. This skewed distribution is primarily because private-sector organisations typically employ a larger workforce in construction projects compared with government agencies. In many construction projects, private-sector firms handle on-site management, subcontracting and execution, which require a higher number of personnel than governmental bodies that focus more on regulatory oversight and funding allocation (Ekung et al. 2021). Consequently, the findings of this study may not be fully generalised to government-led projects, where administrative and bureaucratic challenges may differ. Future research should incorporate a more balanced sample, ensuring greater representation from government stakeholders to provide a more comprehensive perspective on risk factors in construction projects. The mean and standard deviation values for each factor are presented in Table 3.

4.1.1 Exploratory factor analysis of risk factors in irrigation construction project

The results of the preliminary data screening indicated that all variables were normally distributed. Pearson correlation analysis was conducted for 12 variables, revealing a correlation coefficient of 0.77, which indicates a statistically significant positive relationship at the 0.01 level. This value falls within the acceptable range for correlation coefficients (0.3 to 0.9), as recommended by Amarasekara et al. (2018), as shown in Table 4.

Findings from the examination of risk variables in the administration of construction projects—specifically in irrigation works—using principal component analysis (PCA), revealed that the correlation matrix obtained from Bartlett's test of sphericity was statistically significant (p-value < 0.01), which meets the criterion of being less than 0.05. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy was 0.943, indicating a very high value (close to 1), and suggesting that the dataset is

Tab. 3: Mean and SD of risk factors

Risk ID.	Mean	SD
I1	3.33	0.90
I2	3.44	0.91
I3	3.08	0.71
I4	3.48	1.02
I5	3.38	1.07
I6	3.30	0.95
I7	3.35	1.11
I8	3.21	1.29
I9	3.13	0.97
I10	3.12	0.86
I11	3.28	0.96
I12	3.37	1.05
I13	3.15	0.87
I14	3.33	0.91
I15	2.85	0.95
I16	2.90	0.87
I17	2.83	1.05
I18	2.83	1.04
I19	2.95	2.27
I20	2.69	0.99
I21	2.75	1.09
I22	2.77	1.04
I23	2.83	0.97
I24	3.07	0.91
I25	2.76	1.07
I26	2.81	1.01
I27	2.82	1.02
I28	2.80	1.14
I29	2.84	1.16
I30	3.37	0.99
I31	3.13	0.82
I32	3.34	1.06
I33	3.30	0.95
I34	2.93	0.90
I35	3.18	1.02
I36	3.26	1.03
I37	3.34	0.91
I38	3.38	0.94
I39	3.50	0.98
I40	3.41	0.94
I41	3.29	1.70
I42	3.15	0.89
I43	3.25	0.77
I44	3.37	1.27
I45	3.19	0.96
I46	3.19	0.95
I47	3.26	0.94
I48	3.38	0.92
I49	3.30	0.99
I50	3.21	0.66
I51	3.22	0.96
I52	3.30	0.95
I53	3.22	1.07
I54	3.18	1.00
I55	3.13	1.08
I56	3.10	1.08
YI1	3.27	1.03
YI2	3.30	1.04
YI3	3.46	1.06

SD, standard deviation.

well-suited for component analysis. The data significantly deviated from the identity matrix, confirming relationships among the 56 variables analyzed. Therefore, as shown in Table 5, the dataset is appropriate for factor extraction. The extracted components, as presented in Tables 5 to 7, were grouped into six categories: (1) inefficiency in legal administration, (2) inefficiency in project construction management, (3) inefficiency of contractors, (4) inefficiency in design during the construction phase, (5) discovery of antiquities at the construction site, and (6) conditions related to specialized work.

The six groups were derived from the study by Abdaljader and Günal (2024) and other sources reviewed in the risk factors section. These defined groups are aligned with the Project Management Body of Knowledge (PMBOK) framework. The six identified groups of risk factors are critical to construction project management as they represent key areas that significantly influence project performance.

Tab. 4: KMO and Bartlett's test

KMO measure of sampling adequacy		**0.943**
Bartlett's test of sphericity	Approx. chi-square	38,752.817
	df	1,540
	Sig.	0.001

KMO, Kaiser–Meyer–Olkin.

Tab. 5: Number of components, eigenvalue, percentage of variance and percentage of cumulative variance

Components	**Initial eigenvalues**		
	Total	**% of variance**	**Cumulative%**
1	22.747	40.620	40.620
2	12.176	21.742	62.362
3	5.225	9.331	71.693
4	1.910	3.411	75.104
5	1.462	2.611	77.715
6	1.104	1.972	79.687

Tab. 6: Factor loadings

Risk ID.	**Component**					
	1	**2**	**3**	**4**	**5**	**6**
I1			0.733			
I2	0.586					
I3	0.545					
I4	0.800					
I5	0.813					
I6	0.870					
I7	0.797					
I8	0.678					
I9	0.867					
I10	0.749					
I11	0.895					
I12	0.901					
I13	0.848					
I14	0.791					
I15		0.931				
I16		0.835				
I17		0.893				
I18		0.840				
I19		0.374				
I20		0.882				
I21		0.816				
I22		0.889				
I23		0.885				
I24		0.568				
I25		0.928				
I26		0.936				

(*Continued*)

Tab. 6: Continued

Risk ID.	Component					
	1	2	3	4	5	6
I27		0.936				
I28		0.888				
I29		0.882				
I30			0.742			
I31			0.681			
I32	0.592					
I33			0.594			
I34		0.587				
I35			0.665			
I36			0.762			
I37	0.622					
I38	0.626					
I39	0.623					
I40	0.655					
I41						
I42			0.627			
I43	0.685					
I44						
I45				0.551		
I46				0.580		
I47				0.609		
I48	0.630					
I49	0.659					
I50	0.635					
I51			0.882			
I52			0.869			
I53			0.932			
I54			0.879			
I55			0.917			
I56			0.874			

The inefficiency of legal administration is crucial because delays in permits, contracts or legal disputes can disrupt timelines and budgets. The inefficiency of construction management in projects impacts coordination, resource allocation and schedule adherence, all of which are vital for project success. Similarly, the inefficiency of the contractor affects the quality of execution, adherence to deadlines and compliance with project specifications, making contractor performance a cornerstone of project outcomes. The inefficiency of design in the construction phase is another critical factor, as poor design can lead to costly rework, delays, and decreased structural integrity. The discovery of antiquities at the construction site introduces unexpected risks, including delays, additional costs for preservation efforts and legal implications, particularly for projects in historically significant areas. Finally, the condition of special work reflects unique challenges such as hazardous environments or specialised technical requirements, which necessitate careful planning and expertise to avoid accidents or inefficiencies. Together, these six factors represent interconnected risks that, if unmanaged, can escalate into significant obstacles. Addressing them systematically ensures smoother operations, controlled costs and adherence to project timelines, ultimately improving construction project outcomes (McDermot et al. 2022; Gajera 2024).

Tab. 7: Risk group

Risk group defining	Risk factors	Risk ID.
1. The inefficiency of legal administration	Delay factors caused by the approval-material of the employers	I2
	Lack of a good coordination system between parties involved with each other	I3
	The factors of the employees planning the construction project are not detailed (not clear)	I4
	Mistakes against employer’s strike order	I5
1. The inefficiency of legal administration	The contractor lacks knowledge and experience in construction techniques	I6
	The contractor does not pay attention to construction safety	I7
	Accidents caused by the contractor’s construction, such as falls from heights and impacts	I8
	The employers lack control and inspection of the income-expense accounting system of the construction project	I9
	delays in recognising and solving problems between the individuals involved	I10
	Mistake of communication	I11
	The contractor breaches the terms of the contract.	I12
	The text of the contract is unclear. both in terms of meaning, responsibility, contract details	I13
	Continuity in construction work	I14
	Instalment payments are not as scheduled.	I32
	Lack of expertise in the work of supervisors	I37
	The number of supervisors is insufficient	I38
	Supervisors have multiple chains of command, resulting in delayed decision-making	I39
	Failure to take ownership of the construction site and the use of rights on route to the construction site	I40
	The problem of working space conditions has changed from the counterparty contract model	I43
	Delays caused by subcontractor work	I48
	The building does not comply with the contract without matching the specifications or construction drawings	I49
	Failure to comply with the request of the owner of the work that the contractor has agreed to according to that request	I50
2. The inefficiency of construction management in project	Availability of labour in terms of number and skill	I15
	coordination between parties involved in the project	I16
2. The inefficiency of construction management in project	Project management and site supervision	I17
	Financial liquidity of construction projects	I18
	Period for disbursing money from project owners and contractors	I19
	Accuracy and suitability of design data	I20
	The perfection of the design and the details of the design.	I21
	Project planning and budgeting	I22
	delivery of the construction site	I23
	Competence and Compliance of Subcontractors	I24
	personnel competence	I25
	personnel commitment	I26
	communication and coordination	I27
	financial management	I28
	Surveillance and monitoring of performance	I29
	details of designs used in construction	I34
3. The inefficiency of contractor in project	Delays caused by the approval – details of the construction plan (shop drawing) of the employers	I1
	Late approval of the construction drawings (shop drawing).	I30
	The delay from the owner of the project in answering questions from the contractor.	I31
	Deficiencies and unclear construction contracts	I33

(*Continued*)

Tab. 7: Continued

Risk group defining	Risk factors	Risk ID.
	Disorders in coordination on site	I52
	Lack of management and coordination within the contractor's organisation	I53
	Delay in procurement of equipment or construction materials	I54
	Using construction tools or equipment that do not meet the requirements	I55
	Lack of financial liquidity of contractors	I56
4. The inefficiency of design in construction phase	The delay in submitting the construction drawing (shop drawing) is delayed	I45
	The delay in submitting construction drawings (as build drawing) is delayed	I46
	the lack of experience of personnel and expertise in operations or construction planning	I47
5. Discovery of antiquities at construction site	Discovery of antiquities or ancient civilisation sites in construction sites	I41
6. The condition of special work	Problems with the condition of the work site. Hard stones are obstructed, causing the need to use tools. special in destruction	I44

4.2 The results of building the structural model of risk factors in irrigation construction project

This study employs SEM to analyse the effects of 56 identified risk factors on three critical dependent variables: budget, duration and quality. SEM is a sophisticated statistical tool particularly suited for this research because it allows for the simultaneous examination of multiple dependent variables, enabling a holistic understanding of the complex interrelationships within construction projects. Additionally, SEM supports the integration of latent variables that are unobservable constructs such as 'management effectiveness' or 'resource availability', which are derived from measurable indicators. This feature enhances the depth of analysis by capturing nuanced aspects of risk dynamics. Moreover, SEM is capable of modelling both direct and indirect effects, providing insights into how risk factors influence project outcomes through intermediary pathways. Another significant advantage of SEM is its ability to account for measurement errors in the observed variables, thereby increasing the precision and reliability of the results. Through goodness-of-fit indices, SEM ensures that the theoretical model aligns with empirical data, reinforcing the validity of the findings. By leveraging these capabilities, this study provides a robust framework for identifying critical risk factors and their impacts, offering valuable insights for project managers to mitigate risks and enhance the success of construction projects.

The initial SEM shown in the Figure 2 highlights the hypothesised relationships among multiple risk factors, risk management and project outcomes (duration, budget and quality). Six primary risk factors were considered: inefficiency in legal administration, inefficiency in construction management, inefficiency of contractors, inefficiency of design in the construction phase, discovery of antiquities and special work conditions. These factors were expected to contribute to overall project risk, which influences risk management strategies and, subsequently, project outcomes.

The path coefficients reveal varying degrees of influence. Notably, inefficiency in legal administration exhibits the highest factor loading (1.00), indicating its significant contribution to overall project risk. By contrast, factors such as the discovery of antiquities and special work conditions show minimal impact, with factor loadings of 0.03 each. The influence of inefficiency in construction management is negative (–0.20), suggesting a counterintuitive relationship that may require further investigation. The pathways connecting risk management to project outcomes suggest a strong influence, with coefficients of 0.98, 1.02 and 1.00 for duration, budget and quality, respectively. However, the model's fit indices indicate poor overall fit (GFI = 0.813, CFI = 0.864, RMSEA = 0.175), suggesting the need for refinement. High values for normed chi-square (15.024) and RMR (6.619) further indicate discrepancies between the hypothesised model and the observed data.

This initial model underscores the need for iterative adjustments to better align theoretical assumptions with empirical data and improve overall model fit.

The results of analysing the SEM of risk factors affecting irrigation construction projects have found that the initial model was inconsistent with the empirical data, making it impossible to draw conclusions and interpretations, as shown in Figure 2. In addition, there were the under-criteria statistical values, which were chi-square significant (p-value <0.05), relative chi-square value at 20.744 (higher than criteria), NFI value at 0.893 (lower than criteria), GFI value at 0.825 (lower than criteria), CFI value at 0.897 (lower than criteria), standardised RMR value at 0.024 (pass criteria) and RMSEA value at 0.243 (higher than

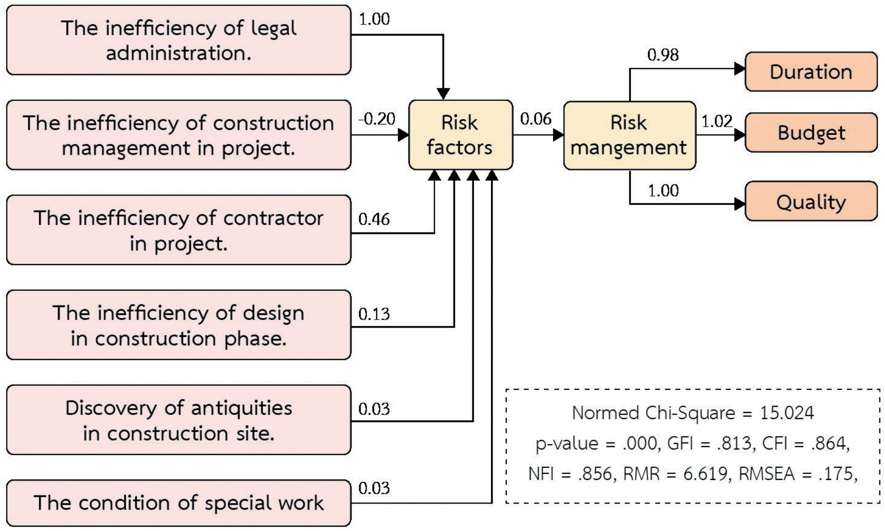

Fig. 2: Management structure model before the adjustment. GFI, goodness of fit index; NFI, normal fit index; RMR, root mean square residual; RMSEA, root mean square error of approximation.

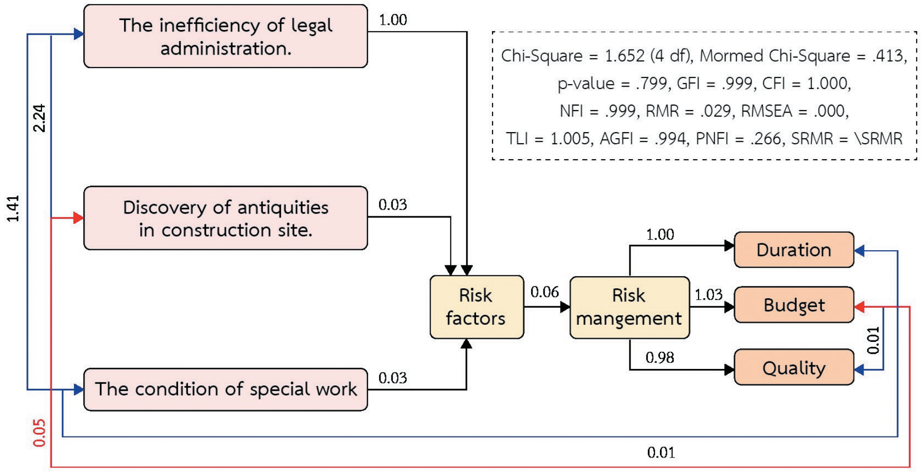

Fig. 3: Risk management structure model after the adjustment. AGFI, adjusted goodness of fit index; GFI, goodness of fit index; NFI, normal fit index; RMR, root mean square residual; RMSEA, root mean square error of approximation.

Tab. 8: Index values of relations in SEM of risk management that affect the irrigation construction project before and after adjustment

Index	Criteria	Before adjusting model		After adjusting model	
		Statistic	Result of consideration	Statistic	Result of consideration
χ^2/df	<3.00	15.024	Unqualified	0.413	Qualified
p-value of χ^2	>0.05	<0.001	Unqualified	0.799	Qualified
NFI	>0.90	0.864	Unqualified	0.999	Qualified
GFI	>0.90	0.856	Unqualified	0.999	Qualified
CFI	>0.95	0.856	Qualified	0.999	Qualified
RMR	<0.08	6.619	Unqualified	0.029	Qualified
RMSEA	<0.08	0.175	Unqualified	0.001	Qualified

The *p*-value also sensitive to sample size >200.

GFI, goodness of fit index; NFI, normal fit index; RMR, root mean square residual; RMSEA, root mean square error of approximation; SEM, structural equation model.

criteria). This indicated that the initial model was inconsistent with the empirical data and needed to be adjusted. Later, the model was adjusted following the model modification indices (MI) value suggestion, and the results are shown in Figure 3. In addition, the statistical values were as follows: chi-square significant (p-value = 0.050), relative chi-square value at 0.212, NFI value at 0.996, GFI value at 0.990, CFI value at 0.999, standardised RMR value at 0.080 and RMSEA value at 0.030. These statistical values passed the criteria, indicating that the SEM of risk factors affecting irrigation construction projects was consistent with the empirical data, as shown in Figure 3. In addition, analysing the consistency and harmony of a measurement model for each latent variable to find the relation was demonstrated in Table 8. Considering the estimation of the parameters from regression analysis (R^2), the result of analysing the structural equation found that the R^2 value was 0.688, which means those factors can interpret the SEM.

To adjust the SEM following the model MI suggested value, the correlation was adjusted based on a review of the relevant literature and theories. Additionally, there were five relations among the variables that were adjusted as shown in Figure 3, which was the relation between the duration of construction projects and the condition of special work, such as when the construction contractor experiences a condition on the site that differs materially from the conditions indicated in the contract with the owner of the project or from what is normally expected in the site area. Almost all construction projects have risks. One of the major risks in construction projects arises when the contractor encounters a different site conditions (Srinavin et al. 2021). Moreover, this risk has been related to the inefficiency of legal administration and the discovery of antiquities at construction sites, which is crucial to construction project management according to the PMBOK. However, most countries try to apply several technologies to avoid risks that affect their projects. Several tools have been developed, such as machine learning and big data (Taylor and Littleton 2008).

The SEM highlights the relationships among identified risk factors, risk management and project outcomes (duration, budget and quality). The model reveals that risk factors such as inefficiency in legal administration, discovery of antiquities at construction sites and special work conditions impact overall project risk, which in turn influences the effectiveness of risk management strategies. Among these, inefficiency in legal administration is the most significant contributor, with a factor loading of 2.24, emphasising the critical need for streamlined legal processes to reduce delays and uncertainties. This is followed by the discovery of antiquities (factor loading 1.41), which underscores the importance of pre-construction assessments in historically significant areas, and special work conditions, which have the least impact (factor loading 0.05), although careful planning is still essential to mitigate minor risks. The model further demonstrates the direct impact of risk management on project outcomes. A path coefficient of 1.00 to project duration indicates that effective risk management plays a crucial role in avoiding delays, while a coefficient of 1.03 to budget highlights its importance in controlling costs. The slightly lower path coefficient of 0.98 to quality reflects that, while critical, risk management has a marginally lesser effect on ensuring project quality compared to cost or time. Overall, the relationships in the model signify that proactive and efficient risk management strategies are indispensable for mitigating the effects of project risks, particularly on financial and temporal outcomes. Additionally, the model stresses the relative importance of addressing legal inefficiencies, as they are the dominant risk factors, and tailoring risk management strategies to address specific high-priority risks effectively. The practical implications include prioritising legal and administrative process improvements, conducting thorough site assessments to identify archaeological risks early, and ensuring that risk management systems are integrated into project planning and execution phases. This approach not only minimises disruptions but also enhances the likelihood of achieving project goals in terms of duration, budget and quality. By understanding the varying influence of risk factors and leveraging efficient risk management, project teams can develop more targeted and effective strategies to ensure success. The SEM thus serves as a valuable tool for identifying critical areas of intervention and optimising project performance through structured risk management practices.

In construction project management, budget and quality are highly related to the status of projects, such as the high quality of work in construction, which should incur a lot of cost if the owner would like to perfect the building (Peterzens-Nysten 1998). This relationship has influenced the discovery of antiquities at construction sites, where remains of ancient civilizations have occasionally been uncovered (Ramaswamy, 2013). It has been studied that Egyptian antiquities are being protected using the dewatering technique. These tools are very expensive and require expertise in this technique. Moreover, some locations are very hard to find (Kusonkhum et al. 2023). When this situation happens in a construction project, it can result in significant costs. The prevention process will save their company, such as risk management (PMBOK), and some technologies will be used to predict the risk and feasibility of users or management, even though some of these tools cannot be applied for some reason in some countries.

Finally, risk management focuses on the time, cost and quality of projects. However, most irrigation projects are looking at soil moving work because they always build dams or canals to serve their people. Thus, the discovery of antiquities at construction sites and the condition of special work are very important in this case. Most of the population in this study proves that most firms in construction industries should be concerned about this result because it will decrease damage to the government and improve their construction management knowledge according to the PMBOK.

The SEM demonstrates the complex interrelationships among risk factors, risk management and project performance outcomes (duration, budget and quality) in construction projects. The model identifies three major risk factors: inefficiency in legal administration (1.00), discovery of antiquities at construction sites (0.03) and the condition of special work (0.03), all of which collectively influence overall risk exposure. Among these, legal inefficiency exerts the strongest impact on risk factors, indicating that bureaucratic obstacles, regulatory delays and contract disputes are dominant sources of uncertainty in construction projects. By contrast, the discovery of antiquities and specialised work conditions have a much smaller effect, suggesting that while these risks exist, their frequency and overall impact on construction projects are relatively low. These risk factors contribute to the overall risk environment, which directly affects risk management (0.06), implying that as risk factors increase, the need for structured risk management approaches becomes more critical. However, the small coefficient suggests that risk management effectiveness can mitigate the negative influence of these risk factors if implemented properly.

The model further demonstrates that risk management serves as a crucial intermediary variable, significantly influencing project outcomes. The strongest impact is observed on budget (1.03), followed by duration (1.00) and quality (0.98), which indicates that financial management is the most sensitive aspect of risk exposure in construction projects. This relationship suggests that poor risk management leads to budget overruns, while effective risk strategies can reduce cost escalations. The slightly lower coefficient for quality (0.98) implies that while risk management plays a critical role in maintaining project standards, other external factors, such as material quality and labour expertise, may also influence quality outcomes independently. Additionally, the interconnections between project performance variables reveal that budget and quality (0.01) are weakly correlated, meaning that cost fluctuations slightly impact quality but do not directly dictate project standards. The model also illustrates a feedback loop between risk factors and project outcomes, emphasising how legal inefficiency (2.24) and financial constraints (0.05) create reinforcing cycles of risk exposure, meaning that poor legal administration not only introduces risks but also exacerbates delays, budget issues and quality concerns over time.

The high model fit indices (chi-square = 1.652, *p*-value = 0.799, CFI = 1.000, GFI = 0.999, RMSEA = 0.000) confirm that the proposed relationships between variables are statistically significant and accurately reflect real-world project dynamics. These findings reinforce the need for proactive legal frameworks, robust risk assessment mechanisms and financial planning strategies to improve the efficiency of construction project. Future research should explore alternative risk variables, such as fluctuating material prices or labour shortages, and integrate qualitative insights through interviews or case studies to provide a more comprehensive understanding of how risk factors interact over time. Additionally, emerging technologies like machine learning and Internet of Things (IoT)-driven risk monitoring systems could be integrated into risk management frameworks to enhance predictive capabilities and improve real-time decision-making. Overall, this SEM highlights the intricate causal relationships among risk factors, management interventions and project outcomes, emphasising the necessity for a structured and data-driven approach to risk mitigation in construction projects.

4.3 Hypothesis and result

4.3.1 Hypotheses development

This study posits three main hypotheses to explore the relationships among risk factors, risk management and project outcomes in construction projects. H1 suggests that risk factors – such as inefficiency in legal administration, inefficiency in construction management, contractor inefficiency, design inefficiency, discovery of antiquities and special work conditions – significantly contribute to overall project risk. This assumption is grounded in the understanding that these factors collectively disrupt project timelines, budgets and quality. H2 hypothesises that these risk factors directly influence the effectiveness of risk management strategies, as effective management often depends on identifying and addressing key risks. Finally, H3 proposes that risk management practices positively impact project outcomes, with effective strategies expected to reduce delays, control costs and maintain quality. These hypotheses reflect the interconnected nature of risk factors, management practices and project performance, as established in the literature.

4.3.2 Hypothesis evaluation

Based on the results of the initial SEM, the findings partially support H1. The inefficiency in legal administration demonstrated the strongest factor loading (1.00), signifying its critical contribution to project risks. However, other factors, such as the discovery of antiquities and special work conditions, showed minimal contributions (0.03 each). Notably, inefficiency in construction management exhibited a negative relationship (–0.20), suggesting complexities that require further investigation. For H2, the weak path coefficient (0.06) between risk factors and risk management suggests a limited impact, indicating that risk management strategies might not fully account for or respond to specific risk factors. While this does not entirely reject H2, it highlights inefficiencies in translating identified risks into effective management practices.

4.3.3 Implications and acceptance

By contrast, H3 is strongly supported by the results. The path coefficients from risk management to project outcomes were significant, with 1.02 for budget, 0.98 for duration and 1.00 for quality. These findings underscore the importance of robust risk management strategies in ensuring project success, particularly in controlling costs and maintaining timelines. Collectively, the results suggest that while the contribution of specific risk factors to overall risk (H1) and their influence on risk management (H2) require further refinement and exploration, the role of risk management in achieving favourable project outcomes (H3) is unequivocal. These findings emphasise the need to prioritise effective legal administration and refine risk management strategies to address diverse risks more comprehensively, ultimately improving project performance. Further refinements of the SEM and additional data collection could provide deeper insights into these relationships.

5 Conclusion

This study underscores the critical role of risk management in construction irrigation projects by employing SEM to analyse key risk factors affecting project success. The findings highlight several significant insights that contribute to the field of construction risk management:

- *Identification of key risk factors*: This study reveals that inefficiencies in legal administration, discovery of antiquities at construction sites and challenges associated with specialised work conditions are the most influential risk factors affecting project performance. Among these, legal inefficiencies exhibit the strongest effect, emphasising the need for streamlined regulatory processes to mitigate project delays and cost overruns.
- *Development of an enhanced SEM*: The research demonstrates that the revised SEM achieves a superior fit with empirical data, confirming its robustness in assessing risk factors. The final model presents strong goodness-of-fit indices (GFI = 0.999, CFI = 0.999, RMSEA = 0.001), validating its reliability for application in construction project risk assessment.
- *Strategic implications for risk management*: This study underscores the importance of proactive risk mitigation strategies, particularly in addressing bureaucratic inefficiencies and unforeseen site conditions. Implementing structured legal frameworks, enhancing stakeholder collaboration and integrating advanced risk management techniques can significantly reduce project uncertainties and improve overall efficiency.

These findings provide valuable guidance for policymakers, project managers and construction stakeholders in optimising risk management practices within government-funded irrigation projects. Future research should explore emerging technologies, such as artificial intelligence and predictive analytics, to further enhance risk assessment and mitigation strategies in large-scale infrastructure projects.

6 Future research and practical implications

Despite its contributions, this study has several limitations that future research should address. One significant challenge was data collection in Thailand, particularly due to limited collaboration with local government agencies. Many officials demonstrated low awareness of research methodologies and their potential societal benefits. For instance, identifying high-risk factors in construction projects could enable authorities to develop more proactive risk mitigation strategies, leading to reduced project delays and improved efficiency. Future research should explore methods to bridge this gap, such as stakeholder engagement programs that enhance awareness and promote the adoption of research-driven risk management practices.

Additionally, real-world observational research and experimental investigations are necessary to validate and expand upon these findings. Future studies could conduct longitudinal analyses of construction projects to track how risk factors evolve over time and how various risk mitigation strategies impact project outcomes. By addressing these limitations, future studies can contribute to more adaptive, efficient and sustainable construction risk management strategies, ultimately benefiting both the industry and society.

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