An Application of Analytic Network Process (ANP) to Assess Critical Risks of Bridge Projects in the Mekong Delta Region

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ABSTRACT

Risk management is one of the critical factors contributing to infrastructure project success. Risk assessment enables both practitioners and decision-makers to identify and analyze potential risks and quantify risk impacts on project performance in terms of time, cost, and quality. Even though many studies attempt to investigate the risk of construction projects with the consideration of technical, organizational, and legal aspects, only a few studies deeply focus on identifying the critical risks of bridge projects with the examination of climate change impact. The current study concentrates on analyzing risks in bridge construction projects in the Mekong Delta region which has been significantly affected by climate change. An intensive review of previous publications and technical project reports from 2010 to 2021 was conducted to identify the list of potential risks and interviews and discussions with engineers and managers involved in bridge projects were carried out to identify critical risks of bridge projects. Analytic Network Process (ANP) method was introduced to evaluate the impact of such risks on the performance of bridge project implementation. The initial results of this study provide a holistic picture of risk management for bridge projects with the consideration of climate change impact. The findings can help the involved parties including owners, contractors, and project managers to assess particular risks and scheme backup plans to mitigate project delays and cost overruns.

Keywords-risk assessment; risk management; bridge projects; Mekong Delta

I. INTRODUCTION

Risk is defined as a positive or negative deviation of a variable from its expected value and is commonly understood as a loss [1]. Due to potential risks, bridge construction projects often fail to achieve their time, quality, budget and operation goals [2]. Risk management plays a vital role in minimizing the negative consequences of unexpected events on the bridge project performance. However, risk management for bridge construction projects is a challenging process with the involvement of uncertainty factors from policy, society, economy, environment, finance, and technology [3]. Even though many studies have attempted to investigate the separate risks of bridge construction projects, only a few studies provide a holistic picture of risk management regarding bridge construction projects. Particularly very few scholars focus on assessing the potential risks of bridge projects in the context of developing countries. Thus, a case study in Vietnam with the consideration of bridge projects in the Mekong Delta region is carefully examined in this paper. The selected case study, the Mekong Delta region, encompasses a large portion of southwestern Vietnam, with an area over 40,500km^2, which has a large number of ongoing bridge projects [4]. Bridge construction projects in this area play a vital role in connecting the Southern areas of Vietnam, and improving the agricultural trading capacity which directly contributes to the local economic growth [5]. Risk management for bridge projects in the Mekong Delta is considered monumental in ensuring the success of strategic connection goals of local governments. In practice, conventional studies on risk assessment in technical and organizational terms have been carried out, but there is a lack of studies concentrating on potential risks caused by climate change. Therefore, in this paper, we aim to provide a holistic picture of risk management by considering potential risks caused by climate change. The Analytic Network Process (ANP) is a promising approach [6] that was selected to identify critical risk factors and assess the impacts of risk on project objectives including time, cost, quality, and operation.

II. RISK IDENTIFICATION

A. Literature Review

In this study, a mini scoping technique was applied for searching articles. The SCOPUS database was selected for searching with the use of the combination of keywords: Construction Projects AND Bridge projects AND Risk management OR Risk identification OR Risk assessment within a specific period from 2000 to 2020. The initial search resulted in 192 articles related to construction project risk management. Next, we focused on the risks of bridge projects to eliminate some articles and a shortlist of 52 articles was produced. Further, our research team carefully read the titles and abstracts and skimmed the whole content of the studies and finally, 28 of 52 publications were selected for analysis.

B. Documentation Review

The Mekong Delta region in Vietnam is one of the affected places by climate change [1]. The implementation of bridge projects in this region suffers from many difficulties and potentially contains significant risks in comparison with bridge construction conditions in other regions in Vietnam. In this study, we carefully examined the documentation of real bridge projects in the Mekong Delta region during the period from 2000 to 2020. As a result, 30 typical projects were selected to clarify practical risks which were used to compare to risks identified from the literature.

C. Risk Identification Results

Through the survey of literature review along with the project documentation review, a list of critical risk factors was identified and is presented in Table I. These risk factors were classified into the following groups: Political and legal risks, Social risks, Technical risks, Economic risks, Environmental risks, and Financial and Commercial risks.

III. APPLICATION OF ANALYTIC NETWORK PROCESS (ANP) TO ASSESS CRITICAL RISKS

A. Analytic Network Process Model

ANP is widely used for multi-criteria-decision-making [52]. ANP is a multi-criteria theory of measurement used to derive relative priority scales of absolute numbers from individual judgments that also belong to the fundamental scale of absolute numbers [53]. The judgments in the ANP model show the relative impact of one of two elements over the other in a pairwise comparison process on a third element in the system [53]. In ANP, pairwise comparisons of the elements in each level are conducted with respect to their relative importance towards their control criterion.

TABLE I. RISK FACTORS IN BRIDGE CONSTRUCTION PROJECTS IN THE MEKONG DELTA REGION

No	Code	Risks	References
I	**PL**	**Political and legal risks**	
	PL1	Changes in the state organization	[2-11]
	PL2	Political interference	[2-5, 12, 13]
	PL3	Legal procedures are complicated and unclear	[3, 9, 14-18]
	PL4	Changes in legal documents and regulations	[3, 8, 9, 16-18]
	PL5	Corruption of officials	[3, 17, 19, 20]
II	**SO**	**Social risks**	
	SO1	Difficulty in ground clearance	[6, 9, 15, 21-25]
	SO2	Compensation cost	[23-25]
	SO3	Opposition of the community	[6, 9, 15, 21, 22]
	SO4	Disputes in projects	[26-29]
	SO5	Security at the construction site	[26, 28, 29]
	SO6	Local resident consensus	[19, 30-33]
III	**TE**	**Technical risks**	
	TE1	Lack of management method	[29, 23]
	TE2	Errors in defining project scope	[4, 7, 14, 29, 35]
	TE3	Incomplete and inaccurate survey and experimental data	[4, 16, 36, 37]
	TE4	Inappropriate project approaches	[9, 10, 21, 37-39]
	TE5	Errors in design appraisal and estimation	[13, 40]
	TE6	Non-compliance with construction standards	[4, 7, 14, 29, 41]
	TE7	Changing design and technical plans	[4, 17, 18]
	TE8	Supply delays	[10, 37-39]
	TE9	Unsuitable construction organization	[8, 14, 21, 37]
	TE10	Machinery breakdown	[8, 14, 17, 22, 36, 39]
	TE11	Capacity of contractors, supervision consultants	[8, 10, 15, 37, 38, 42, 43]
IV	**EC**	**Economic risks**	
	EC1	Inflation	[3, 36]
	EC2	Interest rates change	[3, 4, 43, 44]
	EC3	Economic policy	[3, 4, 9, 10, 37, 44]
	EC4	Currency exchange rate changes	[3, 6, 22, 36]
	EC5	Economic depression	[3, 4, 9, 10, 37, 43, 44]
	EC6	Fuel/material prices change	[13, 45]
	EC7	Macroeconomics	[3, 4, 9, 10, 37, 43, 44]
	EC8	The market changes	[21, 39, 46]
V	**EN**	**Environment risks**	
	EN1	Unstable geology	[6, 9, 15, 21, 22, 47-49]
	EN2	Sea level rise	[10, 14, 21, 43, 50]
	EN3	Erosion	[10, 14, 21, 50]
	EN4	Changes in rainy season, rainfall	[2, 7, 10, 14, 21, 43, 50]
	EN5	Temperature change	[2, 7, 10, 14, 21, 43, 50]
	EN6	Saltwater intrusion	
	EN7	Storms	[6, 8, 50]
	EN8	Floods	[6, 8, 50]
VI	**FC**	**Financial and Commercial risks**	
	FC1	Project funding	[6, 22, 51]
	FC2	The ability to attract finance for the project	[6, 22, 51]
	FC3	Financial capacity of the contractor	[8, 14, 22]
	FC4	Weak financial management	[4, 16, 21, 46]
	FC5	Disrupted commercial activities	[14, 20, 24, 25, 30]
	FC6	Compensation for accidents	[2, 22]
	FC7	Weak contract management	[10, 14, 15, 21, 22]
	FC8	Weak cost management	[5, 18, 21, 50]
	FC9	Exceeded estimated cost	[5, 17, 18, 21, 20]

Once the pairwise comparisons are completed for the whole network, the vectors corresponding to the maximum eigenvalues of the constructed matrices are computed and a priority vector is obtained. The outcome of the comparison process is used in the development of the unweighted matrix, weighted matrix, and limit matrix. The super matrices' outcome of ANP is used to assess the priority of risk groups as in Figure 1. The goal of the ANP model in this study is to assess the priority of risks with the consideration of successful criteria of a bridge project. In the literature, there are common perspectives on success criteria for a construction project, as is clearly shown in Table II.

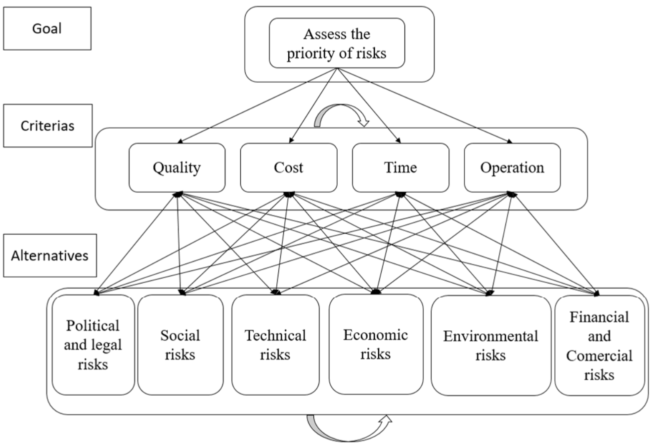

Fig. 1. The ANP model assesses the priority of risks.

TABLE II. SUMMARY OF SUCCESS CRITERIA

No	Success criteria	Reference
1	Cost, Time, Performance, Satisfaction, Operation, Effectiveness	[54]
2	Cost, Time, Technical Requirements, Customer Satisfaction, Operation	[55]
3	Time Performance, Cost Performance, Quality Performance, Health, Safety and Environment (HSE), Client satisfaction	[56]
4	Cost, Time, Meeting the technical specifications, Customer satisfaction, Stakeholder satisfaction, Operation	[57]
5	Cost, Time, Quality, Scope, Customer satisfaction, Safety, Team satisfaction, Shareholder satisfaction	[58]

Conventionally, successful criteria for a construction project often include time, cost, and quality. However, the efficiency of operating bridge projects is a major concern. Thus, we decided to select 4 main successful criteria, i.e. quality, cost, time, and operation to assess the priority of risks to ensure comprehensive risk assessment. In addition, the alternatives in the ANP model are 6 main risk groups (Figure 1) consisting of Political and Legal risks (PL), Social risks (SO), Technical risks (TE), Economic risks (EC), Environmental risks (EN), and Financial and Commercial risks (FC).

B. Questionnaire Survey

The identification of risk factors obtained in the literature review and documentation review (Table I) was used to design a questionnaire survey. The survey was then carried out to collect data from project stakeholders including project owners, project managers, contractors, sub-contractors and consultants who have been involved in the bridge construction projects in the Mekong Delta region. The respondents were asked to rate the impact level of critical risks on project cost, time, quality, and operation on the scale shown in Table III.

TABLE III. SCORE OF IMPORTANCE

Score	Importance	Score	Importance	Score	Importance
1	Extremely low importance	4	Moderately low importance	7	High importance
2	Very low importance	5	Moderate importance	8	Very high importance
3	Low importance	6	Moderately high importance	9	Extremely high importance

IV. RESEARCH RESULTS

A. Questionnare Participants

A total of 170 survey questionnaires were sent to experts in the bridge construction field. Face-to-face and online modes were used to survey. We received 88 full responses, accounting for around 53% of the total number of target participants. Most respondents have more than 5-year experience, and particularly more than 32% of respondents have more than 10-year experience in the construction industry domain.

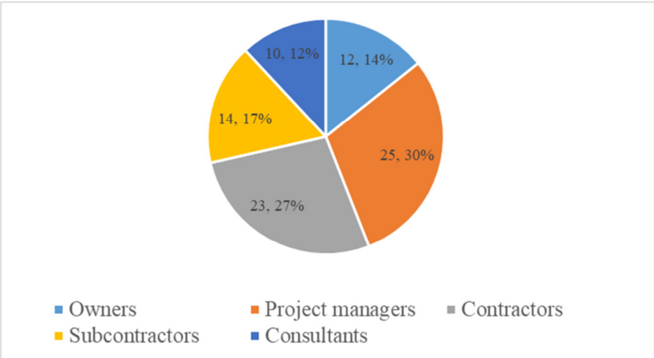

Fig. 2. Stakeholder percentages

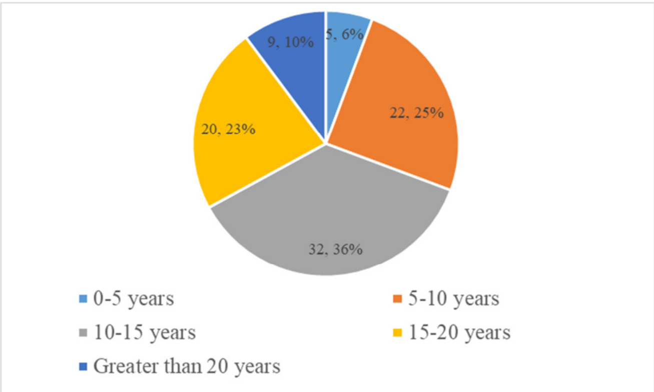

Fig. 3. Expert experience percentages.

B. Impact Risk Level Rating by MSI (Mean Score of Importance) Results

Six main groups and 47 associated risk factors were assessed by experts through the questionnaire survey. The experts participating in the survey were asked to rate the importance of the risk prioritization with the consideration of four main project objectives: Quality cost, time, and operation. The final results are shown in Tables IV-XI.

TABLE IV. IMPORTANCE OF THE CRITERIA THROUGH MSI

Criteria	Min score	Max score	Average score	Ranking
Importance of quality	7	9	8.44	1
Importance of cost	6	9	7.64	3
Importance of time	6	9	7.57	4
Importance of operation	7	9	8.07	2

TABLE V. IMPORTANCE OF RISK GROUPS

Risk groups	Importance				Average score	Ranking
	Quality	Cost	Time	Operation		
PL	4.78	5.94	6.78	6.38	5.97	5
SO	4.17	5.50	6.50	6.22	5.59	6
TE	7.28	6.83	7.16	7.11	7.09	1
EC	5.84	6.78	6.17	6.61	6.35	3
EN	6.00	6.33	6.22	7.22	6.44	2
FC	5.72	6.83	6.17	6.11	6.20	4

TABLE VI. IMPORTANCE OF RISK FACTORS IN POLITICAL AND LEGAL GROUPS

Risk Factors	The importance for				Average score	Ranking
	Quality	Cost	Time	Operation		
PL1	5.11	5.44	5.33	4.72	5.15	5
PL2	5.28	5.72	5.33	5.44	5.44	4
PL3	5.78	7.17	7.00	6.33	6.57	1
PL4	6.06	6.94	6.78	6.27	6.51	2
PL5	6.11	6.78	5.94	5.77	6.15	3

TABLE VII. IMPORTANCE OF RISK FACTORS IN SOCIAL GROUP

Risk Factors	The importance for				Average score	Ranking
	Quality	Cost	Time	Operation		
SO1	6.00	7.89	7.83	6.77	7.12	1
SO2	5.67	7.50	7.39	6.77	6.83	2
SO3	5.39	6.28	6.83	6.22	6.18	3
SO4	4.94	5.89	6.94	6.05	5.96	5
SO5	4.83	5.56	5.78	5.83	5.50	6
SO6	4.94	6.83	6.39	6.50	6.17	4

TABLE VIII. IMPORTANCE OF RISK FACTORS IN TECHNICAL GROUP

Risk Factors	The importance for				Average score	Ranking
	Quality	Cost	Time	Operation		
TE1	5.67	6.22	6.00	7.00	6.22	8
TE2	7.39	6.50	6.67	7.11	6.92	5
TE3	6.89	6.33	6.33	7.05	6.65	7
TE4	7.56	6.39	6.72	7.27	6.99	4
TE5	7.78	6.56	6.56	7.27	7.04	3
TE6	6.83	6.28	6.89	6.72	6.68	6
TE7	6.00	6.11	6.28	5.77	6.04	9
TE8	7.22	6.39	6.50	6.50	6.65	7
TE9	6.39	5.67	5.72	5.94	5.93	10
TE10	7.50	7.44	7.33	7.00	7.32	1
TE11	7.17	7.17	7.11	6.94	7.10	2

TABLE IX. IMPORTANCE OF RISK FACTORS IN ECONOMIC GROUP

Risk Factors	The importance for				Average score	Ranking
	Quality	Cost	Time	Operation		
EC1	5.11	6.39	5.89	5.66	5.76	2
EC2	4.89	6.11	5.89	5.61	5.63	4
EC3	4.89	5.83	6.11	5.66	5.62	5
EC4	4.83	5.56	5.44	5.50	5.33	8
EC5	5.06	6.11	5.61	5.50	5.57	6
EC6	6.11	7.22	6.89	5.72	6.49	1
EC7	5.00	6.22	5.83	5.83	5.72	3
EC8	4.78	6.11	5.56	5.72	5.54	7

TABLE X. IMPORTANCE OF RISK FACTORS IN ENVIRONMENTAL GROUP

Risk Factors	The importance for				Average score	Ranking
	Quality	Cost	Time	Operation		
EN1	6.94	6.72	6.17	6.27	6.53	1
EN2	4.94	6.11	5.33	4.94	5.33	2
EN3	4.94	6.17	5.44	4.77	5.33	2
EN4	5.22	5.67	5.44	4.77	5.28	3
EN5	4.83	5.06	4.83	4.61	4.83	7
EN6	4.89	5.33	4.94	4.61	4.94	5
EN7	5.00	5.00	4.83	4.72	4.89	6
EN8	5.17	5.22	5.39	4.72	5.13	4

TABLE XI. IMPORTANCE OF RISK FACTORS IN FINANCIAL AND COMMERCIAL GROUPS

Risk Factors	The importance for				Average score	Ranking
	Quality	Cost	Time	Operation		
FC1	5.83	7.28	7.00	6.22	6.58	1
FC2	5.28	6.78	6.39	5.61	6.02	7
FC3	6.22	7.33	7.00	5.66	6.55	2
FC4	6.00	6.78	6.61	5.77	6.29	4
FC5	5.22	5.28	5.67	5.33	5.38	9
FC6	5.22	5.78	5.56	5.22	5.45	8
FC7	6.17	6.78	6.22	6.05	6.31	3
FC8	6.00	6.44	6.06	6.00	6.13	5
FC9	5.61	6.50	6.28	5.83	6.06	6

The presented survey results helped us to assess the importance level of the risks on specific groups. However, this approach does not accurately reflect the interaction of risks within the whole project. In order to clarify the impact among criteria and risks, the ANP model was applied to overcome obstacles.

C. Analytic Network Process Rating of the Impact Level of Risks

The purpose of applying the ANP model is to evaluate the priority of the risk groups and risk factors through the calculation of the Risk Priority Index (RPI). This is a method of ranking all risks while taking into account their importance to all considered criteria. Based on the survey results of experts, the MSI has been determined. In addition, along with the opinions of experts in the group discussion, a pairwise comparison matrix for each model will be established which is scored by a pairwise table [53].

1) Criteria Priority

To assess risk priority considering the main criteria, a sub model was established and is depicted in Figure 4.

TABLE XII. PAIRWISE TABLE

Level of importance	Pairwise comparison score
1: Equally important	1:1
2: Equally important to moderate	2:1, 3:2, 4:3, 5:4, 6:5, 7:6, 8:7, 9:8
3: Moderately important	3:1, 4:2, 5:3, 6:4, 7:5, 8:6, 9:7
4: Moderately important to slightly more important	4:1, 5:2, 6:3, 7:4, 8:5, 9:6
5: Slightly more important	5:1, 6:2, 7:3, 8:4, 9:5
6: Slightly important to very important	6:1, 7:2, 8:3, 9:4
7: Very important	7:1, 8:2, 9:3
8: Very important to extremely important	8:1, 9:2
9: Extremely important	9:1

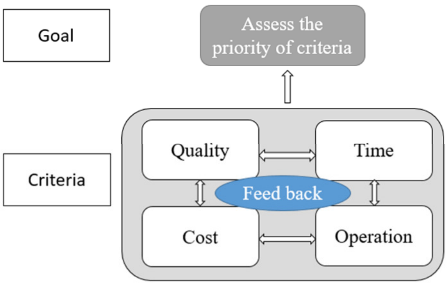

Fig. 4. Sub model for assessing the priority of criteria.

Through the use of Super Decision software, the unweighted super matrix, the weighted super matrix, and the limit matrix of bridge project criteria were calculated and are presented in Tables XIII-XV.

TABLE XIII. UNWEIGHTED SUPER MATRIX CONSIDERING THE FOUR MAIN CRITERIA

Cluster	Quality	Cost	Time	Operation	Priority
Value	0.400	0.00	0.259	0.310	0.167
	0.200	0.310	0.412	0.000	0.333
	0.000	0.195	0.327	0.493	0.333
	0.400	0.493	0.00	0.195	0.167

TABLE XIV. WEIGHTED SUPER MATRIX CONSIDERING THE FOUR MAIN CRITERIA

Cluster	Quality	Cost	Time	Operation	Priority
Value	0.400	0.00	0.259	0.310	0.167
	0.200	0.310	0.412	0.000	0.333
	0.000	0.195	0.327	0.493	0.333
	0.400	0.493	0.00	0.195	0.167

TABLE XV. LIMIT MATRIX CONSIDERING THE FOUR MAIN CRITERIA

Cluster	Quality	Cost	Time	Operation	Priority
Value	0.243	0.243	0.243	0.243	0.243
	0.236	0.236	0.236	0.236	0.236
	0.252	0.252	0.252	0.252	0.252
	0.267	0.267	0.267	0.267	0.267

The Normalized Priority Value (NPV), Total Priority Value (TPV), and Ideal Priority Value (IPV) of criteria were calculated and can be seen in Table XVI.

TABLE XVI. CRITERIA PRIORITY

Criteria	TPV	NPV	IPV	Ranking (R)
Quality	0.333	0.333	1.000	1
Cost	0.167	0.167	0.500	2
Time	0.167	0.167	0.500	2
Operation	0.333	0.333	1.000	1

2) *Risk Group Priority*

The 6 risk groups of bridge construction projects are Political and legal risks (PL); Social risks (SO); Technical risks (TE); Economic risks (EC); Environmental risks (EN); Financial and Commercial risks (FC). The model in Figure 1 could be used to assess the priority of the risk groups. Through the use of Super Decision software, the unweighted super matrix, the weighted super matrix, and the limit matrix of the bridge project criteria were calculated and are shown in Tables XVII-XIX.

TABLE XVII. UNWEIGHTED SUPER MATRIX FOR RISK GROUPS

	NODES	EC	EN	FC	PL	SO	TE	Cost	Operation	Quality	Time
Alternatives	EC	0.000	0.206	0.183	0.252	0.219	0.186	0.222	0.166	0.176	0.100
	EN	0.201	0.000	0.252	0.100	0.136	0.312	0.111	0.223	0.176	0.200
	FC	0.180	0.162	0.000	0.190	0.252	0.121	0.222	0.125	0.176	0.100
	PL	0.222	0.182	0.177	0.000	0.205	0.190	0.111	0.152	0.097	0.200
	SO	0.171	0.249	0.186	0.271	0.000	0.191	0.111	0.111	0.060	0.200
	TE	0.226	0.200	0.201	0.186	0.187	0.000	0.222	0.223	0.315	0.200
Criteria	Cost	0.250	0.250	0.250	0.250	0.250	0.250	0.000	0.000	0.000	0.000
	Operation	0.250	0.250	0.250	0.250	0.250	0.250	0.000	0.000	0.000	0.000
	Quality	0.250	0.250	0.250	0.250	0.250	0.250	0.000	0.000	0.000	0.000
	Time	0.250	0.250	0.250	0.250	0.250	0.250	0.000	0.000	0.000	0.000

TABLE XVIII. WEIGHTED SUPER MATRIX FOR RISK GROUPS

	NODES	EC	EN	FC	PL	SO	TE	Cost	Operation	Quality	Time
Alternatives	EC	0.000	0.103	0.092	0.126	0.110	0.093	0.222	0.166	0.176	0.100
	EN	0.100	0.000	0.126	0.050	0.068	0.156	0.111	0.223	0.176	0.200
	FC	0.090	0.081	0.000	0.095	0.126	0.061	0.222	0.125	0.176	0.100
	PL	0.111	0.091	0.089	0.000	0.103	0.095	0.111	0.152	0.097	0.200
	SO	0.086	0.125	0.093	0.136	0.000	0.095	0.111	0.111	0.060	0.200
	TE	0.113	0.100	0.101	0.093	0.094	0.000	0.222	0.223	0.315	0.200
Criteria	Cost	0.125	0.125	0.125	0.125	0.125	0.125	0.000	0.000	0.000	0.000
	Operation	0.125	0.125	0.125	0.125	0.125	0.125	0.000	0.000	0.000	0.000
	Quality	0.125	0.125	0.125	0.125	0.125	0.125	0.000	0.000	0.000	0.000
	Time	0.125	0.125	0.125	0.125	0.125	0.125	0.000	0.000	0.000	0.000

TABLE XIX. LIMIT MATRIX FOR RISK GROUPS

	NODES	EC	EN	FC	PL	SO	TE	Cost	Operation	Quality	Time
Alternatives	EC	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113
	EN	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116
	FC	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
	PL	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
	SO	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
	TE	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.134
Criteria	Cost	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083
	Operation	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083
	Quality	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083
	Time	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083

The NPV, TPV, and IPV of risk groups were calculated and are shown in Table XX.

TABLE XX. PRIORITY OF RISK GROUPS

Risk Group	TPV	NPV	IPV	R
EC	0.16942	0.16942	0.845723	3
EN	0.174148	0.174148	0.869325	2
FC	0.152897	0.152897	0.763242	4
PL	0.152674	0.152674	0.76213	4
SO	0.150537	0.150537	0.751463	5
TE	0.200325	0.200325	1	1

V. DISCUSSION

A. *Criteria Priority*

Through the ANP, this study ranked the risk priority with the consideration of the main assessment criteria of a bridge construction project. Quality and Operation are the most important criteria with a priority value of 0.333 for both. In addition, Cost and Time had equal importance with a score of 0.167.

B. *Risk Group Priority*

The Technical risk group is the most critical in a bridge construction project in the Mekong Delta region. This group has significant impacts on the Quality, Cost, Time and Operation of projects. The results are similar with the ones of [9, 36, 37]. The results revealed that technical risk is always the first risk priority for construction project management.

The Environmental risk group ranks second among risk groups. This result can be explained by the geographic features of the Mekong Delta region which was significantly influenced by climate change in recent years.

The third-ranking group is the Economic risk. This group consists of 8 risk factors, in which "Fuel/material prices change" is assessed as the most important factor. In fact, the main material prices for bridge construction projects have increased dramatically over the years. For instance, the steel price went up around 40% in one year and the cement price jumped up by approximately 90.000VND (3.94$) per ton compared to the price in 2020. Consequently, bridge projects suffered cost overrun, which this is the main cause leading to project delays.

Finally, while Political and legal risks and Financial and Commercial risks are ranked equally, the Social risk is considered as having less impact on the bridge construction projects in the Mekong Delta region. This shows that the Vietnam government has provided a sustainable political environment and mainly facilitated consistent policy for construction industry development.

The findings of this study are in accordance with the results of recent studies [59-61] and provide insight for policy makers in establishing risk mitigation strategies for large-scale bridge projects.

VI. CONCLUSION

In this paper, we identified 47 potential risk factors with the focus on bridge construction projects in the Mekong Delta region. Such risk factors have been categorized into 6 main groups for assessment, including Political and legal (PL), Social (SO), Technical (TE), Economic (EC), Environmental (EN), and Financial and Commercial (FC). By reviewing the importance of the risk-given groups with the consideration of 4 main criteria (quality, cost, time, and operation) along with practical surveys to collect expert opinions, the priority of risk groups had been determined.

The TE group was ranked at the highest level (IPV = 1) which potentially has the most significant impact on the performance of bridge construction projects. The EN group was ranked at the second-highest level (IPV = 0.8693), which reflects the risk consequences of the climate change on the bridge projects carried out in the Mekong Delta region. In addition, the EC group was also ranked in the top three, which indicates that economic risks have potential influences on the project's success.

The results of this study can enhance project managers to have a backup plan which can mitigate potential risks in the implementation of bridge construction projects in the Mekong delta region. Moreover, the results of this study can be considered as a blueprint for bridge project risk management in the context of developing countries

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REFERENCE LIST

[1] The Core Writing Team, R. K. Pachauri, and L. Meyer, Eds., *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva, Switzerland: IPCC, 2014.

[2] J. H. M. Tah and V. Carr, "A proposal for construction project risk assessment using fuzzy logic," *Construction Management and Economics*, vol. 18, no. 4, pp. 491–500, Jun. 2000, https://doi.org/10.1080/01446190050024905.

[3] D. Skorupka, "Identification and Initial Risk Assessment of Construction Projects in Poland," *Journal of Management in Engineering*, vol. 24, no. 3, pp. 120–127, Jul. 2008, https://doi.org/10.1061/(ASCE)0742-597X(2008)24:3(120).

[4] E. K. Zavadskas, Z. Turskis, and J. Tamosaitiene, "Risk assessment of construction projects," *Journal of Civil Engineering and Management*, vol. 16, no. 1, pp. 33–46, Jan. 2010, https://doi.org/10.3846/jcem.2010.03.

[5] A. Dziadosz and M. Rejment, "Risk Analysis in Construction Project - Chosen Methods," *Procedia Engineering*, vol. 122, pp. 258–265, Jan. 2015, https://doi.org/10.1016/j.proeng.2015.10.034.

[6] S. Iqbal, R. M. Choudhry, K. Holschemacher, A. Ali, and J. Tamosaitiene, "Risk management in construction projects," *Technological and Economic Development of Economy*, vol. 21, no. 1, pp. 65–78, Jan. 2015, https://doi.org/10.3846/20294913.2014.994582.

[7] K. Mhetre, B. A. Konnur, and A. B. Landage, "Risk Management in Construction Industry," *International Journal of Engineering Research*, vol. 5, no. 1, pp. 153–155, 2016, https://doi.org/10.17950/ijer/v5i1/035.

[8] R. M. Choudhry, M. A. Aslam, J. W. Hinze, and F. M. Arain, "Cost and Schedule Risk Analysis of Bridge Construction in Pakistan: Establishing Risk Guidelines," *Journal of Construction Engineering and Management*, vol. 140, no. 7, Jul. 2014, Art. no. 04014020, https://doi.org/10.1061/(ASCE)CO.1943-7862.0000857.

[9] M. Tadayon, M. Jaafar, and E. Nasri, "An Assessment of Risk Identification in Large Construction Projects in Iran," *Journal of Construction in Developing Countries*, vol. 1, pp. 57–69, 2012.

[10] N. B. Siraj and A. R. Fayek, "Risk Identification and Common Risks in Construction: Literature Review and Content Analysis," *Journal of Construction Engineering and Management*, vol. 145, no. 9, Sep. 2019, https://doi.org/10.1061/(ASCE)CO.1943-7862.0001685.

[11] B. Flyvbjerg, "Policy and Planning for Large-Infrastructure Projects: Problems, Causes, Cures," *Environment and Planning B: Planning and Design*, vol. 34, no. 4, pp. 578–597, Aug. 2007, https://doi.org/10.1068/b32111.

[12] S. Q. Wang, M. F. Dulaimi, and M. Y. Aguria, "Risk management framework for construction projects in developing countries," *Construction Management and Economics*, vol. 22, no. 3, pp. 237–252, Mar. 2004, https://doi.org/10.1080/0144619032000124689.

[13] "London Underground: Are the Public Private Partnerships likely to work successfully?," National Audit Office, London, UK, Jun. 2004.

[14] S. Ahn, "A Case Study of the Risk Identification in Construction Project," *Korean Journal of Construction Engineering and Management*, vol. 16, no. 1, pp. 15–23, 2015, https://doi.org/10.6106/KJCEM.2015.16.1.015.

[15] D. Bajaj, J. Oluwoye, and D. Lenard, "An analysis of contractors' approaches to risk identification in New South Wales, Australia," *Construction Management and Economics*, vol. 15, no. 4, pp. 363–369, Jul. 1997, https://doi.org/10.1080/014461997372917.

[16] O. Taylan, A. O. Bafail, R. M. S. Abdulaal, and M. R. Kabli, "Construction projects selection and risk assessment by fuzzy AHP and fuzzy TOPSIS methodologies," *Applied Soft Computing*, vol. 17, pp. 105–116, Apr. 2014, https://doi.org/10.1016/j.asoc.2014.01.003.

[17] B.-G. Hwang, X. Zhao, and G. S. Yu, "Risk identification and allocation in underground rail construction joint ventures: contractors' perspective," *Journal of Civil Engineering and Management*, vol. 22, no. 6, pp. 758–767, Aug. 2016, https://doi.org/10.3846/13923730.2014.914095.

[18] I. Manelele and M. Muya, "Risk identification on community-based construction projects in Zambia," *Journal of Engineering, Design and Technology*, vol. 6, no. 2, pp. 145–161, Jan. 2008, https://doi.org/10.1108/17260530810891289.

[19] Y. Ke, S. Wang, A. P. C. Chan, and E. Cheung, "Understanding the risks in China's PPP projects: ranking of their probability and consequence," *Engineering, Construction and Architectural Management*, vol. 18, no. 5, pp. 481–496, Jan. 2011, https://doi.org/10.1108/09699981111165176.

[20] P. X. W. Zou and G. Zhang, "Managing Risks in Construction Projects: Life Cycle and Stakeholder Perspectives," *International Journal of Construction Management*, vol. 9, no. 1, pp. 61–77, Jan. 2009, https://doi.org/10.1080/15623599.2009.10773122.

[21] R. J. Chapman, "The controlling influences on effective risk identification and assessment for construction design management," *International Journal of Project Management*, vol. 19, no. 3, pp. 147–160, Apr. 2001, https://doi.org/10.1016/S0263-7863(99)00070-8.

[22] N. N. Hlaing, D. Singh, R. L. K. Tiong, and M. Ehrlich, "Perceptions of Singapore construction contractors on construction risk identification," *Journal of Financial Management of Property and Construction*, vol. 13, no. 2, pp. 85–95, Jan. 2008, https://doi.org/10.1108/13664380810898104.

[23] C. A. L. Hilber and F. Robert-Nicoud, "On the origins of land use regulations: Theory and evidence from US metro areas," *Journal of Urban Economics*, vol. 75, pp. 29–43, May 2013, https://doi.org/10.1016/j.jue.2012.10.002.

[24] R. G. Funderburg, H. Nixon, M. G. Boarnet, and G. Ferguson, "New highways and land use change: Results from a quasi-experimental research design," *Transportation Research Part A: Policy and Practice*, vol. 44, no. 2, pp. 76–98, Feb. 2010, https://doi.org/10.1016/j.tra.2009.11.003.

[25] E. L. Glaeser and B. A. Ward, "The causes and consequences of land use regulation: Evidence from Greater Boston," *Journal of Urban Economics*, vol. 65, no. 3, pp. 265–278, May 2009, https://doi.org/10.1016/j.jue.2008.06.003.

[26] H. Alinaitwe, R. Apolot, and D. Tindiwensi, "Investigation into the Causes of Delays and Cost Overruns in Uganda's Public Sector Construction Projects," *Journal of Construction in Developing Countries*, vol. 18, no. 2, pp. 33–47, 2013.

[27] R. M. Fraser, "Compensation for extra preliminary and general (P & G) cost arising from delays, variations and disruptions: the palmiet pumped storage scheme," *Tunnelling and Underground Space Technology*, vol. 5, no. 3, pp. 205–216, Jan. 1990, https://doi.org/10.1016/0886-7798(90)90008-8.

[28] A. H. Al-Momani, "Construction delay: a quantitative analysis," *International Journal of Project Management*, vol. 18, no. 1, pp. 51–59, Feb. 2000, https://doi.org/10.1016/S0263-7863(98)00060-X.

[29] S. Ghosh and J. Jintanapakanont, "Identifying and assessing the critical risk factors in an underground rail project in Thailand: a factor analysis approach," *International Journal of Project Management*, vol. 22, no. 8, pp. 633–643, Nov. 2004, https://doi.org/10.1016/j.ijproman.2004.05.004.

[30] A. S. Akintoye and M. J. MacLeod, "Risk analysis and management in construction," *International Journal of Project Management*, vol. 15, no. 1, pp. 31–38, Feb. 1997, https://doi.org/10.1016/S0263-7863(96)00035-X.

[31] T. de Lemos, D. Eaton, M. Betts, and L. T. de Almeida, "Risk management in the Lusoponte concession—a case study of the two bridges in Lisbon, Portugal," *International Journal of Project Management*, vol. 22, no. 1, pp. 63–73, Jan. 2004, https://doi.org/10.1016/S0263-7863(03)00013-9.

[32] L. Bing, A. Akintoye, P. J. Edwards, and C. Hardcastle, "The allocation of risk in PPP/PFI construction projects in the UK," *International Journal of Project Management*, vol. 23, no. 1, pp. 25–35, Jan. 2005, https://doi.org/10.1016/j.ijproman.2004.04.006.

[33] R. Singh, *Delays and Cost Overruns in Infrastructure Projects: An Enquiry into Extents, Causes and Remedies*. New Delhi, India: University of Delhi, 2009.

[34] R. Miller and D. R. Lessard, *The Strategic Management of Large Engineering Projects: Shaping Institutions, Risks, and Governance*. Cambridge, MA, United States: MIT Press, 2001.

[35] T. Y. Lo, I. W. Fung, and K. C. Tung, "Construction Delays in Hong Kong Civil Engineering Projects," *Journal of Construction Engineering and Management*, vol. 132, no. 6, pp. 636–649, Jun. 2006, https://doi.org/10.1061/(ASCE)0733-9364(2006)132:6(636).

[36] A. Nieto-Morote and F. Ruz-Vila, "A fuzzy approach to construction project risk assessment," *International Journal of Project Management*, vol. 29, no. 2, pp. 220–231, Feb. 2011, https://doi.org/10.1016/j.ijproman.2010.02.002.

[37] S. M. El-Sayegh, S. Manjikian, A. Ibrahim, A. Abouelyousr, and R. Jabbour, "Risk identification and assessment in sustainable construction projects in the UAE," *International Journal of Construction Management*, vol. 21, no. 4, pp. 327–336, Apr. 2021, https://doi.org/10.1080/15623599.2018.1536963.

[38] Y. Sun, D. Fang, S. Wang, M. Dai, and X. Lv, "Safety Risk Identification and Assessment for Beijing Olympic Venues Construction," *Journal of Management in Engineering*, vol. 24, no. 1, pp. 40–47, Jan. 2008, https://doi.org/10.1061/(ASCE)0742-597X(2008)24:1(40).

[39] D. Kasap and M. Kaymak, "Risk Identification Step of the Project Risk Management," in *Portland International Conference on Management of Engineering & Technology*, Portland, OR, USA, Aug. 2007, pp. 2116–2120, https://doi.org/10.1109/PICMET.2007.4349543.

[40] M. Gunduz, Y. Nielsen, and M. Ozdemir, "Quantification of Delay Factors Using the Relative Importance Index Method for Construction Projects in Turkey," *Journal of Management in Engineering*, vol. 29, no. 2, pp. 133–139, Apr. 2013, https://doi.org/10.1061/(ASCE)ME.1943-5479.0000129.

[41] G. A. Hodge, "The risky business of public–private partnerships," *Australian Journal of Public Administration*, vol. 63, no. 4, pp. 37–49, 2004, https://doi.org/10.1111/j.1467-8500.2004.00400.x.

[42] M. Ebrat and R. Ghodsi, "Construction project risk assessment by using adaptive-network-based fuzzy inference system: An empirical study," *KSCE Journal of Civil Engineering*, vol. 18, no. 5, pp. 1213–1227, Jun. 2014, https://doi.org/10.1007/s12205-014-0139-5.

[43] G. Dehdasht, R. Mohamad Zin, M. S. Ferwati, M. Mohammed Abdullahi, A. Keyvanfar, and R. McCaffer, "DEMATEL-ANP Risk Assessment in Oil and Gas Construction Projects," *Sustainability*, vol. 9, no. 8, Aug. 2017, Art. no. 1420, https://doi.org/10.3390/su9081420.

[44] A. Taroun and J.-B. Yang, "A DST-based approach for construction project risk analysis," *Journal of the Operational Research Society*, vol. 64, no. 8, pp. 1221–1230, Aug. 2013, https://doi.org/10.1057/jors.2013.38.

[45] W. Haynes, "Transportation at the millennium: In search of a megaproject lens," *Review of Policy Research*, vol. 19, no. 2, pp. 62–64, 2002, https://doi.org/10.1111/j.1541-1338.2002.tb00265.x.

[46] M. Schieg, "Risk management in construction project management," *Journal of Business Economics and Management*, vol. 7, no. 2, pp. 77–83, Jan. 2006, https://doi.org/10.1080/16111699.2006.9636126.

[47] P. H. V. Nguyen and P. C. Nguyen, "Effects of Shaft Grouting on the Bearing Behavior of Barrette Piles: A Case Study in Ho Chi Minh City," *Engineering, Technology & Applied Science Research*, vol. 11, no. 5, pp. 7653–7657, Oct. 2021, https://doi.org/10.48084/etasr.4389.

[48] P. C. Nguyen, "Nonlinear Inelastic Earthquake Analysis of 2D Steel Frames," *Engineering, Technology & Applied Science Research*, vol. 10, no. 6, pp. 6393–6398, Dec. 2020, https://doi.org/10.48084/etasr.3855.

[49] P. C. Nguyen, "Local Instability Analysis for Axial Compressive Steel Columns," *Engineering, Technology & Applied Science Research*, vol. 12, no. 6, pp. 9527–9531, Dec. 2022, https://doi.org/10.48084/etasr.5238.

[50] S. M. H. Mojtahedi, S. M. Mousavi, and A. Makui, "Project risk identification and assessment simultaneously using multi-attribute group decision making technique," *Safety Science*, vol. 48, no. 4, pp. 499–507, Apr. 2010, https://doi.org/10.1016/j.ssci.2009.12.016.

[51] A. A. G. Hassanein and H. M. F. Afify, "A risk identification procedure for construction contracts—a case study of power station projects in Egypt," *Civil Engineering and Environmental Systems*, vol. 24, no. 1, pp. 3–14, Mar. 2007, https://doi.org/10.1080/10286600600910104.

[52] E. W. L. Cheng and H. Li, "Analytic Network Process Applied to Project Selection," *Journal of Construction Engineering and Management*, vol. 131, no. 4, pp. 459–466, Apr. 2005, https://doi.org/10.1061/(ASCE)0733-9364(2005)131:4(459).

[53] T. L. Saaty, *Theory and Applications of the Analytic Network Process: Decision Making With Benefits, Opportunities, Costs, and Risks*. Pittsburgh, PA, USA: RWS Publications, 2005.

[54] J. Pinto and D. Slevin, "Project success: Definitions and measurement techniques," *Project Management Journal*, vol. 2, pp. 67–72, Jan. 1988.

[55] J. Gomes and M. Romao, "Improving Project Success: A Case Study Using Benefits and Project Management," *Procedia Computer Science*, vol. 100, pp. 489–497, Jan. 2016, https://doi.org/10.1016/j.procs.2016.09.187.

[56] S. Khosravi and H. Afshari, "A Success Measurement Model for Construction Projects," in *International Conference on Financial Management and Economics*, Hong Kong, China, Jul. 2011, pp. 186–190.

[57] D. J. Bryde and L. Robinson, "Client versus contractor perspectives on project success criteria," *International Journal of Project Management*, vol. 23, no. 8, pp. 622–629, Nov. 2005, https://doi.org/10.1016/j.ijproman.2005.05.003.

[58] F. D. Bahia and J. R. de Farias Filho, "Analysis of success criteria in engineering, procurement and construction (EPC) projects," *Revista de Gestao e Projetos*, vol. 1, no. 2, pp. 49–67, 2010, https://doi.org/10.5585/gep.v1i2.15.

[59] A. Alameri, A. S. A. M. Alhammadi, A. H. Memon, I. A. Rahman, and N. a. N. Nasaruddin, "Assessing the Risk Level of the Challenges Faced In Construction Projects," *Engineering, Technology & Applied Science Research*, vol. 11, no. 3, pp. 7152–7157, Jun. 2021, https://doi.org/10.48084/etasr.4020.

[60] M. N. Sharabian, S. Ahmad, and M. Karakouzian, "Climate Change and Eutrophication: A Short Review," *Engineering, Technology & Applied Science Research*, vol. 8, no. 6, pp. 3668–3672, Dec. 2018, https://doi.org/10.48084/etasr.2392.

[61] P. T. Nguyen and P. C. Nguyen, "Risk Management in Engineering and Construction: A Case Study in Design-Build Projects in Vietnam," *Engineering, Technology & Applied Science Research*, vol. 10, no. 1, pp. 5237–5241, Feb. 2020, https://doi.org/10.48084/etasr.3286.