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Research paper

A study on time schedules for construction projects in Hanoi, Vietnam

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Abstract: With its position as the capital, Hanoi is the political center as well as the second largest economic center of the country. Therefore, the city is always allocated a large budget in construction investment to create material facilities for political tasks and economic and social development. During the implementation of construction projects, a number of difficulties and limitations have appeared. In which, projects are delayed in construction and disbursement, reducing investment efficiency and not meeting the expectations of the government and people. From this fact, the authors have conducted a study to evaluate the causes affecting the time schedule of construction projects in Hanoi. The method F-APH (Fuzzy Analytic Hierarchy Process) was used to analyze data objectively and accurately about the causes affecting the time schedule. From there, these causes are classified into groups of subjective causes (from within the project) and groups of objective causes (from outside the project). The results show that subjective causes, originating from project participants, have a stronger influence than objective causes. A number of specific proposals to the actors involved in construction projects are made to eliminate or limit the impact of the causes of construction progress.

Keywords: construction, fuzzy, Hanoi, projects, schedules, Vietnam

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1. Introduction

With its position as the capital, Hanoi is the political center and also the second largest economic center of the country (Fig. 1). According to the requirements of economic and social development, many construction projects have been and are being implemented, with total public investment always kept at a high level. Figure 2 shows public investment capital through the years of 2018, 2919 and 2020 with the total investment for construction projects increased (HSHP, 2021) [1]. In order to promote the progress of implementation and disbursement of projects, the investors have made regular reports and assessments of the overall investment in the whole city. It can be seen that public investment capital in the current period is mostly for public works projects and technical infrastructure works.

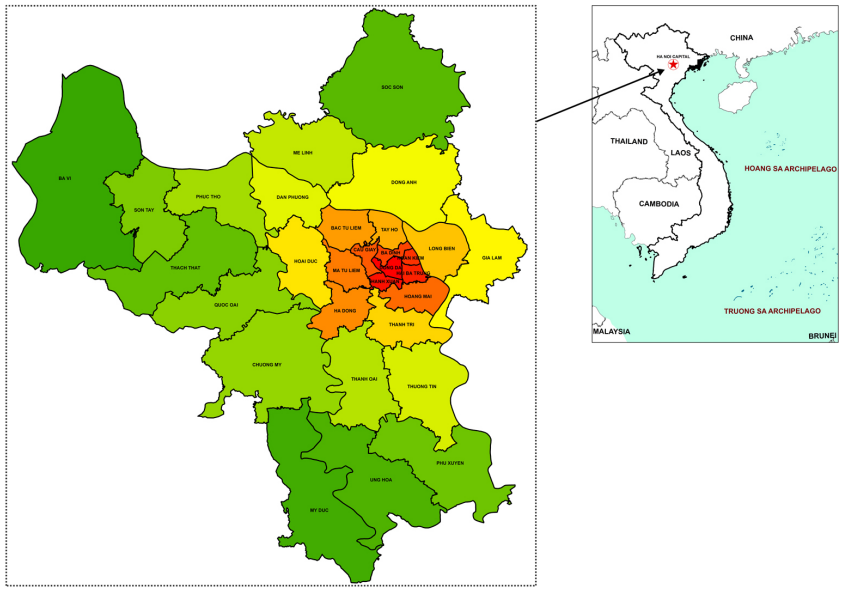

Fig. 1. Location of Hanoi City, Vietnam

For construction projects in Hanoi city, the payment and disbursement according to the construction progress by the end of 2022 is still low, reaching 29.3% of the original plan. This rate is considered lower than the national average. Therefore, Hanoi city is classified into the group of provinces and cities with the lowest disbursement rate in the country. Among the investors who are allocated large investment capital but the disbursement rate is low, the Management Board of Investment Projects for Construction of Technical and Agricultural Infrastructure (20.8%), the Management Board of Urban Railways Hanoi (18.5%), Dong Anh District People's Committee (27.2%), Hoai Duc District People's Committee (23.0%), Ung Hoa District People's Committee (18.2%). Especially, there are four big investors that have not yet disbursed the allocated capital of the government.

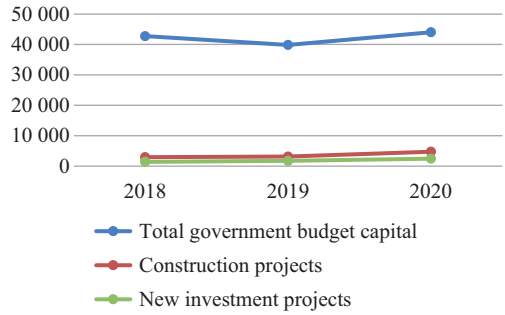

Fig. 2. Total investment capital over the years (billion VND) [1]

Implementation progresses of many projects are currently behind planned schedules, including: the pilot urban railway project in Hanoi city, the section Nhon – Hanoi Railway Station, the project to build the Ring 2 elevated road. Vinh Tuy bridge axis – Nga Tu So intersection, Hanoi Children's Palace project, urban railway project No. 2 Nam Thang Long – Tran Hung Dao section, Water supply project to improve and restore Tich River in Ba Vi, and so on. Projects that are behind schedule are a loss of resources and a waste of public investment. Hanoi has made public and transparent processing information for projects behind schedule. The causes of slow progress are being actively explored to handle and have appropriate solutions. Within the scope of the research, the authors will explore the causes affecting the progress of the construction project implementation phase.

2. Literature reviews

2.1. Related studies

Time is an index that is easily measured and is remembered frequently by the more involved in the project. Based on the schedule plan, resources are mobilized and coordinated with each other. Therefore, the schedule is a closely binding condition between the parties in the project and is often the source of conflicts during project implementation. Studies on projects' progress schedules have been interested in the world and are gradually gaining more attention in Vietnam. It is possible to mention the studies of Vijayalaxmi and Khan [2] evaluating the factors affecting the time in construction projects. Bajjou and Chafi [3] stated that delay is a common problem in construction projects. Yang and Ou [4] using SEM model clearly shows the correlation between the main causes of delay in construction investment projects. In another aspect, Memon, et al. (2010) [5] find the relationship between schedule and cost, the causes of increased costs often have a direct impact on progress before affecting costs. Aziz and Hakam [6] lists 293 causes of project delay, but only 20 main causes come from contractors and consultants that need attention and improvement. Mahamid [7] refers to the main factors affecting the time deviation in construction investment projects such as late payment by owners, changes in construction laws. The authors discrete simulation is applied to evaluate feasible

solutions in terms of schedule robustness with many causes affecting the schedule. Some studies consider time with as blurr variable in schedule planning. McCahon [8] considers time as triangular blurr numbers. Using blurr set theory, the author finds a difference in the expected project completion time and the actual completion time. Ökmen and Öztaş [9] argue that construction activities are carried out under uncertain conditions, so the duration of the works is blurr information. Chanas and Zielinski [10] suggest using blurr critical path in schedule based on work activities with uncertain information. It also added that there are causes that directly affect progress, but sometimes have an indirect impact on progress. Vu [11] and Tai [12] collect influence factors on cost overruns in construction projects. Result of influence factors make the schudule delayment.

In Vietnam, studies on construction projects' progress schedules have been interested for researchers. It is to include Tai [12] summarizing 31 factors affecting the completion progress of public investment projects in general. Toan [13] shows that capital management and progress are issues that strongly affect the ability to complete construction projects using public investment capital. Bang [14] uses a fuzzy set to clarify input information when planning the progress of construction investment projects. Through the research studied, it can be seen that:

1. Progress schedules are an important aspect in any type of construction investment project;
2. Causes affecting progress schedules can come from parties inside the project or from outside the project and will increase if the causes affecting the progress are not properly assessed. The main causes affecting progress schedules of construction investment projects are recorded in Table 3;
3. There has not been any research to thoroughly investigate the factors affecting progress schedules of construction investment projects using public investment capital in Hanoi. The authors study the factors affecting progress schedules, not to rank the factors, but to find out how these factors affect progress schedules;
4. With the ability to solve problems without certain information, fuzzy set theory has the ability to describe progress schedules with fluctuations in the execution of construction projects. Sometimes fuzzy set theory helps to collect information of progress schedules more objectively.

2.2. F-AHP method

F-AHP traditional method (Fuzzy Analytic Hierarchy Process) was developed from AHP (Analytical Hierarchy Pricess) with the integration of fuzzy numbers to effectively deal with the fuzziness of data related to decision making. The F-AHP method has overcome some limitations of the traditional AHP method, so this method is increasingly used by many researchers in practice.

AHP method. AHP method (Analytical Hierarchy Pricess) also known as hierarchical analysis. The AHP method is used to solve unstructured problems in economic, social and management science activities. The AHP methodology helps with complex multi-criteria decision-making problems. AHP enables decision makers to bring together the expertise of subject matter experts, combining objective and subjective data within a logical hierarchical

framework. AHP helps to classify the relative priority for the options, the problem is given based on a scale. This scale is based on the judgment of the decision maker and the importance of those judgments, as well as the consistency in comparing alternatives in the decision-making process. AHP combines both qualitative and quantitative aspects of human thinking. Qualitative through hierarchical arrangement and quantitative through the result set of weights for each hierarchical factor. Three principles when implementing the AHP method: (1) Analyze the decision-making problem (build a hierarchical structure); (2) Comparative evaluation of components (pair comparison of factors); and (3) Aggregate priorities (determine weight matrices).

Fuzzy set theory. The important feature of fuzzy set theory is that it proposes to use membership functions and then fuzzy operations to deal with "uncertain" or incomplete information, whose accuracy is only limited. recognize their relationships with each other, which in many cases can only be described in linguistic terms to make accurate decisions. A fuzzy set is a set whose boundaries are not clear or ambiguous. In a fuzzy set, the membership function is used to represent the membership level of an element. The membership function of a blurr set F over the sum set X denoted μF is determined by: μF: $X > [0, 1]$, where $\mu F(t)$ is the degree of membership of the element t of the set X up a fuzzy set F. A fuzzy number is whose membership function must satisfy the condition that it is continuous and convex. A fuzzy set is said to be normal if there exists a value t such that $\mu F(t) = 1$. There are many different types of fuzzy numbers, but triangular fuzzy numbers are often applied because of simple calculations and easy data processing.

The construction projects at large are notorious for their susceptibility to the volatile conditions of their implementation. The progress schedule is very sensitive to the data that are used in the analysis [15]. Most the progress schedule is used in the construction industry which assume that process durations are deterministic. This assumption is acceptable if actions are taken to reduce the impact of random phenomena or if the impact is low [16]. However, a considerable number of causes affecting progress shcedule have been found and they can be considered as fuzzy variables in schedule planning (Fig. 3).

$$\mu F(t) \begin{cases} 1 - \dfrac{\alpha - t}{\alpha} & \text{if } a - \alpha \le t \le a \\ 1 - \dfrac{\alpha - t}{\beta} & \text{if } a \le t \le a + \beta \\ 0 & \text{for other cases} \end{cases} \tag{2.1}$$

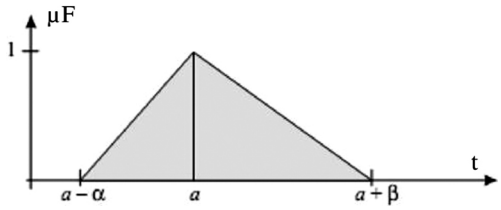

Fig. 3. Triangle fuzzy number

In order to obtain research objectives, the author decise to use the F-AHP method with triangular fuzzy numbers. It is due to following reasons as:

- Experts' assessment of the causes affecting progress schedules for construction projects in Hanoi city using linguistic terms will reveal the nature of the problem rather than assigning them to values on a numerical scale. Linguistic phrases will be coded based on triangular fuzzy numbers to ensure objectivity in expert assessment.
- The causes affecting the progress of construction projects in Hanoi city are compared within a logical hierarchical framework. AHP helps to calculate priority for each cause based on a scale.
- By using F-AHP to some extent, the relationship between the causes is taken into account. The weight of each cause is measured on the relationship of the pairs of causes to each other.

Objective of the paper is to rank and to assess causes affecting implementation progresses of construction projects using public investment capital in Hanoi city. The F-AHP method is applied in the study to take advantages: (1) Rank causes affecting progress schedules based on the relative priority of the causes; (2) Ensure the objectivity of the expert's assessment.

3. Research methodology

To achieve the purpose and expected results, the authors have taken steps to carry out the research sequentially as follows: (1) Synthesize and classify the causes affecting the construction progress in the area. Hanoi City; (2) Establish hierarchical structure; (3) Building the fuzzy pair comparison matrix; (4) Carrying out data collection surveys; (5) Processing and synthesizing data; (6) De-fuzzy; (7) Calculation of weights; (8) Evaluate data consistency; and (9) Conclusion.

(1) Summarize and classify the causes affecting the construction progress in Hanoi city – The causes affecting the implementation progress of construction projects in Hanoi city are collected through reports and official websites of the Hanoi city's Department of Construction and the Ministry of Construction of Vietnam and synthesis through relevant studies. A group of ten experts was assembled to name and categorize the causes in a uniform way. Criteria for selecting experts:
   - Currently they are owners, contractors, and consultants who is participating in the implementation of a construction project using public investment capital in Hanoi.
   - At least seven years of experience working in construction projects in Hanoi city
   - Have a university degree or higher
   - Enthusiastic and willing to participate in answering the questionnaire.

   The results of expert consultation were obtained for the following reasons as in Table 2.

(2) Set up the hierarchical structure – The research problem is divided into three levels including:
   - Level 1 – Research objectives are the causes affecting progress schedules of construction projects in Hanoi city.

– Level 2 – Grouping factors affecting progress schedules according to experts' opinion, including Group of causes related to investment capital, Group of causes related to NT, Group of causes related to phytoplankton, Group of other causes. Corresponding to the 2nd order cause will be the 1st order matrix.
– Level 3 – Specific causes affecting progress. Corresponding to the 3rd degree causes will be the 2nd order matrices.

(3) Constructing a fuzzy pair comparison matrix – The fuzzy pairwise comparison matrix is built based on survey data, but this result has been fuzzyed according to the scale of Table 1. In that scale, the fuzzy coefficient is automatic, taken by 1 according to Saaty's scale. The notation for a fuzzy pair comparison matrix is J, which is made up of j_{ij} triangular fuzzy numbers as follows:

$$\overline{j} = (\overline{J}_{ij})_{n\times m} = \begin{bmatrix} \overline{j}_{11} & \overline{j}_{12} & \cdots & \overline{j}_{1n} \\ \overline{j}_{21} & \overline{j}_{22} & \cdots & \overline{j}_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ \overline{j}_{n1} & \overline{j}_{n2} & \cdots & \overline{j}_{nn} \end{bmatrix} \tag{3.1}$$

(4) Carry out data collection surveys – There are many ways to determine the survey sample size. To simplify the process while still ensuring reliability, the authors use the method of determining the sample size according to Hair [16]. The ratio of observations on an analyte variable is 5:1, ensuring 95% confidence. After Step 1, 20 causes (Table 1) were detected corresponding to 20 observed variables. Thus, the minimum sample size = $20 \cdot 5 = 100$. Data collection method is direct interview survey.

(5) Processing and synthesizing data: Data processing is done with the support of Excel software. Expert opinions are blurred prior to synthesis. The matrix is created by triangular fuzzy numbers [16], the calculation of the sum of triangular fuzzy numbers is as follows:

$$\overline{J}_{ij} = (l_{ij}, m_{ij}, u_{ij}); \quad l_{ij} \le m_{ij} \le u_{ij}; l_{ij}, m_{ij}, u_{ij} \in \left[\frac{1}{9}, 9\right] \tag{3.2}$$

$$l_{ij} = \sqrt[n]{\prod_{1}^{n} l_{ijk}}$$

$$m_{ij} = \sqrt[n]{\prod_{1}^{n} m_{ijk}}$$

$$u_{ij} = \sqrt[n]{\prod_{1}^{n} u_{ijk}}$$

(6) De-fuzzy – To return to the AHP pairwise comparison matrix and be computable, it is necessary to convert the fuzzy numbers (l_{ij}, m_{ij}, u_{ij}) into real numbers [15] proposed to use the α-cut and λ index to indicate the level of confidence and attitude with the survey criteria. The α-cut index has a value from 0 to 1. The closer the α-cut index is to 1, the more confident the respondent is. λ has a value from 0 to 1, getting closer to 1

Table 1. Scale [16]

Value	AHP scale (l, m, u)	Definition	Explanation
1	(1 ,1 ,1)	Equal influence	The influence of two factors is the same
2	(1, 2, 3)	Between level 1 and level 3	
3	(2, 3, 4)	Moderate influential	The factor under consideration has moderate influence compared to the rest of the factors
4	(3, 4, 5)	Between level 3 and level 5	
5	(4, 5, 6)	Quite influential	The factor under consideration is quite influential compared to the other factors
6	(5, 6, 7)	Between level 5 and level 7	
7	(6, 7, 8)	Very influential	The factor under consideration is very influential compared to the other factors
8	(7, 8, 9)	Between level 7 and level 9	
9	(8, 9, 9)	Extremely influential	The factor under consideration is extremely influential compared to the other factors
1/x	$1/(x+1)$, $1/x$, $1/(x-1)$	AHP Scale-1	
1/9	(1/9, 1/9, 1/8)		

indicates optimism, getting closer to 0 indicates pessimism and 0.5 is normal. In this research, the author used $\alpha = 0.5$ and $\lambda = 0.5$, showing that the respondents were in a normal state, not too optimistic or pessimistic when participating in the discussion. The fuzzification ends when the fuzzy numbers have been encoded through α and λ according to the following formulas (Fig. 4).

$$J_\alpha = \begin{bmatrix} [j^\alpha_{11l}, j^\alpha_{11r}] & [j^\alpha_{12l}, j^\alpha_{12r}] & \cdots & [j^\alpha_{1ml}, j^\alpha_{1nr}] \\ [j^\alpha_{21l}, j^\alpha_{21r}] & [j^\alpha_{22l}, j^\alpha_{22r}] & \cdots & [j^\alpha_{2ml}, j^\alpha_{2mr}] \\ \cdots & \cdots & \cdots & \cdots \\ [j^\alpha_{n1l}, j^\alpha_{n1r}] & [j^\alpha_{n2l}, j^\alpha_{n2r}] & \cdots & [j^\alpha_{nml}, j^\alpha_{nmr}] \end{bmatrix} \tag{3.3}$$

$$j^\alpha_{ijl} = (m_{ijij} - l_{ij}) \cdot a + l_{ij}$$

$$j^\alpha_{ijr} = u_{ij} - (u_{ij} - r_{ij}) \cdot \alpha$$

$$j^\lambda_{ij\alpha} = \lambda \cdot j^\alpha_{ijr} + (1 - \lambda) \cdot j^\alpha_{ijl}; \quad \lambda \in [0, 1] \tag{3.4}$$

$$J^\lambda_\alpha = \begin{bmatrix} j^\lambda_{11\alpha} & j^\lambda_{12\alpha} & \cdots & j^\lambda_{1n\alpha} \\ j^\lambda_{21\alpha} & j^\lambda_{22\alpha} & \cdots & j^\lambda_{2n\alpha} \\ \cdots & \cdots & \cdots & \cdots \\ j^\lambda_{n1\alpha} & j^\lambda_{n2\alpha} & \cdots & j^\lambda_{nn\alpha} \end{bmatrix}$$

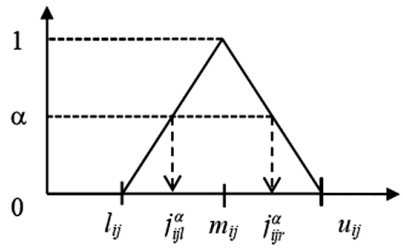

Fig. 4. α-cut index and triangle fuzzy number [16]

(7) Calculate the weight: After deblurrication, the weight calculation is carried out according to the AHP method. The calculation steps are as follows:
   – Step 1 – Sum the columns.
   – Step 2 – Divide each value in the matrix by the sum of the column corresponding to that value, then sum the rows.
   – Step 3 – The calculated value is divided by the total number of criteria of the matrix which is the weight of the criteria to be found.

(8) Assest data consistency – In the AHP pairwise comparison technique, it is necessary to consider the consistency of the data, or in other words, the consistency of the respondents' evaluations during the survey. This requirement is expressed through the most proportional CR. Determine the CR consistency ratio according to the formulas below:

$$CR = \frac{CI}{RI} \tag{3.5}$$

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{3.6}$$

which: *CI* is the consistency index, n is the matrix size, $\lambda_{\max}$ = Max (n)
RI is the random index. *RI* is a consistency index determined from a completely arbitrary matrix of randomly selected elements. By experimental method, Saaty determined the RI values (Table 2) for the n-level comparison matrices.
CR is the consistency coefficient

Table 2. Value of random index (*RI*)

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49

CR coefficient less than 10% is successful. If a $CR > 10\%$ indicates that the respondent's assessment is inconsistent, the data collection process should be repeated.

(9) Conclusion – After the data is evaluated to be consistent, the new weights are calculated to ensure reliability to draw conclusions about the causes affecting the progress of construction projects in Hanoi.

4. Data analysis and finding results

4.1. Causes affecting progress schedules of construction projects funded by state capital in Hanoi city

The main reasons affecting the construction progress of projects in Hanoi are summarized in Table 3.

Table 3. Main delay causes on progress schedules of construction projects

No	2nd reason	3rd reason	
1	Owner (A1)	A11	Late payment from the owners to related parties upon completion of work
2		A12	Late decision-making from the owners when there are incidents or irregularities on the construction site
3		A13	Late handover from the owners of construction site
4		A14	Late acceptance from the owners of completed work
5		A15	Late provision from the owners of documents to stakeholders or the documents provided are not as expected
6	Contractos (A2)	A21	The capacity of the constractors, the ability to meet the resources of the constractors
7		A22	The construction schedule is not reasonable
8		A23	Management capacity of the construction unit, lack of experience in applying new technology in construction
9		A24	Major owner manages minor owner through through a loose contract
10		A25	Inefficient use of construction equipment from the contractor
11		A26	Labor productivity of workers is lower than prescribed
12		A27	Change the source of supplies and materials to ensure the quality of the work
13		A28	There is no design of occupational safety measures in project construction
14	Consultants (A3)	A31	The details in the design documents are not clear or the design details are not suitable with the actual construction conditions
15		A32	Poor management and expertise of supervisors
16		A33	The geological survey is sketchy and inaccurate
17	Others (A4)	A41	Adverse weather conditions
18		A42	There are no binding conditions in the contract to motivate contractors to complete the work early
19		A43	Legal documents change over time
20		A44	Late delivery from the material supply facility unit

4.2. Survey results

The authors conducted surveys at construction projects in Hanoi city. Of which, the total number of distributed ballots is 235, the total number of votes collected is 215, the total number of valid votes is 205 (Fig. 5).

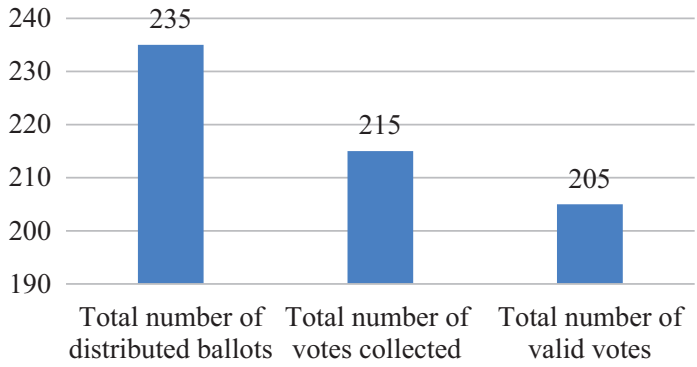

Fig. 5. Summary of survey questionnaires

Regarding the survey participants, managers accounted for 31% of the votes, technical staff accounted for 28% of the votes and support staff and advisors accounted for 26% of the votes (Fig. 6).

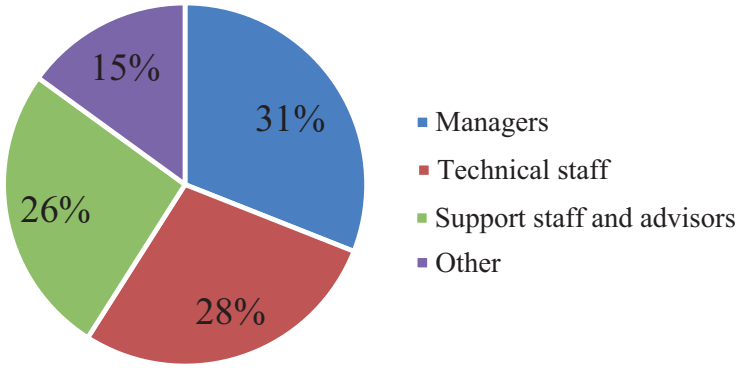

Fig. 6. Survey participants

Regarding work experience, respondents are mainly those with more than 7 years of work experience, accounting for the highest percentage (56%), those with 5–7 years of work experience accounting for 34%, those with experience from 3–5 years accounts for 10% and no respondents have less than 3 years of experience (Fig. 7). The respondents, the majority of them have work experience equivalent to a certificate of type 2 or higher. This shows that the information collected from the survey is objective and has high practical value.

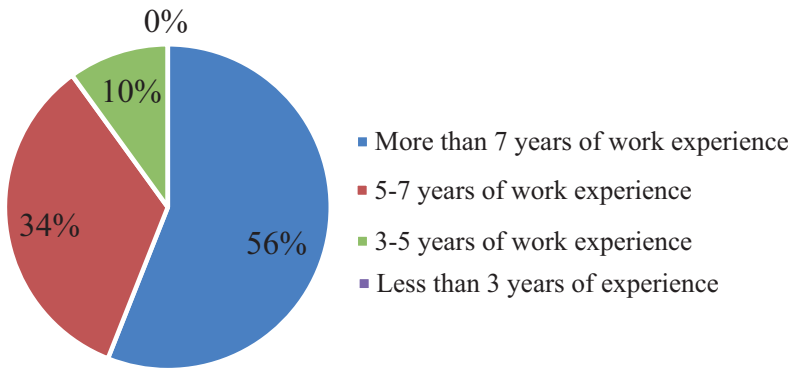

Fig. 7. Respondent's experience

With 205 valid votes, the author conducts data processing to prepare for the next analysis steps. About the project participants: accounted for 30.24% of the respondents working at the investor, 31.71% of the respondents were from consulting units and 38.05% of the respondents were from the private sector contractors (Fig. 8). The proportion of parties in the project participating in the survey is quite even according to the plan.

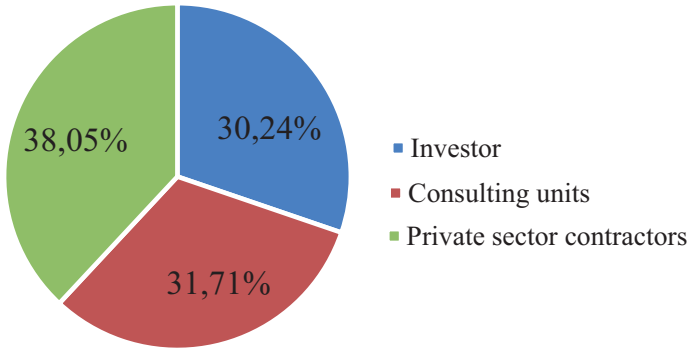

Fig. 8. Project participants

4.3. Data analysis

(1) Level 1 matrix results comparing level 2 causes. Level 1 matrix comparing level 2 causes includes 4 comparative criteria, which are 4 groups of causes that are A1, A2, A3 and A4:

– The result of level 1 matrix fuzzification.

Table 4. The result of level 1 matrix fuzzification

	A1			A2			A3			A4		
A1	1.00	1.00	1.00	2.88	2.89	2.88	1.46	1.66	1.28	3.96	3.77	2.79
A2	0.35	0.35	0.35	1.00	1.00	1.00	1.80	1.80	2.68	3.70	3.79	3.77
A3	0.78	0.60	0.68	0.37	0.56	0.56	1.00	1.00	1.00	3.19	3.14	4.90
A4	0.36	0.27	0.25	0.27	0.26	0.27	0.20	0.32	0.31	1.00	1.00	1.00

– Result of level 1 matrix deblurrication

Table 5. The result of level 1 matrix fuzzification

	A1		A2		A3		A4	
A1	1.00	1.00	2.89	2.89	1.56	1.47	3.87	3.28
A2	0.35	0.35	1.00	1.00	1.80	2.24	3.75	3.78
A3	0.68	0.64	0.45	0.56	1.00	1.00	3.17	4.02
A4	0.30	0.26	0.26	0.27	0.25	0.32	1.00	1.00

– Level 1 composite matrix

Table 6. The result of level 1 composite matrix fuzzification

	A1	A2	A3	A4	Weight
A1	1.00	2.89	1.52	3.57	0.42
A2	0.35	1.00	2.02	3.76	0.28
A3	0.66	0.50	1.00	3.59	0.23
A4	0.28	0.27	0.28	1.00	0.08

– Determination of *CR* rate

Table 7. Consistency rate results for matrix level 1

Weighted sum value	Criteria Weights	Consistency vector	Lamda max	*CI*	*RI*	*CR*
1.842	0.418	4.406	4.235	0.078	0.890	0.088
1.179	0.275	4.281				
0.927	0.226	4.101				
0.334	0.080	4.152				

CR = 0,088 <10% thus ensuring the consistency of the respondents' responses. Weights calculated for admitted grade 1 causes.

(2) The result of the corresponding level 2 matrix comparing the level 3 causes. The corresponding level 2 matrix comparing level 3 causes includes matrices A1, A2, A3 and A4. Matrix A1 includes 5 comparison criteria: A11, A12, A13, A14 and A15:

– A1 matrix blur results

Table 8. The result of A1 matrix fuzzification (causes by the owner)

	A11			A12			A13			A14			A15		
A11	1.00	1.00	1.00	2.31	2.72	2.98	3.51	4.21	4.96	3.77	4.58	5.36	2.16	2.43	2.97
A12	0.34	0.37	0.43	1.00	1.00	1.00	2.25	2.53	3.21	1.57	1.59	1.86	1.21	1.35	1.69
A13	0.20	0.24	0.28	0.31	0.40	0.44	1.00	1.00	1.00	1.95	1.37	1.45	1.19	1.12	1.19
A14	0.19	0.22	0.27	0.54	0.63	0.64	0.69	0.73	0.51	1.00	1.00	1.00	1.09	1.01	1.57
A15	0.34	0.41	0.46	0.59	0.74	0.83	0.84	0.89	0.84	0.64	0.99	0.92	1.00	1.00	1.00

– Defuzzification Matrix A1

Table 9. The result of A1 matrix fuzzification (causes by project owners)

	A11		A12		A13		A14		A15	
A11	1.00	1.00	2.52	2.85	3.86	4.59	4.18	4.97	2.30	2.70
A12	0.35	0.40	1.00	1.00	2.39	2.87	1.58	1.73	1.28	1.52
A13	0.22	0.26	0.35	0.42	1.00	1.00	1.66	1.41	1.16	1.16
A14	0.20	0.24	0.58	0.63	0.71	0.60	1.00	1.00	1.05	1.29
A15	0.37	0.44	0.66	0.78	0.87	0.87	0.78	0.95	1.00	1.00

– Composite Matrix A1

Table 10. The result of A1 matrix fuzzification (causes by project owners)

	A11	A12	A13	A14	A15	Weight
A11	1.00	2.68	4.22	4.57	2.50	0.44
A12	0.37	1.00	2.63	1.65	1.40	0.20
A13	0.24	0.38	1.00	1.54	1.16	0.12
A14	0.22	0.61	0.65	1.00	1.17	0.11
A15	0.40	0.71	0.87	0.85	1.00	0.13

– Determination of *CR* index

Table 11. Result of A1 matrix consistency index (causes by project owners)

Weighted sum value	Criteria Weights	Consistency vector	Lamda max	*CI*	*RI*	*CR*
2.305	0.444	5.193	5.133	0.033	1.110	0.030
1.040	0.200	5.203				
0.615	0.121	5.101				
0.554	0.109	5.070				
0.645	0.126	5.100				

$CR = 0.030 < 10\%$ thus ensuring the consistency of the respondents' responses. Weights calculated for owner-related causes are acknowledged.

(3) A2 matrix results
A2 matrix includes 8 comparison index: A21, A22, A23, A24, A25, A26, A27 and A28:

– The result of A2 matrices fuzzification

Table 12. The result of A2 matrix fuzzification (causes by project owners)

	A21			A22			A23			A24		
A21	1.00	1.00	1.00	2.29	2.88	2.58	1.79	1.20	1.80	1.67	1.22	1.55
A22	0.39	0.35	0.44	1.00	1.00	1.00	3.90	4.98	3.99	1.47	1.53	1.42
A23	0.56	0.83	0.56	0.25	0.20	0.26	1.00	1.00	1.00	1.68	1.96	1.78
A24	0.65	0.82	0.60	0.70	0.65	0.68	0.56	0.51	0.60	1.00	1.00	1.00
A25	0.38	0.37	0.36	0.39	0.42	0.41	0.40	0.40	0.39	0.37	0.36	0.40
A26	0.40	0.41	0.35	0.44	0.38	0.39	0.26	0.27	0.29	0.38	0.42	0.35
A27	0.41	0.46	0.45	0.43	0.35	0.42	0.41	0.36	0.43	0.37	0.40	0.50
A28	0.25	0.30	0.31	0.39	0.33	0.28	0.38	0.42	0.45	0.26	0.25	0.29
	A25			A26			A27			A28		
A21	2.79	2.67	2.61	2.85	2.44	2.49	2.24	2.19	2.45	3.26	3.38	3.99
A22	2.44	2.39	2.56	2.58	2.61	2.27	2.39	2.88	2.32	3.55	3.06	2.56
A23	2.57	2.50	2.51	3.44	3.71	3.90	2.33	2.78	2.45	2.21	2.37	2.61
A24	2.49	2.78	2.70	2.84	2.39	2.64	2.02	2.50	2.73	3.47	3.98	3.87
A25	1.00	1.00	1.00	2.89	2.89	2.39	3.40	4.63	4.93	2.34	2.27	2.21
A26	0.42	0.35	0.35	1.00	1.00	1.00	0.76	1.70	1.49	2.37	2.39	2.52
A27	0.20	0.22	1.32	0.67	0.59	1.32	1.00	1.00	1.00	2.50	1.41	1.23
A28	0.45	0.44	0.43	0.40	0.42	0.42	0.81	0.71	0.40	1.00	1.00	1.00

– A2 matrix fuzzification results

Table 13. A2 matrix blurrication results (causes by contractors)

	A21		A22		A23		A24		A25		A26		A27		A28	
A21	1.00	1.00	2.59	2.73	1.50	1.50	1.45	1.39	2.73	2.64	2.65	2.47	2.22	2.32	3.32	3.69
A22	0.37	0.39	1.00	1.00	4.44	6.48	1.50	1.48	2.42	2.48	2.60	2.44	2.64	2.60	3.31	2.81
A23	0.67	0.67	0.15	0.23	1.00	1.00	1.82	1.87	2.54	2.51	3.58	3.81	2.56	2.62	2.29	2.49
A24	0.72	0.69	0.68	0.67	0.53	0.55	1.00	1.00	2.64	2.74	2.62	2.52	2.26	2.62	3.73	3.93
A25	0.38	0.37	0.40	0.41	0.40	0.39	0.36	0.38	1.00	1.00	2.89	2.64	4.02	4.78	2.31	2.24
A26	0.41	0.38	0.41	0.39	0.26	0.28	0.40	0.38	0.38	0.35	1.00	1.00	1.23	1.60	2.38	2.46
A27	0.43	0.45	0.38	0.38	0.38	0.39	0.38	0.44	0.21	0.25	0.63	0.81	1.00	1.00	1.96	1.32
A28	0.27	0.30	0.36	0.30	0.40	0.44	0.25	0.27	0.45	0.43	0.41	0.42	0.76	0.51	1.00	1.00

– A2 composite matrix

Table 14. Results of the A2 composite matrix (causes by the contractor)

	A21	A22	A23	A24	A25	A26	A27	A28	Weight
A21	1.00	2.66	1.50	1.42	2.69	2.56	2.27	3.50	0.21
A22	0.38	1.00	5.46	1.49	2.45	2.52	2.62	3.06	0.21
A23	0.67	0.18	1.00	1.85	2.52	3.69	2.59	2.39	0.16
A24	0.71	0.67	0.54	1.00	2.69	2.57	2.44	3.83	0.15
A25	0.37	0.41	0.40	0.37	1.00	2.77	4.40	2.27	0.11
A26	0.39	0.40	0.27	0.39	0.36	1.00	1.41	2.42	0.07
A27	0.44	0.38	0.39	0.41	0.23	0.71	1.00	1.64	0.06
A28	0.29	0.33	0.42	0.26	0.44	0.41	0.61	1.00	0.04

– Determination of *CR* index

Table 15. A2 matrix consistency coefficient results (contractor causes)

Weighted sum value	Criteria Weights	Consistency vector	Lamda max	*CI*	*RI*	*CR*
1.951	0.213	9.162	8.894	0.128	1.400	0.091
2.073	0.208	9.958				
1.379	0.156	8.867				
1.290	0.147	8.762				
0.927	0.108	8.567				
0.558	0.067	8.384				
0.495	0.058	8.519				
0.386	0.043	8.932				

CR = 0.091 < 10% thus ensuring the consistency of the respondents' responses. Weighted calculations for recognized contractor-related causes.

(4) A3 matrix results

A3 matrix includes 3 comparison indexes: A31, A32 and A33:

– A3 matrix fuzzification results

Table 16. A3 matrix fuzzification results (causes by contractors)

	A31			A32			A33		
A31	1.00	1.00	1.00	2.11	2.51	2.64	1.80	1.77	1.99
A32	0.38	0.40	0.47	1.00	1.00	1.00	1.98	1.65	1.71
A33	0.50	0.56	0.56	0.58	0.61	0.51	1.00	1.00	1.00

– A3 matrix fuzzification results

Table 17. A3 matrix fuzzification results (causes by contractors)

	A31		A32		A33	
A31	1.00	1.00	2.31	2.58	1.79	1.88
A32	0.39	0.43	1.00	1.00	1.82	1.68
A33	0.53	0.56	0.60	0.55	1.00	1.00

– A3 composite matrix

Table 18. A3 composite matrix results (causes by the consultant)

	A31	A32	A33	Weight
A31	1.00	2.44	1.83	0.51
A32	0.41	1.00	1.75	0.28
A33	0.55	0.57	1.00	0.21

– *CR* index determination

Table 19. A3 composite matrix results (causes by the consultant)

Weighted sum value	Criteria Weights	Consistency vector	Lamda max	*CI*	*RI*	*CR*
1.582	0.507	3.121	3.080	0.040	0.520	0.077
0.860	0.280	3.072				
0.650	0.213	3.047				

$CR = 0.077 < 10\%$ thus ensuring the consistency of the respondents' responses. Weights calculated for causes related to the recognized consultant.

(5) A4 matrix results

A4 matrix includes 4 comparison index: A41, A42, A43 and A44:

– A4 matrix fuzzification results

Table 20. A4 matrix fuzzification results (other causes)

	A41			A42			A43			A44		
A41	1.00	1.00	1.00	1.67	1.89	2.12	2.56	3.22	4.17	2.86	3.31	4.53
A42	0.47	0.53	0.60	1.00	1.00	1.00	1.88	2.68	2.38	1.65	2.80	2.61
A43	0.24	0.31	0.39	0.42	0.37	0.53	1.00	1.00	1.00	1.78	1.56	1.80
A44	0.22	0.30	0.35	0.38	0.36	0.61	0.56	0.64	0.56	1.00	1.00	1.00

– A4 matrix defuzzification results

Table 21. A4 matrix fuzzification results (other causes)

	A41		A42		A43		A44	
A41	1.00	1.00	1.78	2.01	2.89	3.70	3.09	3.92
A42	0.50	0.56	1.00	1.00	2.28	2.53	2.23	2.71
A43	0.27	0.35	0.40	0.44	1.00	1.00	1.67	1.68
A44	0.26	0.32	0.37	0.45	0.60	0.60	1.00	1.00

– A4 composite matrix

Table 22. A3 composite matrix results (other causes)

	A41	A42	A43	A44	Weight
A41	1.00	1.89	3.29	3.50	0.46
A42	0.53	1.00	2.41	2.47	0.28
A43	0.30	0.42	1.00	1.68	0.15
A44	0.29	0.41	0.60	1.00	0.11

– *CR* index determination

Table 23. A4 matrix consistency index results (other causes)

Weighted sum value	Criteria Weights	Consistency vector	Lamda max	*CI*	*RI*	*CR*
1.865	0.460	4.058	4.040	0.013	0.890	0.015
1.151	0.283	4.061				
0.589	0.147	4.018				
0.444	0.110	4.023				

CR = 0,015 <10% thus ensuring the consistency of the respondents' responses. Weights calculated for other causes are assumed.

5. Assess causes affecting progress schedules of construction projects funded by state budget in Hanoi city

From the analysis with level 1 weights, it is shown that the group of causes related to the investor has the highest influence during the implementation of the construction project, with a weight of 0.42. The next highest level of influence is the group of contractor-related

causes, with a weight of 0.28. Next is the group of causes related to the consulting unit, with a weight of 0.23. The group of other causes with the lowest weight of 0.08 showed the lowest degree of influence of the four groups of causes considered (Table 24). According to the opinions of survey participants, investors always play a key role in decisions related to the implementation of Hanoi construction projects. Investors hold capital and expand their role throughout the project implementation. This makes the schedule strongly influenced by investors in construction investment projects in Hanoi.

Table 24. Rating for cause groups

Rating	Names of cause group	Rating value
1	A1	0.42
2	A2	0.28
3	A3	0.23
4	A4	0.08

Compared with the results from the conducted studies, it can be seen that the investor's budget plan has a great impact on the project implementation progress in construction projects using state capital. The results on the factor of weather conditions are also evaluated similarly to the conducted studies. However, the projects implemented in Hanoi show a difference: The factors which are caused by the contractor have a clear influence on the project implementation progress from construction capacity, schedule planning, apply construction technology, manage construction, ensure the source of materials.

5.1. Causes related to project owners

Looking specifically at the causes related to the owner (Table 3), it is found that the problem of late payment and slow decision-making when there is an unusual incident in the project are the causes that strongly affect the project schedule judgment. These causes have occurred in most of the current slow-moving projects and have become more serious in some projects such as: CV1 Harmonized Lake Park project, Phung Khoang Lake Park project, construction project construction of an overpass at the intersection of Chua Boc-Pham Ngoc Thach, the project of building an overpass at the intersection of An Duong-Thanh Nien road phase 2. In addition, factors such as the owner's delay in handing over the construction site, the owner's delay in taking over the completed work, and the owner's delay in providing documents to stakeholders also occurred and affected the progress for a period of time short time, there is no lasting effect on the total progress of the project. The weight of these causes has a lower score, respectively 0.12; 0.11; 0.13. The reasons being considered are directly related to the owner's capacity and professionalism in the work. In the face of decision-making issues such as payment decisions, acceptance decisions for main construction tasks or construction phase transitions, decisions on serious construction site incidents, etc., the owner took a long time for consideration. This delay is causing great hindrance to other parties in the project and delaying the project implementation progress.

Construction project implementation phase is the most resource consuming stage. During the bidding process, contractors were required to have working capital for the project. Advance terms for projects using public investment capital are currently kept at 10-15%. With this advance, the contractor can smoothly implement the project's work. But the reality shows that contractors are heavily dependent on payment for completed works from owners. This reason leads to the late payment by the owner, which will make it difficult for the contractor to pay for the subcontractor, pay for labor and procure materials to prepare for the next work. In addition, accounting for over 80% of projects under medium-term capital, the owner's annual capital plan is approved by the subjective agency. The annual funding plan is often delayed due to many objective reasons from the governing body. This also slows down the solvency of the owner. The combination of reasons that caused the owner to delay payment to the project parties upon completion of the work has a high degree of influence on projects' progress schedules.

Table 25. The level of influence of the causes related to project owners

No	Causes	Influence weight
1	Late payment from the owner to related parties when completing the work	0.44
2	The owner makes a slow decision when there is an incident or reward on the construction site	0.20
3	Late to hand over the construction site from the owner	0.12
4	The owner is slow to take over the completed work	0.11
5	The owner provides documents late to the stakeholders or the documents provided are not as expected	0.13

5.2. Causes related to contractors

Contractor-related causes (Table 3) are more uniform than other groups. This does not represent low-impact contractor causes. It shows that the causes related to the contractor have not much difference in the level of influence when making a pairwise comparison between the causes. Therefore, contractors participating in the implementation of construction projects using public investment capital in Hanoi need to pay attention to all the reasons under consideration. In which, it is necessary to pay attention to two issues: the capacity of the contractor and the appropriate construction schedule for the project.

Regarding the construction schedule for the implementation of construction projects: The cause "Inappropriate construction schedule" has a higher weight of influence than other causes. According to the survey participants, in projects using public investment capital, contractors in Hanoi have not paid attention to and properly assessed the role of the project's schedule. Before the contractor starts to implement the project, the contractor will submit the total progress to the supervision consultant, project management consultant and the owner for approval. After being approved, the total schedule is the basis for the parties in the project to

have an appropriate arrangement of resources and capital. Also based on the total progress, the monthly schedule and the weekly schedule are detailed. However, these schedule plans are often prepared by a technical staff member who is not yet able to cover the project and understand the contractor's ability to provide resources. The timelines for each work item are set based on the subjective judgment of the scheduler. With short-term progress plans by week, by month, delays in implementation are better controlled, but they are far from the total approved progress schedule. The schedule plan does not take into account the downtime in construction and omitting this time leads to the delay in the progress of the whole project. It should also be added that the schedule plan made by the contractor without the participation of the owner or the consultant, leads to the plans of the parties in the project not matching the actual schedule currently building the project. When there is an adjustment or change in the contractor's progress, the other parties are passive and find it difficult to control their progress schedules.

About the contractor's capacity: Along with progress schedules, the contractor needs to have the right supply of resources. Feedback from the respondents said that over 80% of projects are having problems of providing resources that are not consistent with the project implementation schedule. Over 80% of the projects recorded from the survey occurred the situation of materials and materials arriving at the construction site massively but the workers were not ready to accept the job, the construction equipment was slow to be delivered to the construction site, or the condition of the materials was not ready. Material for a job lacks one type, excess of the other leads to insufficient construction conditions, etc. The supply of human resources for the current projects is also a problem. Construction workers in Hanoi are generally assessed as hardworking people, but their compliance with the work plan is not good, and their work discipline is not appreciated. Construction workers in Hanoi and some neighboring provinces are highly dependent on foreign workers and are affected by the agricultural season. During the seasonal season (October-November crop, May-June crop),

Table 26. The level of influence of causes related to the contractor

No	Causes	Influence weight
1	The capacity of the contractors. the ability to meet the resources of the contractors	0.21
2	The construction schedule is not reasonable	0.21
3	Management capacity of the contractors. lack of experience in applying new technology in construction	0.16
4	Major contractors manages minor contractors through loose contract	0.15
5	Contractors uses construction equipment inefficiently	0.11
6	Labor productivity of workers is lower than prescribed	0.07
7	Change the source of supplies and materials to ensure the quality of the work	0.06
8	There is no design of occupational safety measures in project construction	0.04

workers are difficult to find and often have a serious reduction in the number of workers at construction sites in Hanoi. During off-season, idle labor is easier to attract for construction projects. A summary of construction sector reports [1–3] shows that in 2018, there were 176 projects that were delayed for a long time and 276 projects that had to be adjusted to the total schedule. In 2019, 68 projects were delayed for a long time and 394 projects had to adjust the total progress of construction projects. In 2020, there were 113 projects that were delayed for a long time and 82 projects had to adjust the total schedule.

Besides, the price of raw materials fluctuates unpredictably, directly affecting the construction of contractors. Many projects use public investment capital in the form of package contracts, leading to high risks for contractors. Faced with risks, some contractors choose to extend the schedule in the hope that the price of materials decreasing. This is also an issue that can be taken foreseen problem and needs to be resolved in the public investment projects.

5.3. Reasons related to consultants

Reviewing the causes related to the consultant found the cause from the design unit "Details in the design documents are not clear or the design details are not suitable with actual construction conditions" weighted more prominently than other causes (effect weight: 0.51). This also reflects the reality of current Hanoi projects. Over 90% of projects are exposed to design risks at the level of cost and schedule interventions. Errors in the design are often discovered during construction, so they are not proactive in adjusting and approving the adjusted design. This result leads to the problem that design documents play a very important role in construction projects in Hanoi. The selection of a design consultant should be carefully considered by the owner, and at the same time, strict verification and appraisal are carried out to minimize design risks, thereby avoiding negative impacts from design errors on projects' progress schedules. Reasons "Poor management and expertise in monitoring" and "Sketch and inaccurate geological survey" have lower weights, scores 0.28 and 0.21, respectively.

Table 27. The level of influence of the causes related to consultants

No	Causes	Influence weight
1	The details in the design documents are not clear or the design details are not suitable with the actual construction conditions	0.51
2	Poor management and expertise of supervisors	0.28
3	The geological survey is sketchy and inaccurate	0.21

5.4. Other causes

In the group of other causes, the cause "Unfortunate weather conditions" has a high weighted score. In recent years, climate change is taking place globally. Hanoi is also affected by this situation. The laws of the weather change in an unusual and difficult to control direction. Flooding occurs when there is heavy rain and storms occur more often. The cause of flooding

in Hanoi is analyzed largely because the water surface area and agricultural land area are gradually shrinking under the impact of rapid urbanization. In the period 2015–2020, the urban natural water surface area will decrease by 203.63 ha. Many ponds and lakes have been leveled to make land fund for urban development and technical infrastructure, the situation of people encroaching on water surface area for business and exploitation. This causes many difficulties for socio-economic development, as well as the construction sector in Hanoi. Low-base constructions are at risk of flooding, especially in the western part of Hanoi including rural areas located in green belts along river routes. From the survey, there are 5 projects that were forced to adjust the design during construction after considering the issues of climate change. Besides, progress plans in most construction investment projects in Hanoi must be adjusted more or less to adapt to climate conditions.

An issue that needs more attention in public investment projects in Hanoi is that the requirement to accelerate progress schedules is always ignored. The parties in the project are more interested in the project implementation process in accordance with the law than in promoting the project progress. The control of state management agencies through legal documents has not been synchronized and the general model has been inconsistent, which has indirectly affected the progress of construction projects. The binding of the parties on the schedule is not tight. In the contract, there is a term to complete the project, but the project progress is not specified in the contract. The regulations on rewards and penalties for delay are not mentioned or are not strong and it is difficult for the parties to handle the causes of delay.

Table 28. The influence of other causes

No	Causes	Influence weight
1	Adverse weather conditions	0.46
2	There are no binding conditions in the contract to motivate contractors to complete the work early	0.28
3	Legal documents change over time	0.15
4	The material supply facility is slow to deliver	0.11

6. Discussion

There are 20 factors that affect the progress of the Hanoi construction project which use the funded by State Budget. These are the main influencing factors during project implementation. Considering the aspects of project management content, the factors affect the progress cover all project management contents from quality, cost, design, labor safety. The causes affecte the progress schedules in countries such as Ethiopia, Egypt, and Palestine are quite similar to Vietnam in terms of content and some obtained results. The payment according to the schedule and the weak capacity of the project participants are outstanding issues that need to be solved during the project implementation in these countries as well as in Vietnam.

The outstanding feature of the construction projects which use the state budget capital is that they are strongly inspired by the legal system on public investment, especially capital regulations. The results obtained clearly reflect this feature. It also makes a difference from construction projects using other capital sources. The related studies show that the contractor is the subject that causes a lot of influence on the project progress in terms of both the number of influencing factors and the degree of impact of the factors. However, the results are recorded the projects using state budget capital in Hanoi show that the contractor causes many impacting factors, but owner is the subject cause higher influence. This also shows that the issue of capital is a very important factor, contributing significantly to the results of construction projects in Hanoi.

The progress can be seen form the implementation framework for the project. Other management contents are established on the basis of the implementation schedule progress, and at the same time they also affect the progress to change the approved schedule progress. This effect is complex and chain property. But it is very difficult to consider this interplay fully. In this study, the factors are considered under the assumption that they are independent. This is a limitation between research and practice. However, this does not affect the results of the study much.

7. Conclusions

Although the speed of construction is taking place strongly in Hanoi, however, the number of projects implemented behind schedule is increasing and serious. Based on the progress of the work, the resources are mobilized, the parties work together to promote the development of the project. The author has investigated 20 reasons that affect the progress of the Hanoi construction project. The causes are classified into four main groups. The results show that the groups of factors related to the project participants who are investors, contractors and consultants have a higher level of influence than other causes.

In order to minimize the delay and enhance the progress management in construction projects in Hanoi city, a drastic change from the project stakeholders is required. First, project parties need to pay more attention to the causes directly related to each actor. Investors need to have a clearer and more appropriate plan on capital sources and payment stages. The contractor needs to establish a detailed schedule that is feasible and reasonable, based on the calculation of the provision of resources for the project. The consulting unit considers carefully during the design, supervision and management of the project. Next, the project parties also need to recognize and actively respond to adverse weather conditions. The planning, especially the outdoor construction works, must be calculated according to the weather rules of the Northern region and weather forecast to make reasonable adjustments.

The project implementation phase is a stage that requires the participation of many parties and consumes a lot of resources. This is a complicated process. The progress considerations should be placed in each relationship with the requirements of quality, cost, contractor's ability to provide resources, ability to meet capital, risk. In the study, the factors which affect the progress are considered assuming they are independent of each other. The obtained results

are a useful but incomplete reference for the project managers who consider the management solutions suitable. An extended study should be done of all other project phases such as project preparation phase, project operation phase. This is carried out to assess better of causes affecting progress schedules on construction investment projects funded by state budget in Hanoi City.

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