Analysis of Multiple Key Success Factors in Construction Project Management in the Petrochemical Industry of Thailand

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Abstract — The objective of this paper is to determine the key success factors of construction project management in the intermediate and downstream petrochemical industry of Thailand. To identify the success factors, an empirical study based on related researches in scholarly literatures and expert opinions are collected to design the questionnaire. In determining the key success factors, the techniques of fuzzy theory and factor analysis are employed. The results revealed 17 key success factors which can be used as guidelines for planning, implementing, controlling, and evaluating the performance of construction projects and also provide lessons for improving the performance of similar new construction projects.

Keywords — construction project, fuzzy, multi-criteria decision analysis, petrochemical, success factors

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I. INTRODUCTION

The petrochemical industry is one of the biggest businesses; in 2017 accounting for 27.1% of GDP in manufacturing industry sector of Thailand [1]. Its end products are driving forces behind many business sectors such as transportation, electronics, plastics and automobile. Furthermore, it has substituted feedstock imports to exports. World petrochemical product demands increased by 4.3%, 4.5% and 4.5% during 2019 – 2021, and thereafter [2]. In order to increase the competitiveness of the petrochemical business in Thailand, good project management and suitable project selection under a proper economic model including practical assumptions are essential conditions to bring project success and the expected desirable benefits. In addition, there are many related empirical studies on project management that showed various key success factors for general construction projects, but none were conducted in petrochemical construction. Petrochemical industry construction projects have some differences in terms of the technologies used, special construction methods, and the complexities when compared with general construction projects. However, some factors can be implemented or used as guidelines in determining success factors in petrochemical construction projects. There are three levels in petrochemical construction projects; upstream, intermediate, and downstream levels. The upstream level concerns oil drilling or offshore construction with high technology. The intermediate level is concerned with plant construction in the manufacture of polymer and plastics, ethaline oxide, aromatic products, olefins, etc. The downstream level includes chemical industries for packaging, automobiles, electronics, medical, etc. In regard to the technology used, the amount of capital investment, and the complexity of the project at each aforementioned level, the upstream level is very different with respect to the other two levels.

The objective of this paper is to determine the key success factors in construction project management for the intermediate and downstream levels of the petrochemical industry in Thailand. These key success factors can be used as performance measures in construction projects for control and evaluation for future improvement of similar new projects. The related literatures are presented in Section II. In Section III, the methodology is presented. The results and conclusions are presented in Sections IV and V, respectively.

II. RELATED LITERATURES

Empirical studies on petrochemical and construction management have been reviewed and it was revealed that the key success factors can be grouped in 3 main factors: project execution, management and skills, and performance and results as in [3] and [4]. They are divided into 30 sub-factors. Project execution consists of 19 sub-factors [5] [6]. They are project selection, project characteristics, collective engineering design, construction management, project cost estimation and control, project planning and control, project change management, quality management, safety-security-health-environment (SSHE) management, permits and licenses management, procurement and contracting management, document management, economic and financial change, risk management, company law and regulation, top management support, development of project organization, clear roles and responsibility, and future potential improvement.

For managerial and skills, [7] and [8] classified them into 5 sub-factors. They are project manager competence, project team competence, contractor competence, communication and coordination skill, and commitment from the team. Last, performance and results, [9] and [10] proposed 6 sub-factors consisting of project profitability and return, stakeholder satisfaction, project completion on schedule, project completion within budget, quality of project completion, and safety and accident record.

III. Methodology

A. Questionnair Design

In designing the questionnaire, the first stage, an open-ended questionnaire is applied to collect additional expert opinions on the key success factors gathered from the related literatures. The unweighted 0-1 factor model is used to select factors where 0 and 1 represent "yes or no" or "suitable or not suitable", respectively [11]. In the second stage, significant feedback will be used to modify the closed-ended questionnaire before launching the official survey. By employing a Likert scale, importance weight scores ranging from 1 to 5 are used. The scores of 1, 2, 3, 4, and 5 represent very unimportant, less important, moderately important, important, and strongly important, respectively. Since importance weights are expressed in terms of linguistic language, fuzzy theory based on triangular fuzzy numbers is applied in order to reduce human fuzziness. The fuzzy membership function consists of three real numbers; lower bound, medium bound and upper bound denoted as "*l*", "*m*" and "*u*" [12]. The relationship between triangular fuzzy numbers and linguistic expressions are shown in Table I.

TABLE I. TRIANGULAR FUZZY NUMBER

Linguistic Expression	*Triangular Fuzzy Number*
5 = Very Important	(0.75, 1, 1)
4 = Important	(0.5, 0.75, 1)
3 = Moderately Important	(0.25, 0.5, 0.75)
2 = Less Important	(0, 0.25, 0.5)
1 = Unimportant	(0, 0, 0.25)

In order to convert triangular fuzzy numbers to measurable values called crisp values, the following steps are employed:

- Converting linguistic expressions to fuzzy numbers as defined in Table I.
- Defuzzification by using the center of gravity approach. Defining "*l*", "*m*" and "*u*" as triangular fuzzy numbers (l, m, u). Then, aggregate value of "l", "m" and "u" and divide by three representing an importance score for each factor.

B. Identify Experts Group Criteria

Because of the lack of information about the population, [13] suggested that a random sampling of size of at least 384 experts should be used. However, in cases where experts are required with specific characteristics, [14] recommended to use a smaller sample size with a homogeneous group. Regarding the information required in the survey to determine the key success factors in the performance measurement of petrochemical construction projects, homogeneous groups of experts are required as shown in Table II.

TABLE II. CRITIRIA SELECTION OF EXPERT GROUPS

Expert's Position Level	*Expert Criteria*
Project Director	Experienced in project management and execution for project value more than 300 million baht for at least 3 projects
Project Manager	Experienced in project management and execution for project value between 100 - 300 million baht for at least 3 projects
Senior Project Engineer	Experienced in project management and execution for project value between 30 - 100 million baht for at least 3 projects

The expert group criteria were selected based on working experience in petrochemical construction. For the first and the second stages of the questionnaire design and the importance weight determination, questionnaires were distributed to 7 petrochemical construction companies and 3 contractor companies via online application. Each company was requested at least 8 experts to response the questionnaire, 80 responses were totally returned, Three types of qualified expert as shown in Table II are considered as the expected respondents.

C. Combining Success Factors

Factor analysis is a statistical approach applied for factor combination. Factors which are related to others can be reduced and combined into a new factor [15]. The following steps describe the procedures of the factor analysis method that are used to reduce the number of success factors.

- Collecting data and constructing a correlation matrix.
- Extracting factors and cumulative of variance at a significance level more than 70% with an eigenvalue more than 1 are considered.
- Rotating axis using varimax method and considering a loading score more than 0.5 is a decision criterion for combining factors.
- Combining the significant correlated factors and the naming of the new factor is completed.

Data analysis is performed by employing the SPSS program.

D. Factor Classification

In order to ensure that the combined success factors obtained from Step C reflect appropriate performance factors in the construction project, a second round of interview sessions by the selective experts was conducted.

IV. Results

A. Success Factors Determination

The results of the first stage, the open-ended questionnaire, were collected from the aforementioned samples and the total number of returned questionnaires was 64 or 80 percent. They indicate that there are 3 main success factors for construction projects that involve project execution, management and skills, and performance and results. For the project execution factor, the proposed questions consist of 19 sub-factors as potential success factors. It was found that one factor was eliminated; future potential improvement. More than 60% of the respondents indicated that this factor was not suitable for measuring project performance because every project is started by project initiators and also has its own purpose at the initiation stage. In addition, there are 6 additional factors proposed by the experts. They are project staff selection, company policy, stakeholder management, human resource management, shortage of skilled labor, and project auditing. These proposed factors will be added into the modified questionnaire in the second stage. For managerial and skills, the proposed questions consist of 5 sub-factors and it was found that all were suitable. Furthermore, an additional 3 factors were proposed by experts. They are project team building, conflict management, and ethics. For the performance and results factor, the proposed questions consist of 6 sub-factors. All of them were suitable to measure project performance. No additional factors were proposed.

The results of the first stage were modified. Regarding the 3 main success factors, the aforementioned sub-factors were regrouped based on the judgment of the selected 6 experts via an interviewing and classified as sub-factors and detailed-factors in the questionnaire design of the second stage. On the other hand, the success factors are divided into 3 hierarchical levels consisting of the main factors in the first level, the sub-factors in the second level, and detailed-factors in the third level. In the second questionnaire, 8 sub-factors and 38 detailed-factors are proposed as a closed-ended questionnaire. The survey is conducted via an online questionnaire to the same groups of the experts as mentioned earlier. The total number of returned questionnaires was 53 or 66.3 percent. The results are summarized in Tables III, IV, and V.

TABLE III. SUCCESS FACTORS OF PROJECT EXECUTION (X_1)

No.	Sub- Factors	Detailed-factors
1	Suitability of Economic and Financial factors (X_{11})	Project Selection (X_{111})
		Project Characteristics (X_{112})
		Economic & Financial Change (X_{113})
2	Project Execution Management (X_{12})	Construction Management (X_{121})
		Project Planning & Control (X_{122})
		Project Cost Estimation & Control
		Project Change Management (X_{124})
		Collective of Engineering Design (X_{125})
		Document Management (X_{126})
		Quality Management (X_{127})
		SSHE Management (X_{128})
3	Project External Management Factors (X_{13})	Permits & Licenses Management (X_{131})
		Procurement & Contracting Management (X_{132})
		Risk Management (X_{133})
4	Project Stakeholder Management (X_{14})	Project Staff Selection (X_{141})
		Human Resource Management (X_{142})
		Stakeholder Management (X_{143})
		Shortage of Skilled Labor (X_{144})
5	Company Strategy (X_{15})	Top Management Support (X_{151})
		Company Policy (X_{152})
		Company Law & Regulation (X_{153})
		Project Auditing (X_{154})
6	Suitability of Project Organization & Responsibility (X_{16})	Development of Project Organization (X_{161})
		Clearly Roles & Responsibility (X_{162})

TABLE IV. SUCCESS FACTORS OF MANAGERIAL AND SKILLS (X2)

No.	Sub- Factors	Detailed-factors
7	Management & Skills (X_{21})	Project Manager Competence (X_{211})
		Project Team Competence (X_{212})
		Contractors Competence (X_{213})
		Communication & Coordination Skills (X_{214})
		Commitment from Team (X_{215})
		Project Team Building (X_{216})
		Conflict Management (X_{217})
		Ethic (X_{218})

TABLE V. SUCCESS FACTORS OF PERFORMANCE AND RESULTS (X_3)

No.	Sub- Factors	Detailed-factors
8	Performance & Results (X_{31})	Project Profitability & Return (X_{311})
		Project Completion on Schedule (X_{312})
		Project Completion within Budget (X_{313})
		Stakeholder Satisfaction (X_{314})
		Quality of Project Completion (X_{315})
		Safety & Accident Record (X_{316})

B. *Key Success Factor Determination*

The obtained importance score for each success factor as shown in Tables III, IV, and V were based on linguistic language, and were transformed to fuzzy scores as mentioned in Table I. The defuzzification was done to obtain a crisp value that will be used as input data for factor analysis.

With respect to each sub-factor, the significant correlated success factors were analyzed. Non-combined and combined sub-factors were performed based on the proposed procedures of factor analysis. A new name for the combined detailed-factors was given and they were considered as the key success factors for performance evaluation for the petrochemical construction project. The key success factors and their measures are presented in Table VI.

TABLE VI. KEY SUCCESS FACTORS AND PERFORMANCE MEASURES

Detailed-Factors	Key/Combined detailed-factors	Measures
Project Selection (X_{111})	Suitability of Economic and Financial factors (Y_1)	Estimated internal rate of return (% per year)
Project Characteristics (X_{112})		
Economic & Financial Change (X_{113})		
Construction Management (X_{121})	Project Planning & Control (Y_2)	Average monthly percentage of actual progress compared to planned project (% deviation from planned project)
Project Planning & Control (X_{122})		

Detailed-Factors	***Key/Combined detailed-factors***	***Measures***
Project Cost Estimating & Control (X_{123})	Cost Estimating & Change Control (Y_3)	Average monthly actual costs compared to planned project's costs (% deviation from planned project's costs)
Project Change Management (X_{124})		
Collective of Engineering Design (X_{125})	Project Quality Management (Y_4)	Level of work execution quality (% completion)
Document Management (X_{126})		
Quality Management (X_{127})		
SSHE Management (X_{128})	SSHE Management (Y_5)	Safety procedure compliance (% completion)
Permits & Licenses Management (X_{131})	Project External Factors Management (Y_6)	Competency level of external factor management (scaling score)
Procurement & Contracting Management (X_{132})		
Risk Management (X_{133})		
Project Staff Selection (X_{141})	Project Stakeholder Management (Y_7)	Competency level of stakeholder management (scaling score)
Human Resource Management (X_{142})		
Stakeholder Management (X_{143})		
Shortage of Skilled Labor (X_{144})		
Top Management Support (X_{151})	Company Strategic (Y_8)	Supporting level from management (scaling score)
Company Policy (X_{152})		
Company Law & Regulation (X_{153})		
Project Auditing (X_{154})		
Development of Project Organization (X_{161})	Suitability of Project Organization & Responsibility (Y_9)	Competence level of workload arrangement (scaling score)
Clear Roles & Responsibility (X_{162})		
Project Manager Competence (X_{211})	Project Member and Contractor Competence (Y_{10})	Technical competence level of team members (scaling score)
Project Team Competence (X_{212})		
Contractors Competence (X_{213})		
Communication & Coordination Skills (X_{214})	Problem Solving & Soft Skills Competence (Y_{11})	Competence of problem solving skills of team members (scaling score)
Commitment from Team (X_{215})		
Project Team Building (X_{216})		
Conflict Management (X_{217})		
Ethic (X_{218})		

Detailed-Factors	***Key/Combined detailed-factors***	***Measures***
Project Profitability & Return (X_{311})	Project Profitability & Return (Y_{12})	Actual internal rate of return (% per year)
Project Completion on Schedule (X_{312})	Project Completion on Schedule (Y_{13})	Completion date of actual compared to plan (% deviation from planned project)
Project Completion within Budget (X_{313})	Project Completion within Budget (Y_{14})	Budget variance at the end of project (% deviation from budgeted project)
Stakeholder Satisfaction (X_{314})	Stakeholder Satisfaction (Y_{15})	Satisfaction level of stakeholder (scaling score)
Quality of Project Completion (X_{315})	Quality of Project Completion (Y_{16})	End project quality compared to standard quality (scaling score)
Safety & Accident Record (X_{316})	Safety & Accident Record (Y_{17})	Accident case at the end of project (number of accidents)

V. CONCLUSION

Regarding to the empirical studies' results on petrochemical and construction management, there are three main success factors; project execution, management and skills, and performance and results. In practice, they are key project success indicators for project performance evaluation in general and limited in use when applied to the special project as in petrochemical construction projects. In this research, the key success factors for the performance evaluation of petrochemical construction projects were analyzed and proposed based on the empirical survey that was grounded on the judgment and experience of selected experts. The screening process reduced 38 success factors to 17 key success factors using a reliable method; factor analysis. These key success factors can help project managers as guidelines for planning, implementing, controlling, and evaluating the performance of a construction project. They also provide lessons for improving the performance of similar new construction projects. For the implementation of the proposed key success factors, decision makers need to realize that these factors have to be revised or modified when they change in the contemporary business environment.

Future research on importance weight settings for each key success factor is recommended. For project performance evaluation, there are many techniques that are implemented whether with multiple attribute decision analysis or multiple criteria optimization. However, in cases where there is no historical data, a non-parametric analysis approach is an alternate approach. In such circumstances, a new variant of multiple criteria decision making, network data envelopment analysis, is recommended. It is appropriate for cases in which there are many performance measures and limitations of historical data.

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