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Research paper

Delay factors in the construction of irrigation and hydropower projects in Vietnam

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Abstract: Irrigation and hydropower are among the most important sectors in the construction industry that propel the economic needs of a developing country like Vietnam. The construction of these projects often suffers from severe delays, leading to financial losses and other negative impacts on the economy. This paper aims to determine delay factors in the construction of these projects. Among many, 39 most important candidates of delay causes were identified from the literature review. Further surveys on project participants were conducted for the severity of these causes. An exploratory factor analysis was utilized to identify latent factors that cause delays in construction projects. The analysis result categorized a few groups of factors such as abnormal factors on the construction site (e.g., labor accidents, hydrology, water flow, extreme weather) and technical factors related to the construction contractor (e.g., unsuitable schedule, outdated construction technology, unprofessional workers) that have the greatest impact on the delay in construction of irrigation and hydropower projects in Vietnam. These findings contribute to the body of knowledge of project management and risk management, hence an improvement in the efficiency of the project sectors' performance.

Keywords: hydropower, irrigation, construction, projects, delay factors, Vietnam

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1. Introduction

Irrigation and hydroelectricity are important fields in socio-economic development, where they improve the quality of life of people. During the period of national construction and development, irrigation and hydropower project investment has been intensified by the State of Vietnam. Until 2021, there are 818 hydropower projects with the total designed capacity of 23,182 MW, contributing 40% of total designed capacity and 42,87% electrical capacity of the country [1]. In the context of climate change, level of deforestation today, irrigation and hydropower projects play an important role in the task of slowing and reducing flood in the downstream. In addition, implementing the national target program to restructure agriculture [2] and new rural areas [3], irrigation and hydropower works have an important contribution. Therefore, irrigation and hydropower projects will continue to get funds for construction, upgrade, and reparation. However, irrigation and hydroelectric projects often suffer from severe delays, especially in the construction phase [4]. The delay in construction causes cost overruns and may deteriorate the quality of the assets [5]. Therefore, the main objective of this study is to analyse the influence of factors that cause delay in irrigation and hydropower construction and their relationships by statistical methods. Followed with a linear regression analysis on obtained latent factors to assess their impacts. The paper continues with a review of literature, an introduction of the research method, which includes a survey. Results from the survey were analysed for latent factors and in a linear regression consequently. Conclusions and recommendations go as the end of the paper.

2. Literature reviews

Irrigation and hydropower projects share similar basics with other construction projects, especially causes of delays and cost overruns. Many authors, such as Chan (1997) [6], Al-Ghafly (1999) [7], Al-Momani (2000) [8], Iyer and Jha (2005) [9], Sadi and Sadiq (2006) [10], El-Razek et al. (2008) [11], Al-Kharashi and Skitmore (2009) [12], Olawale and Sun (2010) [13], Chang et al. (2011) [14], Geraldine (2012) [15], Lee et al. (2013) [16], Ramanathan (2018) [17] focused their research on the subjects and listed more than 100 factors that can affect the construction progress. Other scholars turned their interest into technical problems that cause delays in construction [18]. For instance, rework is responsible for the delay that averages 22% of scheduled time [19]. However, identified factors, despite their similarity in nature, have been rarely categorized analogously.

In Vietnam, scholars have paid attention on the causes of delays in construction projects as well. Luan (2006) [20] points out the reasons for the slow progress of construction projects in Vietnam. They are ineffective management, weak capacity of contractors, complexity and scale of the project, and limited resources. Lan (2012) [21] studies the progress of construction works considering the uncertainty in selected projects in Vietnam. Uncertain factors that may cause construction delays are weather conditions, legal changes, the impact of the economy and the natural environment surrounding the projects. Dung

(2004) [22] in a study aimed to optimizing the construction schedule also mentioned the technical and social causes affecting the construction progress. The causes of this construction delay will affect the cost, quality, and customer satisfaction at different levels. A study by Long et al. (2008) [23] summarized and compared the causes of the delay in construction industry in Asia and Africa. The followings are the delay causes synthesized from aforementioned literature, totalling 39 factors.

– Design related group: Unclear details and conflicting interpretations in design documents; Poor or inaccurate geological survey; Re-construction due to design changes during construction; Incomplete design adjustment dossier during the construction; Rework due to wrong design; Change of design manager;
– External related group: Severe weather conditions; Hydrological and flow factors; Geological issues (landslide, sand flow. . .); Deviations in site conditions;
– Owner related group: The owner delays decisions; The owner delays providing documents to the contractors; The owner delays accepting the completed work for the contractors; The owner delays payment; The owner delays handing over the site to the contractors; Conflicts between the owner and other parties; Lack of encouragement for early finish;
– Monitoring related group: Work accidents; Poor management and supervision; Lack of professional technical team; Improper inspection and testing methods;
– Legal related group: Change of scope (increase); The local authorities do not cooperate; Change in law;
– Contractor related group: Delay providing materials; Conflicts on the construction site (local people protest, workers strike. . .); Improper storage of materials, causing damages; Changes of subcontractors or sign contracts with many contractors, subcontractors; Conflicts, contradictions, bureaucracy among individuals of the contractors/subcontractors; Poor organized structure of contractors; Poor contract terms (between contractor and subcontractor); Unrealistic construction schedule; Financial constraints of contractors; Poor labor productivity; Inexperienced contractor; Inefficient use of equipment; Old construction technology/wrong method; Changes in the supply of human and material resources.

3. Research methodology

The nature of this study is to explore latent factors from candidates of factors that cause delays in irrigation and hydropower projects. In reality, factors usually share similar features such as causes, high correlations – or tend to happen at the same time. In management, categories of factors are important, since management decision makers should understand the shared featured of factors so that they can (i) select the best order of interferential activities and (ii) distribute organizational resources wisely. With the mentioned intention of the authors, Exploratory Factor Analysis (EFA) is the most appropriate technique in this study. EFA was first introduced in 1904 [24] to determine psychical tendencies, in a study that Spearman tried to analyze the correlations between mental tests. Following the notion, other scholars furthered the research on the topic [25–27] and disseminated the technique to other fields such as health, business, education management. Until recently, scholars continued to apply EFA in many research problems, while extending the class of methods [28–33]. The path from observed variables to latent factors can be understood if one thinks of the variance between the observed variables and the latent factors this way [29]:

Observed variance = common variance + unique variance

where: unique variance = specific variance + error variance

A useful notion is introduced in EFA – the *communality* – which is the proportion of variance accounted for by the common factors:

Communality = common variance/observed variance

Similarly, *reliability* is introduced to assess the EFA model:

Reliability = (common variance + specific variance)/observed variance

Considering an example with six measured variables (MV). First, correlations between pairs of MVs are depicted in a correlation matrix. To determine the proper number of common factors (CF), there are a few methods that are utilized. According to the principal components method, the total amount of variance that can be explained by a given principal component is sought for, and are called eigenvalues. The rule that dictates the minimum value of eigenvalue for a common factor varies [34, 35]. The following example shows the relationships between measured variables (MV) and latent variables (common factors (CF) and unique factors (U) (Fig. 1):

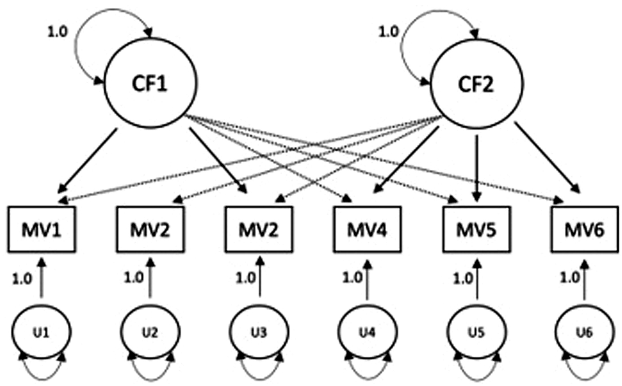

Fig. 1. A common factor model in which two common factors are explored from six measured variables [29]

Of course, EFA should be used with care: there are rules about variables, data, and how to interpret results. Readers can consult a guide by Watkins (2021) [36], which refers to relevant advanced literature. Going back to the purposes of the study, data must be obtained before EFA can be applied. Figure 2 depicts the research flow of the study.

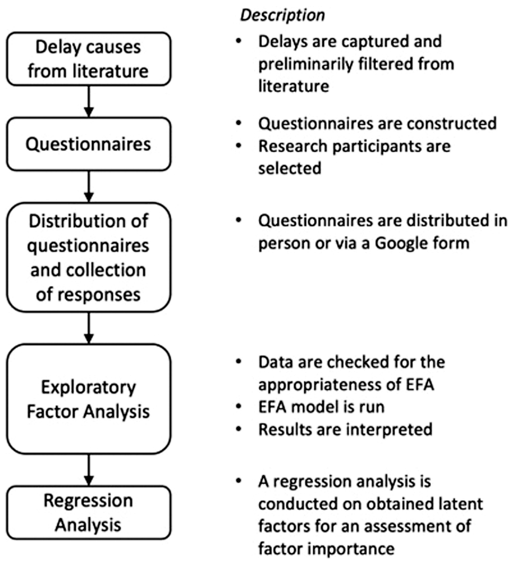

Fig. 2. Research methodology

3.1. Questionnaire preparation

The implementation of factor analysis and questionnaire preparation is an important part of this study. To facilitate the process of data collection and analysis, a common survey for the respondents has been designed. Several related researches was reviewed, such as Chan (1997) [6], Al-Ghafly (1999) [5], Al-Momani (2000) [8], Dung (2004) [22], Ku et al. (2004) [37], Iyer and Jha (2005) [9], Luan (2006) [20], Sadi and Sadiq (2006) [10], El-Razek et al. (2008) [11], Long et al. (2008) [23], Al-Kharashi and Skitmore (2009) [7], Olawale and Sun (2010) [13], Geraldine (2012) [15], Lan (2012) [21], Ramanathan (2018) [17], and Wu et al. (2020) [38]. The authors had interviewed key experts in the field of irrigation and hydroelectricity. Thus, the research questionnaire is proposed to consist of 6 preliminary groups of factors presented at the end of the Literature review section. On that basis, the proposed hypothesis model is shown in Fig. 3 with the influence and probabilities of the factors assessed on the 5-point scale Likert presented in Table 1.

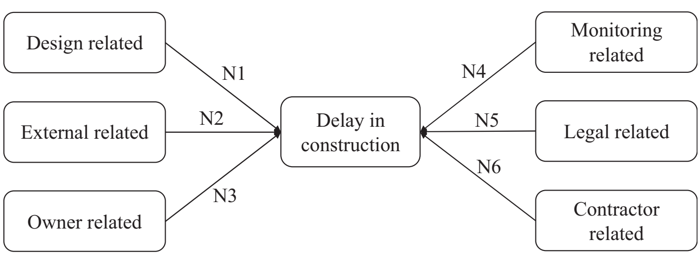

Fig. 3. Hypothetical Research Model

Table 1. Influence Level and Probability of Factors

Level	Influence		Level	Probability
1	Very low		1	Very low
2	Low		2	Low
3	Medium		3	Medium
4	High		4	High
5	Very high		5	Very high

3.2. Respondent information

The selected respondents are members of owner and individuals of construction units, design consultancy, supervision consultancy of irrigation and hydropower projects. They are grouped by years of experience: under 3 years, from 3 to 5 years, from 5 to 10 years, from 10 to 15 years and from 15 years or more. The questionnaires were mailed, collected during in-person meetings and via Google Docs. Respondents' characteristics are shown on Table 2.

Table 2. Respondents' characteristics

Survey composition (Total sample: 310)		Frequency (People)	Percentage (%)
Work experience	< 3 years	49	15,8
	3–5 years	35	11.3
	5–10 years	103	33.2
	10–15 years	78	25.2
	> 15 years	45	14.5
Level of education	Doctor	5	1.61
	Master	103	33.6
	Bachelor	192	61.6
	Colleges	9	2.9
	High school	1	0.32
Current working role	State owner	101	32.6
	Non-State owner	21	6.8
	Management project consultancy	15	4.9
	Supervision consultancy	20	6.5
	Construction contractor	103	33.2
	Design consultancy	50	16.2

Table 2 [cont.]

Survey composition (Total sample: 310)		Frequency (People)	Percentage (%)
Current position	Leader	38	12.3
	Department/Deputy head	73	23.5
	Technical staff	121	39
	Captain	35	11.3
	Design manager	1	0.32
	Project manager	1	0.32
	Owner assigner	2	0.65
	Main supervisor	27	8.71
	Design engineer	8	2.58
	Researcher	1	0.32
	Supervision consultant	3	0.97
Total investment of current project	< 2 million (USD)	113	36.4
	2–4 million (USD)	54	17.4
	4–20 million (USD)	60	19.4
	> 20 million (USD)	83	26.8

3.3. Ranking factors

Using the expert scoring formula to calculate ranking factors. Each expert will have 100 points for assigning indicators according to the importance given by the expert. The weight of norm I (W_i) is as follows:

$$W_i = \frac{\sum\limits_{j=1}^{n} B_{ji}}{n \cdot 100} \tag{3.1}$$

with: B_{ji} is Score of expert j for norm I_i; n is the number of experts. The properties are arranged in order, the highest W_i or rank 1 indicates that it has the greatest impact on the delay in construction while the lowest ranking factor indicates that it has few effect on time lag.

4. Research results

4.1. Analysis of factors

Considering the data for the Exploratory Factor Analysis (EFA) method, Child (2006) [28] recommends that the minimum sample size is 100, and the observed / variable measure ratio is 5:1, meaning that an variable needs a minimum of 5 observations. Therefore, in this study, it is expected that with the total number of observed variables equal 39, the minimum and necessary sample size is $39 \times 5 = 195$ subjects. The sampling method used here is a simple random sampling method. Respondents will receive surveys in paper form and in the form of links via https://forms.gle/5g6AAEVdbYwUZe5P8. The units that receive the votes will then notify the members to participate in the survey. The summary of shared and completed survey forms are as follows:

– Printed questionnaire: the total number of released questionnaires is 40, the number of withdrawn questionnaires is 22 (response rate is 55%). After the authors analyze and check the data, four tables were rejected due to lack of information. Therefore, through this method, 18 respondents provided completed forms.
– Questionnaire shared through e-mail: the total number of emails that were sent is 330, the number of responses received through an automatic spreadsheets of Google Drive is 292 (response rate is 88.48%). Because during the questionnaire creation process, all questions (except the last question asking for personal information) are required to be answered before clicking the "Submit" button, therefore the aggregated results from this format do not have the results "of the" tables excluded due to lack of information. Then, this method allowed us to obtain responses from 292 subjects.

After collecting the answer sheet, proceed to Step 1: Exploring Factor Analysis (EFA). KMO test (Kaiser–Meyer–Olkin) is an indicator to consider the appropriateness of EFA, condition: KMO $\geq$ 0.5, or better, greater than 0.6 [39]. After the observed variables had included the EFA, they were compacted into six groups of factors with 31 observed variables (Fig. 2). These groups of factors were not convergent in accordance with the initial hypothesis model, so the authors had divided them to six new groups of factors based on site construction processes. The construction process is as follows: Group of factors related to Contractor Techniques (X1), Group of factors related to Unusual Site Impacts (X2), Group of factors related to Human Resources (X3), Group of factors related to Construction Procedures (X4), Group of factors related to Design Processes (X5), and Group of factors related to Legal Aspects (X6). Continuously, proceed to Step 2: Testing the reliability of the scale by Cronbach's Alpha coefficient. This method helps eliminate variables that are not suitable for each component scale through the correlation coefficient of the correction.

The results from Bartlett's Test of Sphericity indicate that variables are corelated: Kaiser–Meyer–Olkin measure of sampling adequacy = 0.831; df = 741; approximated Chi-Square = 8921.023; p-value < 0.001. Using a rule for extracting factors (eigenvalue greater than 1), six factors were extracted explaining 20.336%, 18.423%, 9.814%, 7.201%, 5.260%, and 4.787% of variance in all 39 variables (Fig. 4 and Table 3).

After orthogonal rotation totalling (or rotating), 59.7% of variance explained by six factors. The results of variables with loadings on each of the six factors are shown in six tables correspondingly. The reliability of the scale was assessed by the method of intrinsic consistency through Cronbach's Alpha coefficient [40]. When reliability coefficients are > 0.9, they are considered excellent and sufficient for critical decisions (DeVellis, 2017); coefficients that are between 0.8–0.9 are good and sufficient for non-critical decisions;

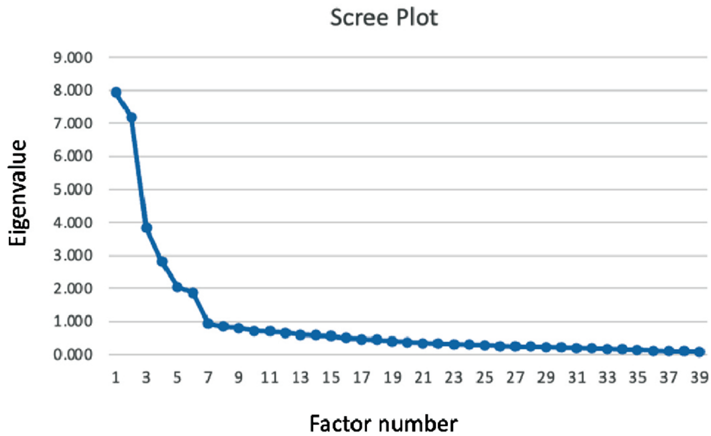

Fig. 4. The scree plot

Table 3. Total variance explained by factors

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.931	20.336	20.336	7.603	19.495	19.495	6.038	15.483	15.483
2	7.185	18.423	38.759	6.775	17.372	36.866	3.887	9.968	25.451
3	3.828	9.814	48.574	3.454	8.855	45.722	3.710	9.512	34.963
4	2.808	7.201	55.774	2.350	6.027	51.749	3.493	8.956	43.919
5	2.052	5.260	61.035	1.656	4.245	55.994	3.458	8.867	52.786
6	1.867	4.787	65.822	1.450	3.719	59.713	2.702	6.927	59.713
7	0.930	3.537	69.358						
8	0.852	2.992	72.351						
9	0.802	2.057	74.408						
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

coefficients that are between 0.7–0.8 are adequate for group experimental research; finally, coefficients that are < 0.7 are inadequate for most applications [41, 42].

Six group factors ($X1 - X6$) are depicted in Tables 4–9, showing delays categorized in, and the Cronbach's alpha ranging from 0.810 to 0.950.

– Group of factors $X1$: This group has eight factors, Cronbach's Alpha coefficient is $0.95 > 0.7$ (Table 4), showing that the scale of component of technical factors affecting the construction schedule is reliable. Most of the delays are related to how the contractors perform and manage construction activities. Even the BN5 delay "Change in material prices" can be managed by the procurement management of the contractors. Therefore, this group factor is titled "Contractor professionalism related".

Table 4. Cronbach's Alpha Coefficient of Group Factor $X1$

Code	Factor	Loading	Cronbach's Alpha
BN5	Change in material prices	0.780	**0.950**
NT8	Unsuitable schedule	0.792	
NT9	Financial constraints of the construction contractor	0.767	
NT10	Poor labor productivity	0.796	
NT11	Lack of experience of contractors	0.723	
NT12	Inefficient use of equipment	0.789	
NT13	Outdated or unreasonable construction technology	0.705	
GS4	Improper inspection and testing methods	0.811	

– Group of factors $X2$: Testing the scale for Cronbach's Alpha coefficient is $0.906 > 0.7$ (Table 5), showing that the component scale of the abnormal impact factor on the construction site which has an influence on schedule is reliable. Most of the delays represent many kinds of risks that can happen during the construction phase. Hence, the group factor is titled "Construction Site risks".

Table 5. Cronbach's Alpha Coefficient of Group Factor $X2$

Code	Factor	Loading	Cronbach's Alpha
BN1	Severe weather conditions	0.612	**0.906**
BN2	Hydrological factors	0.586	
BN3	Geological issues (landslide, sand flow. . .)	0.609	
NT1	Slow supply of materials from distributors	0.600	
CDT1	The owner delays decisions	0.533	
GS1	Work accidents	0.599	

– Group of factors $X3$: The result of testing the scale for Cronbach's Alpha coefficient is $0.894 > 0.7$ (Table 6), showing that the component scale of the human factor affecting the construction progress is reliable. Most of the delays in this group factor are related to the human issues; therefore, the group factor is titled "Human Relationships and Issues".

Table 6. Cronbach's Alpha Coefficient of Group Factor $X3$

Code	Factor	Loading	Cronbach's Alpha
TK6	Change of design manager	0.638	**0.894**
NT4	Changes of subcontractors or sign contracts with many contractors, subcontractors	0.597	
NT5	Conflicts, contradictions, bureaucracy among individuals of the contractors/subcontractors	0.587	
CDT6	Conflicts between the owner and other parties	0.655	
GS3	Lack of professional technical team	0.628	

– Group of factors $X4$: The test results show that the scale with Cronbach's Alpha coefficient is $0.884 > 0.7$ (Table 7), indicating that the component scale of the process factor affects schedule is reliable. Most of the delays in this group factor are caused by the owners in the construction phase, except NT3 "Improper storage of materials, causing damages". This group factor can be named "Construction Procedures".

Table 7. Cronbach's Alpha Coefficient of Group Factor $X4$

Code	Factor	Loading	Cronbach's Alpha
NT3	Improper storage of materials, causing damages	0.686	**0.884**
CDT2	The owner delays providing documents to the contractors	0.703	
CDT3	The owner delays accepting the completed work for the contractors	0.451	
CDT4	The owner delays payment	0.696	
CDT5	The owner delays handing over the site to the contractors	0.673	

– Group of factors $X5$: The result of testing the scale with Cronbach's Alpha coefficient is $0.81 > 0.7$ (Table 8), this result shows that the component scale of the factors related to the design affects the construction progress is reliable. These delays are all design related. Therefore, this group is named "Design Processes".

Table 8. Cronbach's Alpha Coefficient of Group Factor $X5$

Code	Factor	Loading	Cronbach's Alpha
TK1	Unclear details and conflicting interpretations in design documents	0.694	**0.810**
TK3	Change of scope (increase)	0.639	
TK5	Rework due to wrong design	0.631	

– Group of factors $X6$: Results of testing the legal-related factor scale with Cronbach's Alpha coefficient are $0.847 > 0.7$ (Table 9), showing that the scale of the components of legal factors which has an influence on schedule is reliable. These delays are related to the law, hence named "Legal Aspects".

Table 9. Cronbach's Alpha Coefficient of Group Factor $X6$

Code	Factor	Loading	Cronbach's Alpha
PL2	The local authorities do not cooperate	0.496	**0.847**
PL3	Change in law	0.498	
NT7	Poor contract terms (between contractor and subcontractor)	0.468	

Results are captured in a new model that are presented in Fig. 5. It is noteworthy that there are six delays left out due to their low communalities: Poor or inaccurate geological survey, Incomplete design adjustment dossier during the construction, Deviations in site conditions, Lack of encouragement for early finish, Poor management and supervision, Change of scope (increase), Conflicts on the construction site (local people protest, workers strike. . .), Poor organized structure of contractors, Changes in the supply of human and material resources. Though left out, these delays are quite common, and therefore are categorized in the "Other risks" group.

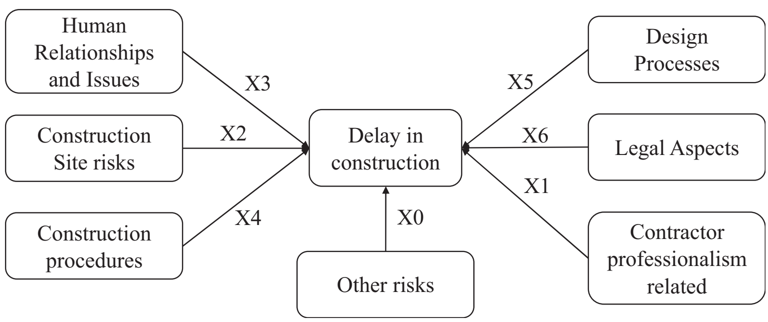

Fig. 5. Modified Research Model

Discussion of the hypothesis model and the modified model:

In the hypothesis model, delays are grouped based on *their nature* (e.g. *similar causes*). There are 39 delays; the six groups are actually related cause entities. On the other hand, in the modified model, the delays are categorized into six main groups and a miscellaneous group. Upon consideration, the authors realize that the modified model groups delays based on *how the delays affect the construction progress*. This observation is interesting, since it provides project managers with another perspective in how to design management strategies against delays in the contruction of irrigation and hydropower projects.

4.2. Regression analysis

After the EFA was conducted on the results of delays, a regression analysis would provide further explanation of the importance of these group factors. The null hypothesis (N0) is: the dependent variables have no linear relationship with the independent variables. The alternative hypothesis (Na) is: the dependent variables have linear relationship with the independent variables.

The regression analysis results showed that the value $R = 0.739$; it means that the relationship between variables in the model is relatively close. The determination coefficient is $R^2 = 0.546$, this indicates the model's suitability is 54.6%. In addition, the adjusted R^2 value more accurately reflects the model's suitability with the whole, the analysis results show that the adjusted R^2 value is 0.537 (or 53.7%) which means only 53, 7% of the variation of the dependent variable (Y) "The delays in construction progress of irrigation and hydropower works in Vietnam" is explained by 06 variables in the model, while 46.3% will be due to factors other than the model and random errors. The regression equation has the following form:

$$Y = a + b_1 X_1 + b_2 X_2 + \ldots b_m X_m \tag{4.1}$$

In which Y is dependent variable, a is constant and limited in Y axis (group factor X_0 may be captured in this constant coefficient); from b1 to bm are estimated regression coefficients; from X_1 to X_m are values of the explanatory variables. Results in Table 10 shows that:

$$\text{Delay in construction} = 0.913 + 0.183X_1 + 0.248X_2 + 0.175X_3 + 0.081X_4 + 0.093X_5 + 0.072X_6 \tag{4.2}$$

Table 10. Summary Table of Regression Analysis Results

Model	Non-standardized coefficient		Standardized coefficient	Statistic t	Statistic Sig.	Multi-collinearity statistics		
	B	Standard deviation		Beta		Acceptance	VIF	$R^2 = 0.546$ / Adjusted $R^2 = 0.537$ statistical values $F = 60.6$ Dublin–Watson = 1.848
Constant (including X0)	0.913	0.170		5.363	0.000			
X1	0.183	0.025	0.321	7.385	0.000	0.796	1.257	
X2	0.248	0.029	0.390	8.639	0.000	0.736	1.359	
X3	0.175	0.031	0.253	5.674	0.000	0.751	1.331	
X4	0.081	0.028	0.132	2.891	0.004	0.720	1.390	
X5	0.093	0.029	0.131	3.230	0.001	0.914	1.094	
X6	0.072	0.030	0.103	2.384	0.018	0.808	1.237	

5. Conclusions and recommendations

In this study, delays in the construction of irrigation and hydropower projects in Vietnam are collected from literature and distributed to project practitioners. Results are used to perform an EFA to explore latent factors. Six main groups and a miscellaneous group were extracted. Through multivariate regression analysis, the group factor that has the highest corelation on the delay of construction in irrigation and hydropower projects is the construction site risks. This will help project participants pay attention to precautions, risk management, supervision to promptly handle unusual problems on the construction site. In planning the construction schedule, it is necessary to have estimated time to handle these potential abnormalities.

Contractor professionalism factors also have a significant influence on the delay of construction progress. Therefore, it is necessary to increase transparency from the stage of selection of contractors and strict controls from the stage of construction planning and measures to limit the delay due to the professionalism of contractors. Currently, the Ministry of Planning and Investment requires contractors to publicize their capacity and online bidding national wise. This requirement provides practitioners with a measure to improve the quality of contractor selection right from the bidding stage.

This study also benefits the body of knowledge in the sense that it provides another perspective of how practitioners should perceive the risk of delaying the construction of irrigation and hydropower: not only the *similar causes of delays* but also to categorize different delays based on *the way they affect the total delays* of an irrigation/hydropower project.

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