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APPLICATION OF FUZZY THEORY IN SCHEDULING CONSTRUCTION PROJECTS IN THE MEKONG DELTA

FIELD OF STUDY: CIVIL ENGINEERING

CODE : **9580201**

SUMMARY OF DOCTORAL THESIS IN ENGINEERING

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INTRODUCTION

1. Reasons for choosing the topic

Over the years, due to construction and development requirements, many large construction investment projects have been approved and implemented. Thereby creating important changes in material and technical foundations, strongly promoting economic restructuring, increasing production capacity, improving urban areas, making decisive contributions to economic development, society in the process of industrialization and modernization of the country...The management and implementation of projects in recent years are still limited and weak, leading to loss and waste of investment capital, poor investment efficiency, long implementation time, and delay in progress, and reduce the quality of economic growth.

There are many reasons that cause this situation from the stage of investment preparation, investment implementation, investment supervision, acceptance and handover of works into use... The progress making and management of construction project implementation progress is based on the construction estimate norms studied and proposed by the Ministry of Construction. However, project implementation is a dynamic process and it is influenced by many of the risk factors discussed above. It is these factors that have caused many difficulties for the management and implementation of the construction project progress

Currently, studies on project scheduling also include actual factors affecting the process, but are still at a simple level due to incomplete and uncertain input data. Therefore: the calculation results do not reflect the actual results of the project. In fact, scheduling needs a suitable method and algorithm to determine the influence of these uncertain factors and provide results with high reliability, good service and practicality for project management.

Fuzzy set with the ability to handle problems with lack of information and uncertain data such as: objective and subjective risk factors that occur during construction with that basis, the use of theories, The algorithm of fuzzy set theory to design the project implementation plan will have a solid scientific basis to give high reliability predictive calculation results, thereby serving as a basis for forecasting the project implementation situation. .

Fuzzy sets have the advantage of forecasting with uncertain data such as: objective factors, subjective factors occurring during construction. This will help a lot in planning the implementation of the construction project in the Mekong Delta. For the reasons mentioned above, the PhD student selected the topic "*Application of fuzzy theory in scheduling construction projects in the Mekong Delta*".

2. Objectives of the study

Systematize and supplement theories on project implementation schedule as well as the impact of project implementation schedule on project construction investment costs in general and in the Mekong Delta in particular.

Assessing the current situation of applying fuzzy set theory in construction project implementation schedule in the Mekong Delta, identifying and measuring factors affecting the progress of construction projects in the Mekong Delta .

Proposing solutions to apply fuzzy set theory in scheduling construction projects in the Mekong Delta to limit the negative impact of project implementation progress on construction investment costs in the Mekong Delta .

3. Object and scope of the research

- Research object: Applying fuzzy set theory in scheduling construction projects in the Mekong Delta.

- Research scope:

+ Research space: Construction projects using state capital (including 3 main sources of capital: state budget, government bonds, ODA) in the Mekong Delta

+ About research time: State-funded construction projects in the Mekong Delta in the period 2009 ÷ 2020. Within the scope of the thesis, the author focuses on the project implementation phase.

+ About the research content

The project will go through 3 phases including: Project preparation phase, Project implementation phase, Construction completion phase. In which, the project implementation phase includes the following tasks: preparation of construction sites, demining (if any); Construction survey; elaboration, appraisal and approval of construction designs and

estimates; granting construction permits (for works as prescribed, a construction permit is required); selecting contractors and signing construction contracts; Construction works; supervision of construction; advance, payment of completed volume; operation, test run; acceptance test for completion of construction works; handing over the works and putting them into use and other necessary works.

4. Research Methods

- Theoretical method: analyzing and synthesizing the scientific basis based on the collected documents, applying to the assessment and prediction.

- Survey method: using the survey form to consult experts, national and regional managers to determine quantitatively the factors affecting the progress of construction projects.

- Statistical probabilistic method: synthesize data, collected information, solve probability problems as a basis for determining the membership of data when using fuzzy set theory.

- Expert method: carry out research, consult experts in the field of construction investment project management through directly and conferences and seminars as a basis for research.

- Inheritance method: refer to using research results on construction investment project management.

5. Scientific and practical significance of the topic

Scientific significance: The topic "Application of fuzzy set theory in scheduling construction projects in the Mekong Delta" is a complete and clear research work. The study contributes to perfecting the theoretical basis of fuzzy set theory in making progress of construction projects in the Mekong Delta.

Practical significance: The research can serve as a basis for organizations, individuals, and project participants to refer to, evaluate and apply in the progress of construction projects in the Mekong Delta. Applying fuzzy set theory in project implementation schedule, thereby proposing solutions suitable to actual conditions.

6. New contributions of the thesis

- Supplementing and perfecting the theoretical basis of using fuzzy theory in construction project implementation schedule.

- Determine and measure the factors affecting the progress carefully before making the schedule, so that the schedule is closely aligned with the construction conditions.

- Practical application of fuzzy theory in scheduling implementation of some typical construction projects in the Mekong Delta. Use a tool to measure influencing factors such as fuzzy theory, so that the results are objective, not imposed by the scheduler.

- Solutions to apply fuzzy theory in scheduling construction projects in the Mekong Delta, which will help investors, consultants, contractors and related units in the project, which to perfect their capacity, thereby working well together to make the project implemented on schedule.

7. The thesis structure

In addition to the introduction, conclusions, recommendations and appendices. The thesis is presented in 4 chapters, the content of each chapter is as follows:

Chapter 1: Research overview on the use of fuzzy in construction project implementation schedule

Chapter 2: Theoretical basis for making and managing progress, using fuzzy sets in making progress of construction investment projects

Chapter 3: Practical application of fuzzy set theory in scheduling implementation of some typical construction projects in the Mekong Delta

Chapter 4: Solution to apply fuzzy set theory in scheduling construction projects in the Mekong Delta.

CONTENT

In the area of construction investment management, the mechanism of construction investment management continues to be fundamentally and comprehensively innovated in order to conform to

the market mechanism, to be in line with international practices, and to meet integration requirements.

1.1.2. *Situation of construction investment in the Mekong Delta*

The plan for public investment capital in the 2016-2020 period allocated to the Mekong Delta is nearly VND 184,000 billion [2]. In which, the capital part of the Ministry of Agriculture and Rural Development deciding to invest in the Mekong Delta has a total capital of about VND 28,200 billion, accounting for about 29% of the total medium-term public investment managed by the Ministry of Agriculture and Rural Development. Construction project implementation schedule

1.2. Construction project implementation schedule

1.2.1. Introduction to construction project implementation schedule

The schedule plan is generally a solid framework for project planning, scheduling, monitoring, and control.

The schedule is always a key issue in any construction project. Scheduling has a great influence on the project, it determines the construction time to complete the work, complete the project, helping the manager to manage the construction in a scientific way. Construction progress is considered reasonable and effective when it ensures three factors: technology, organization and safety.

1.2.2.Current status of construction project progress making in the Mekong Delta

1.2.2.1. Overview of construction projects in the Mekong Delta

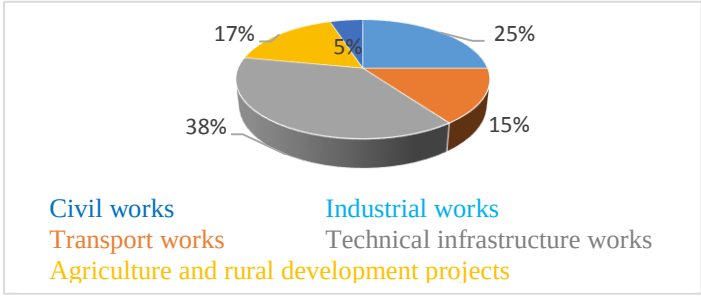


Fig. 1.1. Project division ratio

1.1.2.2. Scheduling methods:

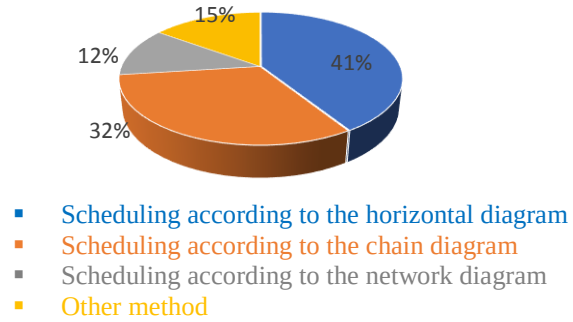


Fig. 1.2. Ratio of scheduling methods in projects

1.1.2.3. Problems exist

- The capacity of the scheduler is limited
- There are many mistakes in scheduling work
- Project progress management is not yet thorough

1.3. Factors affecting the progress of construction projects in the Mekong Delta

1.3.1.Survey results

1.3.1.1Results

The survey process took place in 7 months in 3 provinces of Can Tho, Vinh Long and Ben Tre. Through colleagues, work partners, the author has compiled a list of people who need to be surveyed, along with contact information. Next, the author conducts a face-to-face survey and sends questionnaires via email to officials who cannot meet face-to-face. After the direct investigation the data obtained. Total votes: 235 votes, total number of votes collected: 215 votes, total votes: 205 votes.

1.3.1.2.Respondent Information

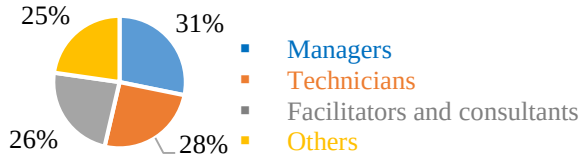


Fig. 1.1. Categorize respondents by position, years of experience

1.3.1.3.Point evaluation

Table 1.1. Point evaluation

Value range	Infulence level	Explaining
>0 ÷ ≤2	lower	No or little influence on the progress of the construction project; If the factor occurs, it is possible to determine the delay period lasting from 1 to several days, it is easy to compensate for the period of delay by proactive measures such as increasing human resources, working overtime, etc. .; factors that occur behind schedule but do not affect the progress of the next work, therefore, do not affect the overall progress of the project.
>2 ÷ ≤3	Medium	Impact on project progress is moderate; if the factor occurs, it will affect the next work, thereby affecting the overall progress of the project; The time delay lasts from 1 to a few days, but it is difficult to compensate for the delay time by proactive measures such as increasing resources, working overtime,....
>3 ÷ ≤5	high	The impact of delaying the project progress lasts from 1 to a few weeks, making it difficult to compensate for the delay time by proactive measures such as increasing resources, working overtime,....

1.3.2.Factors affecting the progress of construction projects in the Mekong Delta

On the basis of related previous studies, opinions from experts in the construction industry combined with the actual situation in the Mekong Delta, the author proposes 33 factors affecting the actual

progress of the project. Existing construction investment project. These factors include:

- Group 1: External factors
- Group 2: Factors caused by the investor
- Group 3: Factors due to contractors
- Group 4: Factors due to construction supervision consultant
- Group 5: Elements by design consultant
- Group 6: Legal factors, administrative procedures
- Group 7: Other factors

1.3.2.3.Results of assessment of factors affecting the progress of construction investment projects in the Mekong Delta

Table 1.2. Evaluation score of factors affecting the progress of construction investment projects in the Mekong Delta

Sign	Factors affecting progress	Point of influence	Conclusion
1	**External factors**		
NT1	Weather condition	2.63	Medium influence
2	**Factors caused by the investor**		
NT2	The investor is late in paying related parties when completing the work	3.41	High influence
NT3	The investor provides documents late to the stakeholders or the documents provided are not as expected	2.46	Medium influence
NT4	The investor is slow to hand over the construction site	3.86	High influence
NT5	The investor is slow to take over the completed work	2.58	Medium influence
NT6	The investor makes a slow decision when there is an incident or abnormality on the construction site	3.70	High influence
NT7	Conflicts between investors and related parties	1.00	Low influence
3	**Factors due to contractors**		
NT8	The capacity of the construction unit, the ability to meet the requirements of the construction unit	3.21	High influence
NT9	Management capacity of the construction unit, lack of experience in applying new technology in construction	3.14	High influence

Sign	Factors affecting progress	Point of influence	Conclusion
NT10	The construction unit changes subcontractors or signs contracts with many subcontractors	1.78	Low influence
NT11	Main contractor manages subcontractors through loose contracts	3.88	High influence
NT12	Contractors use construction equipment inefficiently	3.91	High influence
NT13	Labor productivity of workers is lower than prescribed	4.77	High influence
NT14	The construction unit lacks funds to implement the project	0.99	Low influence
NT15	Conflict between local people and construction unit, workers on strike	1.95	Low influence
NT16	Lack of workers working on Sundays and public holidays	1.52	Low influence
NT17	Change the supply of labor and materials to ensure the quality of the work	2.48	Medium influence
NT18	Conflicts within the construction unit	1.77	Low influence
NT19	Making an unreasonable construction project implementation schedule	4.03	High influence
NT20	There is no design of occupational safety measures in project construction	3.98	High influence
4	**Factors due to construction supervision consultant**		
NT21	Poor management and expertise of supervisors	3.99	High influence
5	**Elements by design consultant**		
NT22	The workload increased much more than the actual volume in the contract	1.04	Low influence
NT23	Design changes during construction	1.95	Low influence
NT24	The details in the design documents are not clear or the design details are not suitable with the actual construction conditions	3.90	High influence
NT25	The geological survey is sketchy and inaccurate	4.27	High influence
NT26	Design documents adjusted during construction are not completed on time	1.90	Low influence
NT27	Redo the design file due to the wrong design	1.01	Low influence

Sign	Factors affecting progress	Point of influence	Conclusion
NT28	Change the design leader or change the architect	1.37	Low influence
6	**Legal factors, administrative procedures**		
NT29	There are no binding conditions in the contract to motivate contractors to complete the work early	3.00	Low influence
NT30	Local authorities trouble and cause harassment in administrative procedures	1.79	Low influence
NT31	Legal documents change over time	3.78	High influence
7	**Other factors**		
NT32	Material prices change	1.81	Low influence
NT33	The material supply facility is slow to deliver	3.84	High influence

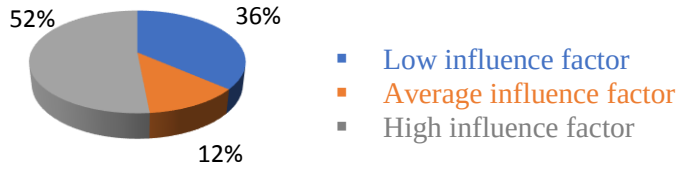


Fig. 1.5. Ratio chart of factors affecting scheduling

1.4. Using fuzzy in scheduling construction projects

1.4.1. Introduction to fuzzy sets

Learn about the fuzzy of concepts that are understood as follows:

(1) Fuzzy

A fuzzy A on a background space X is defined as follows:

$$\tilde{A} = \{(x, \mu_A(x)) \mid x \in X\}$$

(2) Number of fuzzy

A fuzzy number is a normalized convex fuzzy, the membership function of which is continuous at least at each interval, and the function has the value μA(x) = 1 at exactly one element.

1.4.2. Applications of fuzzy set theory in scheduling construction projects

+ When the input data is incorrect, fuzzy theory is considered to be more suitable for the natural form of the problem than CPM or PERT.

+ Using two methods of calculating Fuzzy PERT with the job completion time being discrete and continuous fuzzy numbers in the form of a trapezoid.

+ Apply FPNA Fuzzy Project Network Analysis method to analyze network diagrams. Using both combined and comparative methods in fuzzy number analysis to come up with an effective algorithm to solve the project dispatching problem.

+ Use fuzzy theory to evaluate factors affecting project progress through pairing fuzzy factors (F-AHP).

1.4.3.Features of fuzzy set in construction schedule implementation.

Having the capacity to solve problems without certain information, fuzzy sets are capable of describing uncertain quantities in terms of random quantities as risk factors affecting the implementation of construction projects.

1.5. Research works related to the use of fuzzy sets in construction project implementation schedule

Based on several domestic and international research, conclusions are drawn from the overview of research works related to the topic.

- Firstly, fuzzy theory has been applied to solve many different problems in terms of structure, schedule, cost, machine operation, concrete strength, calculation of earthworks....

- Second, fuzzy theory is also applied in many different types of works such as public works, industrial works, traffic works, civil works,....

- Third, the highlight of fuzzy theory is to clarify as much as possible the unclear factors in the projects.

- Fourth, the research has clearly developed and perfected the fuzzy theory applied in construction.

- Fifth, the research results have been applied and practiced in many projects and networks.

1.6. Identify research gaps and problems

The progress of construction project implementation in the

Mekong Delta has not been focused on in-depth research, and there has not been a schedule close to actual conditions.

CHAPTER 2: THEORETICAL BASIS FOR MAKING AND MANAGING PROGRESS, USING FUZZY SETS IN MAKING PROGRESS OF CONSTRUCTION INVESTMENT PROJECTS

2.1.General theory of construction project implementation schedule

2.1.1.Scientific basis:

Ruilding projects, construction project implementation progress, forms to show the progress of construction projects, requirements for making construction project implementation schedule, types of progress of construction projects, characteristics of construction project implementation progress, software to schedule construction projects.

2.1.2. Legal basis:

Regulations on management of construction investment project implementation progress, other related documents.

2.1.3.Practical basis:

International experience, domestic experience.

2.2.Fuzzy theory applied in construction

Fuzzy theory has been applied to solve many problems in construction, such as: Fuzzy technical economics; Fuzzy inventory management; Plan the location and layout of the translucent floor; Fuzzy decision making; Some other applications in construction

2.3.Fuzzy theory application in project implementation schedule

2.3.1.Fuzzy theory in scheduling construction projects:

Triangular fuzzy numbers were used to calculate progress-affecting multipliers in this study.

$$A(t) = \begin{cases} 1 - \dfrac{\alpha - \tau}{\alpha} \; if \; \text{a} - \alpha \leq \text{t} \leq \text{a} \\ 1 - \dfrac{\alpha - \tau}{\beta} \; \text{if} \; a \leq \text{t} \leq \text{a} + \beta \\ 0 \text{ other case} \end{cases}$$

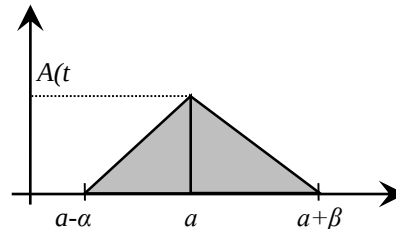


Fig. 2.1. Triangular fuzzy numbers [19]

$$A(t) = \begin{cases} 1 - \frac{\alpha - \tau}{\alpha} \; \text{if a} - \alpha \leq \text{t} \leq \text{a} \\ 1 - \frac{\alpha - \tau}{\beta} \; if \; b \leq \text{t} \leq \text{b} + \beta \\ 0 \text{ other case} \end{cases}$$

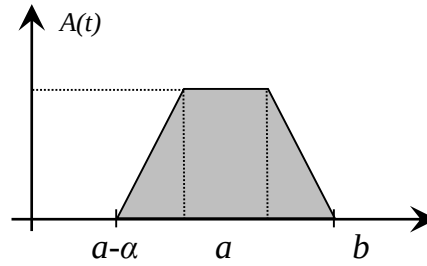


Fig. 2.2. Trapezoidal fuzzy number [19]

2.3.2.AHP method:

The AHP method enables decision makers to assemble experts' knowledge of the research problem and to combine both objective and subjective data within a logical hierarchical context.

2.3.3.F-AHP method:

The F-AHP method is developed from the traditional AHP one with the integration of fuzzy numbers in order to effectively solve the fuzziness of data related to decision making.

2.4.Research framework for the implementation of the thesis

2.4.1.Research framework:

The study was conducted in 5 steps. Each step will employ different research methods.

2.4.2.Investigate and identify factors affecting the progress of construction projects in the Mekong Delta

(1) The actual investigation process is carried out according to the diagram,(2) Determining the survey sample size,(3) Criteria for selecting respondents to the questionnaire, (4) Survey investigation plan

CHAPTER 3: PRACTICAL APPLICATION OF FUZZY SET THEORY IN SCHEDULING IMPLEMENTATION OF SOME TYPICAL CONSTRUCTION PROJECTS IN THE MEKONG DELTA

3.1.General introduction

The application of fuzzy set theory is carried out in two projects including project A and project B in the Mekong Delta.

3.2. Building a fuzzy theoretical model to measure the factors affecting the construction progress schedule.

3.2.1..Implementation process

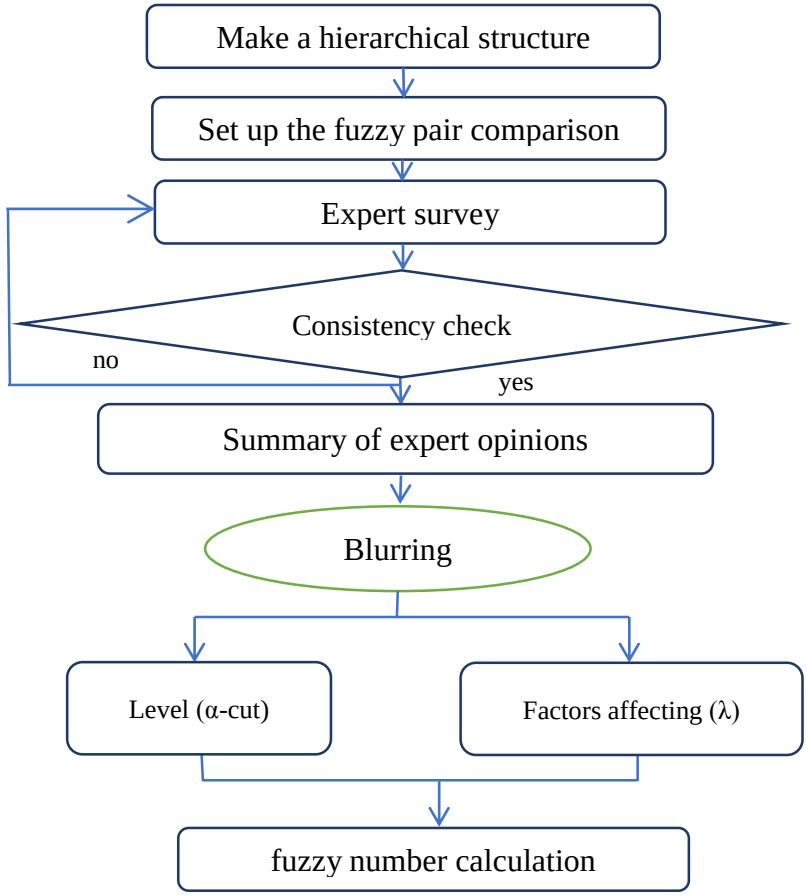
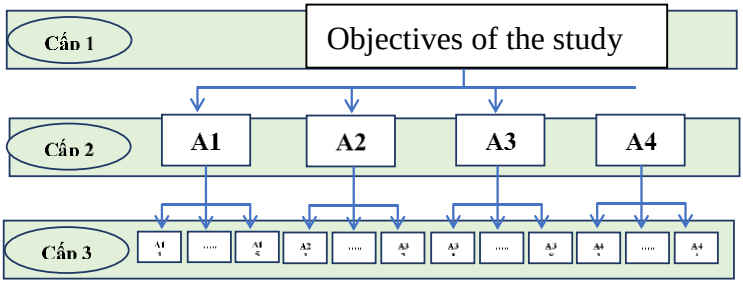


Fig. 3.1. Steps to build a fuzzy theoretical model to assess the factors affecting the progress of construction projects in the Mekong Delta

3.3.Practical results of applying fuzzy theory in scheduling construction projects in the Mekong Delta

3.3.1.Make a hierarchical structure: choose a 3-level structure as



3.3.2.Set up the fuzzy pair comparison matrix

The matrices are made as follows:

(1) Matrix A_1

	A_{11}	**A_{12}**	**A_{13}**	**A_{14}**	**A_{15}**
A_{11}	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}
A_{12}	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}
A_{13}	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}
A_{14}	a_{41}	a_{42}	a_{43}	a_{44}	a_{45}
A_{15}	a_{51}	a_{52}	a_{53}	a_{54}	a_{55}

(2) Matrix A_2

	A_{21}	**A_{22}**	**A_{23}**
A_{21}	a_{11}	a_{12}	a_{13}
A_{22}	a_{21}	a_{22}	a_{23}
A_{23}	a_{31}	a_{32}	a_{33}

(3) Matrix A_3

	A_{31}	**A_{32}**	**A_{33}**	**A_{34}**	**A_{35}**	**A_{36}**	**A_{37}**	**A_{38}**
A_{31}	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}	a_{17}	a_{18}
A_{32}	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	a_{26}	a_{27}	a_{28}
A_{33}	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}	a_{36}	a_{37}	a_{38}
A_{34}	a_{41}	a_{42}	a_{43}	a_{44}	a_{45}	a_{46}	a_{47}	a_{48}
A_{35}	a_{51}	a_{52}	a_{53}	a_{54}	a_{55}	a_{56}	a_{57}	a_{58}
A_{36}	a_{61}	a_{62}	a_{63}	a_{64}	a_{65}	a_{66}	a_{67}	a_{68}
A_{37}	a_{71}	a_{72}	a_{73}	a_{74}	a_{75}	a_{76}	a_{77}	a_{78}
A_{38}	a_{81}	a_{82}	a_{83}	a_{84}	a_{85}	a_{86}	a_{87}	a_{88}

(4) Matrix A_4

	A_{41}	A_{42}	A_{43}	A_{44}
A_{41}	a_{11}	a_{12}	a_{13}	a_{14}
A_{42}	a_{21}	a_{22}	a_{23}	a_{24}
A_{43}	a_{31}	a_{32}	a_{33}	a_{34}
A_{44}	a_{41}	a_{42}	a_{43}	a_{44}

3.3.3.Expert survey

(1) Results at project A:

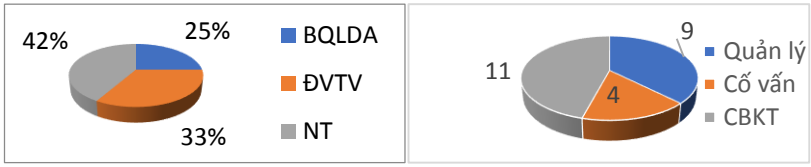


Fig. 3.2. Surveying parties at project A

(2) Results at project B

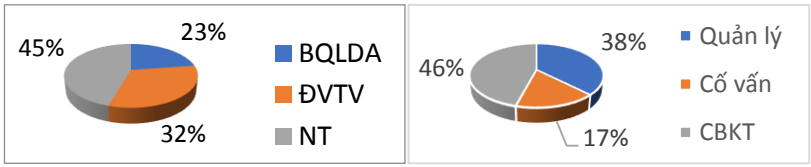


Fig. 3.3. Surveying parties at project B

3.3.4.Check the consistency of experts

Consistency coefficient CR is checked at all matrices A1, A2, A3, A4 in two projects A and B.

Table 3.1. Consistent coefficient results

A1	A2	A3	A4
Consistency coefficient at the project A			
0,090	0,087	0,078	0,091
Consistency coefficient at the project B			
0,081	0,067	0,077	0,069

3.3.5.Summary of expert opinions

The synthesis of expert opinions is represented by the fuzzy matrices. Based on the established matrices A1, A2, A3, A4, the evaluation values are attached to the matrix, the l_{ij},m_{ij}, u_{ij} values are determined. Detailed expert opinions are summarized in the Appendix in the Appendix. 6 and Appendix 7.

3.3.6.Defuzzification

3.3.6.1.Defuzzification results at project A

(1) Matrix A_1

- Fuzzy rating matrix A_1

	A_{11}			A_{12}			A_{13}			A_{14}			A_{15}		
A_{11}	1	1	1	2.22	2.62	2.99	3.41	4.14	4.85	3.68	4.46	5.24	1.78	2.23	2.79
A_{12}	0.33	0.38	0.45	1	1	1	2.00	2.51	3.07	1.39	1.39	1.71	0.99	1.28	1.58
A_{13}	0.21	0.24	0.29	0.33	0.4	0.5	1	1	1	0.94	1.14	1.33	0.74	0.90	1.06
A_{14}	0.19	0.22	0.27	0.59	0.72	0.72	0.75	0.88	1.06	1	1	1	0.80	0.97	1.16
A_{15}	0.36	0.45	0.56	0.63	0.78	1.01	0.94	1.11	1.35	0.86	1.03	1.244	1	1	1

- Matrix about A_1

	A_{11}		A_{12}		A_{13}		A_{14}		A_{15}	
A_{11}	1	1	2.42	2.81	3.77	4.5	4.07	4.85	2	2.51
A_{12}	0.36	0.41	1	1	2.26	2.79	1.39	1.55	1.13	1.43
A_{13}	0.22	0.26	0.36	0.44	1	1	1.04	1.23	0.82	0.98
A_{14}	0.21	0.25	0.65	0.72	0.81	0.96	1	1	0.89	1.06
A_{15}	0.4	0.5	0.7	0.88	1.02	1.22	0.94	1.13	1	1

- Defuzzification Matrix A_1

	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}
A_{11}	1	2.61	4.14	4.46	2.26
A_{12}	0.38	1	2.52	1.47	1.28
A_{13}	0.24	0.4	1	1.14	0.9
A_{14}	0.22	0.68	0.88	1	0.97
A_{15}	0.44	0.78	1.11	1.03	1

(2) Matrix A_2

- Fuzzy rating matrix A_2

	A_{21}			A_{22}			A_{23}		
A_{21}	1	1	1	0.85	1.10	1.41	0.44	0.56	0.73
A_{22}	0.71	0.91	1.18	1	1	1	0.38	0.45	0.55
A_{23}	1.37	1.79	2.28	1.82	2.2	2.64	1	1	1

- Matrix about A_2

	A_{21}		A_{22}		A_{23}	
A_{21}	1	1	0.98	1.25	0.5	0.64
A_{22}	0.8	1.02	1	1	0.42	0.5
A_{23}	1.55	2.01	1.99	2.4	1	1

- Defuzzification Matrix A_2

	A_{21}	A_{22}	A_{23}
A_{21}	1	1.11	0.57
A_{22}	0.9	1	0.46
A_{23}	1.75	2.18	1

(3) Matrix A_3

- Fuzzy rating matrix A_3

	A_{31}			A_{32}			A_{33}			A_{34}			A_{35}		
A_{31}	1	1	1	2.14	2.74	3.42	0.97	1.40	1.92	0.73	1.00	1.31	0.55	0.75	1.12
A_{32}	0.29	0.36	0.47	1	1	1	0.52	0.69	0.90	0.33	0.41	0.53	0.23	0.26	0.30
A_{33}	0.52	0.72	1.03	1.12	1.46	1.91	1	1	1	0.58	0.80	1.03	0.31	0.39	0.49
A_{34}	0.77	1	1.38	1.89	2.43	3.04	0.97	1.25	1.72	1	1	1	0.37	0.46	0.58
A_{35}	0.89	1.34	1.81	3.32	3.9	4.41	2.05	2.58	3.19	1.73	2.19	2.734	1	1	1
A_{36}	0.64	0.83	1.14	1.41	1.76	2.18	0.52	0.66	0.94	0.62	0.77	1.009	0.28	0.35	0.5
A_{37}	0.45	0.58	0.81	0.86	1.05	1.35	0.44	0.55	0.76	0.35	0.43	0.589	0.2	0.23	1.07
A_{38}	1.22	1.7	2.19	3.24	3.93	4.59	2.14	2.67	3.25	1.7	2.27	2.939	0.76	0.93	1.19

	A_{35}			A_{36}			A_{37}			A_{38}		
A_{31}	0.55	0.75	1.12	0.88	1.21	1.55	1.23	1.71	2.23	0.46	0.59	0.82
A_{32}	0.23	0.26	0.30	0.46	0.57	0.71	0.74	0.96	1.17	0.22	0.25	0.31
A_{33}	0.31	0.39	0.49	1.06	1.52	1.92	1.31	1.81	2.29	0.31	0.37	0.47
A_{34}	0.37	0.46	0.58	0.99	1.29	1.60	1.70	2.32	2.89	0.34	0.44	0.59
A_{35}	1	1	1	1.99	2.82	3.59	3.38	4.28	5.04	0.84	1.08	1.32
A_{36}	0.28	0.35	0.5	1	1	1	0.94	1.30	1.67	0.27	0.34	0.44
A_{37}	0.2	0.23	1.07	0.6	0.77	1.07	1	1	1	0.17	0.20	0.25
A_{38}	0.76	0.93	1.19	2.25	2.93	3.69	4.01	4.95	5.82	1	1	1

- Matrix about A_3

	A_{31}		A_{32}		A_{33}		A_{34}		A_{35}		A_{36}		A_{37}		A_{38}	
A_{31}	1	1	2.44	3.08	1.18	1.66	0.86	1.15	0.65	0.94	1.04	1.38	1.47	1.97	0.52	0.70
A_{32}	0.32	0.41	1	1	0.61	1.24	0.37	0.47	0.24	0.28	0.51	0.638	0.85	1.06	0.24	0.28
A_{33}	0.6	0.85	0.81	1.65	1	1	0.69	0.92	0.35	0.44	1.29	1.718	1.56	2.05	0.34	0.42
A_{34}	0.87	1.16	2.13	2.7	1.09	1.44	1	1	0.41	0.52	1.14	1.448	2.01	2.61	0.39	0.51
A_{35}	1.07	1.54	3.59	4.14	2.28	2.85	1.93	2.43	1	1	2.41	3.203	3.83	4.66	0.96	1.2
A_{36}	0.72	0.96	1.57	1.95	0.58	0.77	0.69	0.88	0.31	0.42	1	1	1.12	1.48	0.31	0.39
A_{37}	0.51	0.68	0.94	1.18	0.49	0.64	0.38	0.5	0.21	0.26	0.67	0.895	1	1	0.19	0.23
A_{38}	1.42	1.91	3.55	4.24	2.38	2.93	1.94	2.56	0.84	1.04	2.55	3.268	4.43	5.35	1	1

- Defuzzification Matrix A_3

	A_{31}	A_{32}	A_{33}	A_{34}	A_{35}	A_{36}	A_{37}	A_{38}
A_{31}	1	2.76	1.42	1.01	0.79	1.21	1.72	0.61
A_{32}	0.36	1	0.92	0.42	0.26	0.58	0.96	0.26
A_{33}	0.7	1.08	1	0.8	0.39	1.5	1.81	0.38
A_{34}	0.99	2.38	1.24	1	0.46	1.29	2.31	0.45
A_{35}	1.26	3.84	2.53	2.15	1	2.81	4.25	1.08
A_{36}	0.83	1.74	0.66	0.77	0.36	1	1.3	0.35
A_{31}	0.58	1.05	0.55	0.43	0.24	0.77	1	0.21
A_{32}	1.63	3.87	2.62	2.21	0.93	2.86	4.85	1

(4) Matrix A_4

- Fuzzy rating matrix A_4

	A_{41}			A_{42}			A_{43}			A_{44}		
A_{41}	1	1	1	1.71	1.99	2.27	2.90	3.53	4.18	2.99	3.75	4.57
A_{42}	0.44	0.5	0.58	1	1	1	1.73	2.18	2.74	1.63	2.06	2.53
A_{43}	0.24	0.28	0.34	0.37	0.46	0.58	1	1	1	1.09	1.34	1.68
A_{44}	0.22	0.27	0.33	0.4	0.49	0.61	0.59	0.74	0.92	1	1	1

- Matrix about A_4

	A_{41}		A_{42}		A_{43}		A_{44}	
A_{41}	1	1	1.85	2.13	3.22	3.86	3.37	4.16
A_{42}	0.47	0.54	1	1	1.95	2.46	1.84	2.29
A_{43}	0.26	0.31	0.41	0.51	1	1	1.22	1.51
A_{44}	0.24	0.3	0.44	0.54	0.66	0.82	1	1

- Defuzzification Matrix A_4

	A_{41}	A_{42}	A_{43}	A_{44}
A_{41}	1	1.99	3.54	3.77
A_{42}	0.5	1	2.2	2.07
A_{43}	0.28	0.45	1	1.36
A_{44}	0.27	0.48	0.73	1

3.3.6.2.Defuzzification results in project B: matrix setup and calculation are similar to project A

3.3.7.Calculating fuzzy numbers:

The weight calculation formula is applied to calculate the weights.

3.4.Evaluation of actual results after applying fuzzy theory in scheduling construction projects in the Mekong Delta

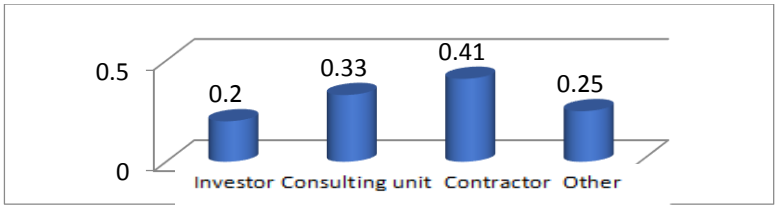


Fig. 3.4. Level of influence of factor level 1 – project A

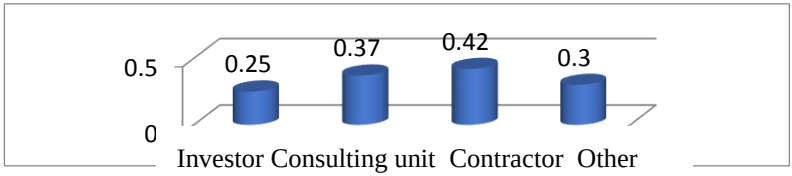


Fig. 3.5. Level of influence of factor level 1 – project B

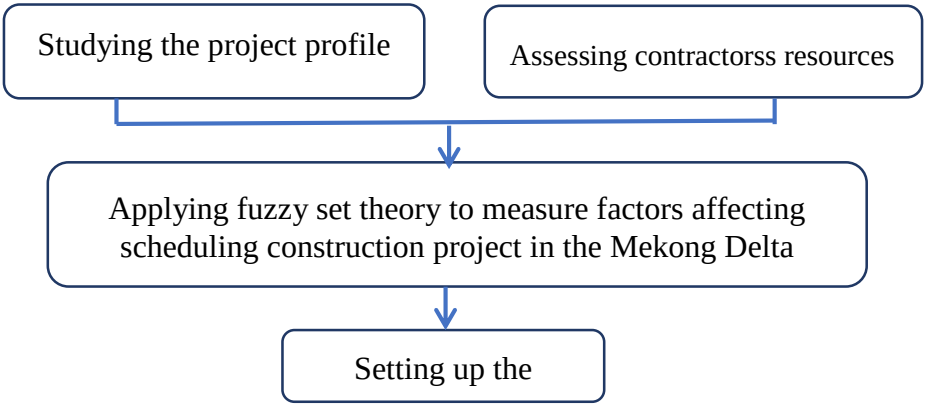
CHAPTER 4: SOLUTION TO APPLY FUZZY SET THEORY IN SCHEDULING CONSTRUCTION PROJECTS IN THE MEKONG DELTA.

4.1.Solution Orientation:

The solution orientation is built based on the point of view, purpose and principles of solution building.

4.2.Solution to apply fuzzy theory in scheduling construction projects in the Mekong Delta

4.2.1.The sequence of making progress on construction projects in the Mekong Delta



4.2.2.List of factors affecting the progress of construction projects in the Mekong Delta:

Including 33 factors

4.2.3.Determining the backup time in making progress of construction projects in the Mekong Delta:

Schedule delay of construction project is undesirable, nonetheless, delay occurs frequently and causes the parties to think through the projects in the Mekong Delta. Nevertheless, how long schedule delay can be accepted by the project parties? Based on this acceptance, all of the parties may have the preparation and strategy for corresponding source mobilization in order that they can take the initiative if the schedule delay take places.

4.3.Solutions to improve the capacity of construction project implementation schedule for parties in the Mekong Delta project

4.4.General solutions

Completing the system of legal documents on progress, finalize the policy, make progress towards favorable progress control, regulations binding on the progress between the parties in the project.

4.5. Specific solutions to prepare to cope with the factors affecting the project implementation schedule in the Mekong Delta

Develop a payment plan for the project, information transparency solution in the project, solution to survey the construction site to set up the project implementation schedule, solutions to support

construction contractors to comply with the design, solutions to improve labor productivity of construction workers in projects in the Mekong Delta, making project implementation schedule taking into account weather conditions

4.6. Discussing research results

Fuzzy theory application in project implementation schedule in the Mekong Delta and impact of climate change on project implementation schedule in the Mekong Delta

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

Progress is an important content in project management. The progress has greatly contributed to the realization of the project's goals: "Quality - Time - Safety - Efficiency" of the project. Based on the progress of the work, the resources are mobilized, the parties work together to create the development of the project. Construction speed is taking place strongly in the Mekong Delta. However, the number of projects behind schedule is increasing, affecting the construction investment situation in this area. The problem of project schedule management is raised and requires rapid change.

The obtained results of the thesis:

Within the scope of the study, with the content presented above, the author summarizes the results that the thesis has achieved:

1- Systematize and supplement the theory on making progress of construction investment projects.

2- Systematize and contribute to perfecting the basis of fuzzy theory in construction project implementation schedule.

3- Investigate and identify factors affecting the progress of construction projects in the Mekong Delta.

4- Identify 33 factors that affect the progress of construction projects in the Mekong Delta. In which, factors with high influence accounted for 52%, factors with medium influence accounted for 12%

and factors with low influence accounted for 36%.

5- Analyze and identify the causes of the delay in the implementation of construction projects in the Mekong Delta.

6- Propose and evaluate the feasibility and effectiveness of solutions to apply fuzzy set theory to the progress of construction investment projects in the Mekong Delta.

New contributions of the thesis

On the basis of assessment of the current situation and empirical application, the researcher proposes a number of solutions to apply fuzzy theory to the implementation progress of construction investment projects in the Mekong Delta, focusing on a number of points:

- Supplementing and perfecting the theoretical basis of using fuzzy in construction project implementation schedule.

- Determine and measure the factors affecting the progress carefully before making the schedule so that the schedule is closely aligned with the construction conditions.

- Practical application of fuzzy theory in scheduling implementation of some typical construction projects in the Mekong Delta. Use a tool to measure influencing factors such as fuzzy theory so that the results are objective, not imposed by the scheduler.

- The solution to apply fuzzy theory in scheduling construction projects in the Mekong Delta will help investors, consultants, contractors and related units in the project perfect their capacity. , thereby coordinating well with each other so that the project is carried out on schedule

Recommendations

Progress is an objective to measure the success of the project. Making an accurate schedule based on a correct assessment of resources and influencing factors is an important task of schedulers. The results obtained will be very useful to the project participants and to the state management agency in charge of construction.

(1) With contractors in the Mekong Delta

Contractors need to select staff with experience, ability to overview the whole project, have a clear understanding of resources and ability to

mobilize resources to schedule construction projects. The project scheduler should also be the schedule manager for understanding and appropriate adjustment when there are influencing factors.

Before setting up the project implementation schedule, the contractor needs to follow the steps to make the construction project schedule proposed in the above content items. In which, fuzzy theory is applied to measure the factors affecting the progress to make the schedule as closely as possible to the reality of the project. At the same time determine the backup time for the project according to the methods mentioned in Section 4.2.1.

In addition, the contractor needs to disseminate the progress to the officials and workers in the project in detail and specifically to avoid losing control over the progress.

(2) For investors and consultants in the Mekong Delta

Investors and consulting units need to understand that the progress associated with the project is not the sole responsibility of the contractor. Therefore, investors and subcontractors need to support contractors in making project implementation schedule with clear requirements on the timelines for completion of main items in the project, opinions on other factors, etc. At the same time, when the schedule is submitted by the contractor and approved by the parties, there should be strict adherence to the schedule.

Investors also need to develop a capital plan to ensure adequate and continuously contribute to promoting the progress of construction projects.

(3) With the state management agency specialized in construction

The delay will lead to slow disbursement of projects in the Mekong Delta. State management agencies specialized in construction need to monitor more closely the progress of construction projects in the Mekong Delta. This monitoring is through periodical and ad hoc reporting activities.

LIST OF PUBLISHED SCIENTIFIC ARTICLES OF THE AUTHOR RELATED TO THE THESIS

1. Truong Cong Bang (2019), *Current status of management of construction investment projects in the Mekong Delta*. Vietnam Journal of Construction, No 12/2019, Pp. 156-158.

2. Truong Cong Bang (2021), *Using fuzzy theory in making progress of construction nvestment projects*, Vietnam Journal of Construction, No 7/2021, Pp. 136-140.

3. Truong Cong Bang (2021), *Project schedule process using fuzzy theory* Vietnam Journal of Construction, No 10/2021, Pp. 101-107.

4. Truong Cong Bang (2022), *Factors affecting the progress of construction projects in the Mekong Delta*, Vietnam Journal of Construction, No 10/2022, Pp. 80-83