Developing a risk based engineering manager competency standard for oil and gas EPC project in Indonesia

A D B Tarihoran* and Y Latief

Civil Department, Engineering Faculty, Universitas Indonesia, Depok, Indonesia

*andiga@yahoo.com

Abstract. One key to a project's success other than the competence of the Project Manager is the competence of the project team personnel. Many problems occur that affecting the success of the Oil and Gas EPC (Engineering, Procurement, and Construction) project such as project schedule delayed, cost overruns, poor quality project performance to a life-threatening safety problem caused by incompetent personnel. The goal of this paper is to develop competency standard for Engineering Manager as one of the key personnel in the EPC project in the oil and gas industry. The competency standard will be developed based on literature study and data from several project execution plans in Indonesia which are validated by experts. Furthermore, risk analysis will be conducted by survey to get major risk that may be faced by an Engineering Manager which affecting time, cost, quality and safety to the project. As a result, risk based standard competency for engineering manager is expected to be produced.

1. Introduction

Oil and gas (O&G) projects have unique characteristics that differentiate them from other projects, there are huge investments, massive interfaces, and complex engineering endeavors [1], complex technology [2], environmental and social impacts [3] and it is usually done in remote areas [4].

In Indonesia, investment in the O&G industry is around US$ 10.3 billion in 2017 and in 2018 the government set a target of US$ 17.04 billion [5]. However, in recent years, the O&G industry’s contribution to the state revenue is not in a good condition. It has fallen sharply from 14% in 2014 to 4% in 2015, and dropped to 3% in 2016 before recovering to 5% in 2017 [5]. In 2018, the Indonesian government plan to have 9 new projects with investment cost US$ 4.2B [6].

There are many problems occurred in O&G projects worldwide. Only 22% of the projects could be called successful, while the other 78% were equally unimpressive [7]. In other study, Ernst & Young reported [8], globally, out of 205 O&G megaprojects around the world, there were 64% of projects experiencing cost overruns and from 242 projects there were 73% of projects experiencing delays. In Asia Pacific, Ernst & Young also restudied there were 68% projects facing cost overruns and 80% facing delays [8]. In recent research, Rui et al. found overall average cost overrun of O&G projects is 18% and indicated that the overall cost performance of O&G projects is worse than expected [9]. Meanwhile in Indonesia, Simanjuntak reported that in 2012, out of 75 oil and gas projects that were running, there were 60% of projects experiencing delays, leaving only 40% of the projects still underway as planned [10].

Project management team have important role and positive significant association in success of any project [11,12]. Incompetence of project team has been considered as one of the major risk in O&G
project [13]. In his research, Spalek concluded that establishing experienced and competent project team is one of the critical factors in project success [14].

Engineering Manager (EM) as one of the key member in O&G project team has responsibility in overall engineering design and act as a coordinator for all engineering disciplines which usually consist of Process, Electrical, Equipment/Mechanical, Layout & Piping, Instrumentation and Control, and Civil [15]. Poor design engineering may cause time, cost and quality problem in project [13]. Badiru mentioned there are three challenges in oil and gas projects [1]: technical challenges, managerial challenges, and human resource challenges. El-Baz added that an EM is expected to have technical competence as well as managerial competence and both must be balanced [16]. The objectives of this research are to identify the major risk factors for EMs when doing their duties and responsibilities in an O&G project that affecting cost, time, quality and safety performance, to get response for each risk and finally to develop risk based standard competency for EM in O&G industry in Indonesia.

1.1. Success in EPC O&G project
Project is a temporary endeavor undertaken to create a unique product, service, or result [17]. EPC is stand for Engineering, Procurement and Construction, a type of construction contract where the contractor holds the responsibilities for design, procurement of materials, and construction [18]. EPC project, or often called as turnkey project is a stage in project life cycle, where detail engineering, procurement and construction phase took place. In his research, Hansen concluded there are three main categories of EPC project’s characteristics [19], they are: general aspect, legal & contractual aspect, and technical aspect.

Time, cost, and quality are always considered as important factor for project management success [17,20,21]. In O&G project, the same factors are also applied. the project should be completed within its budget estimate, within its initial scheduled time frame, and performed as it was designed to function [22,23]. For a construction project such as in EPC project, safety is also to be considered to be important in project success [24-26].

1.2. Engineering manager competency
Competency is underlying characteristic of a person or individual which results in effective and/or superior performance on the job [27-29]. There are five characteristic of competencies that affect individual performance, they are knowledge, skill, self-concept, trait and motives [30]. According to UU No. 13, work competency is the work ability of each individual which includes aspects of knowledge, skills, and work attitudes in accordance with established standards [31].

Wu et al. have developed competencies in engineering management as six factors: personality and motivation, capability, skills, knowledge, managerial behavior and general qualification [32]. In other research, El-Baz and El-Sayegh have developed four core engineering management competencies [33]: technical competencies, management competencies, leadership competencies and financial competencies.

EMBOK mentioned there are eight domains for engineering management knowledge area, they are [34]: Market Research, Assessment and Forecasting; Strategic Planning and Change Management; Product, Service and Process Development; Engineering Projects and Process Management; Financial Resource Management; Marketing, Sales and Communications Management; Leadership and Organizational Management; and Professional Responsibility, Ethics and Legal Issues.

Kocaoglu mentioned in his research there are five scopes of engineering management program in Universities throughout the world that need to be learned [35]: Management of Engineers and Scientists, Management of Engineering and R&D Projects, Management of Technological Systems, Management of Technical Organizations, and Management of Critical Resources.

Indonesia has its own national competency standard for specific job position which is called as SKKNI (National Work Competency Standardization System) [36]. There is a national competency standard available for EM [37] but it is intended to railroad construction.
2. Research method

To satisfy all of the objectives in this research, literature study and data collections by questionnaire and survey were performed. Questionnaire and interview to experts were done to obtain content and construct validity of the competency unit, competency elements, and performance criteria for EM; to validate the major risk factors; and to get response for each major risk factors. There are five experts contributed in this research with criteria for those who is or was a practicing EM in O&G project with total experience more than 30 years.

Literature study and Delphi technique was used to identify all risk factors for EM by finding all mistakes that might be happened when they failed to perform their duties and responsibilities. After all risk factors identified and validated by experts, survey was performed to get respondents perception about risk factors that may be faced by an EM that affecting the success of the project which have negative impact to time, cost, quality and safety performance. The target population for this survey was practicing EM or PM involved in O&G project.

This research used statistical analysis using SPSS version 22 to get homogeneity, validity and reliability test of the 33 respondents participate in the survey.

3. Results and discussion

3.1. Major risk for EM

There are total 134 risk factors for EM identified and validated by experts that may be affecting project performance.

Risk factor (R) is calculated using formula:

\[ R = P \times I \]

Where, \( P \) = Probability/frequency of occurrence; \( I \) = negative impact of the risk. For \( P \), PMBOK [17] suggested “very high” “high,” “medium,” “low” and “very low” take values of 0.9, 0.7, 0.5, 0.3, 0.1, respectively; and for \( I \) suggested values of 0.8, 0.4, 0.2, 0.1, 0.05, respectively. Risk factor will be classified as a high risk or major risk if average risk value from 33 respondents participated in the survey is equal or more than 0.09.

In summary, there are 18 risk factors classified as high risk or major risk according to survey result and validated by experts. Some risk factors have more than one negative impact to project performance.

| No | Variable | Risk Factor |
|----|----------|-------------|
| 1  | X1.2     | Negligence for not doing clarification during bidding stage. |
| 2  | X1.20    | Mistake for not doing risk assessment. |
| 3  | X1.25    | Engineering Execution Plan is not in line with the Procurement Execution Plan. |
| 4  | X1.26    | Engineering Execution Plan is not in line with the Construction Execution Plan. |
| 5  | X1.41    | Long Lead Item material is not identified at the earliest of the project. |
| 6  | X1.48    | Mistake in selecting engineering team personnel. |
| 7  | X1.61    | Overdue engineering deliverables submission by related disciplines. |
Table 2. High risk factor affecting cost performance.

| No | Variable | Risk Factor |
|----|----------|-------------|
| 1  | X1.1     | Misinterpretation of bidding documents for engineering scope of work. |
| 2  | X1.2     | Negligence for not doing clarification during bidding stage. |
| 3  | X1.3     | Underestimating of the Bill of Quantity/ volume of material and equipment at the bidding stage. |
| 4  | X1.4     | Underestimating of man-hour requirement at the bidding stage. |
| 5  | X1.5     | Underestimating the engineering team activity duration at the bidding stage. |
| 6  | X1.17    | Mistake for not checking detailed plan drawings. |
| 7  | X1.19    | Mistake in identifying specifications, design bases and project data. |
| 8  | X1.20    | Mistake for not doing risk assessment. |
| 9  | X1.25    | Engineering Execution Plan is not in line with the Procurement Execution Plan. |
| 10 | X1.41    | Long Lead Item material is not identified at the earliest of the project. |
| 11 | X1.48    | Mistake in selecting engineering team personnel. |
| 12 | X1.104   | Inadequate contingencies and construction spare due to improper checking during engineering. |
| 13 | X1.105   | Technical evaluation of vendors are not done properly. |

Table 3. High risk factor affecting quality performance.

| No | Variable | Risk Factor |
|----|----------|-------------|
| 1  | X1.3     | Underestimating of the Bill of Quantity/ volume of material and equipment at the bidding stage. |
| 2  | X1.48    | Mistake in selecting engineering team personnel. |
| 3  | X1.105   | Technical evaluation of vendors are not done properly. |
| 4  | X1.125   | Negligence for not reviewing engineering deliverables before being submitted to the client. |

Table 4. High risk factor affecting safety performance.

| No | Variable | Risk Factor |
|----|----------|-------------|
| 1  | X1.67    | Safety is not considered in engineering deliverables. |
| 2  | X1.122   | Safety study recommendation are not applied into design. |

3.2. EM standard competency for EM in O&G project

After the risk analysis and risk responses by experts, a risk-based competency standard for EM is finalized consisting 13 units of competency and 50 competency elements (see table 5).

Table 5. Competency standard for EM.

| No | Unit of Competency | Competency Elements |
|----|--------------------|---------------------|
| 1  | Manage engineering activities at the bidding stage (Pre-Award Activity) | 1.1 Form engineering team personnel during bidding stage.  |
|    |                     | 1.2 Perform clarification to the owner during bidding stage. |
|    |                     | 1.3 Perform engineering risk assessment. |
|    |                     | 1.4 Estimate BoQ or volume of material and equipment to help Procurement estimate costs. |
|    |                     | 1.5 Estimate manpower / manhour required by the engineering team. |
|    |                     | 1.6 Estimate duration for engineering team activities. |
|    |                     | 1.7 Propose separation of scope of work with engineering subcontractors. |
| 2  | Review scope of work | 2.1 Compile engineering documents related to the contract. |
|    |                     | 2.2 Identify engineering scope of work, time, and deliverables. |
|    |                     | 2.3 Identify engineering activities that require special studies. |
| Table 5. Cont. |   |                                                                 |
|----------------|---|-----------------------------------------------------------------|
| 3              | 3.1 | Identify design drawings.                                       |
|                | 3.2 | Identify design basis, engineering specifications and data.     |
|                | 3.3 | Analyze risks in contract documents.                           |
| 4              | 4.1 | Prepare Engineering Execution Plan                              |
|                | 4.2 | Organize site survey                                            |
|                | 4.3 | Prepare schedule for engineering team.                         |
|                | 4.4 | Perform value engineering.                                     |
|                | 4.5 | Manage engineering design for long lead item (LLI) material.   |
|                | 4.6 | Prepare report for engineering work.                           |
| 5              | 5.1 | Develop organization for engineering team.                     |
|                | 5.2 | Select engineering team personnel.                             |
|                | 5.3 | Resolve conflicts in the engineering team.                     |
|                | 5.4 | Assessing engineering team personnel.                          |
| 6              | 6.1 | Manage routine meetings both internally and externally with the Client. |
|                | 6.2 | Manage all engineering deliverables.                           |
|                | 6.3 | Manage the implementation of non-deliverables engineering activities. |
|                | 6.4 | Control engineering schedule.                                  |
|                | 6.5 | Control engineering man power.                                 |
|                | 6.6 | Manage technical query                                         |
| 7              | 7.1 | Interpret information and work instructions received related to the execution of work. |
|                | 7.2 | Communicate work instructions to related disciplines.           |
|                | 7.3 | Manage coordination between engineering disciplines related to any engineering issues. |
|                | 7.4 | Manage coordination meetings with other units such as procurement, construction, commissioning for any problems related to engineering. |
| 8              | 8.1 | Identify activities that are in change order.                  |
|                | 8.2 | Manage change order documents.                                 |
| 9              | 9.1 | Manage material volume.                                        |
|                | 9.2 | Manage vendor selection process with Procurement Manager through technical evaluation. |
|                | 9.3 | Conduct meetings for clarification with bidders / vendors / subcontractors. |
| 10             | 10.1 | Provide input to Construction Manager in sub-contractors selection. |
|                | 10.2 | Manage work drawing preparation and Detailed Engineering Design (DED) for project construction. |
|                | 10.3 | Manage quantity/work volume belong to sub-contractor scope of the work. |
|                | 10.4 | Mobilize site engineering team.                               |
|                | 10.5 | Manage site query.                                            |
| 11             | 11.1 | Anticipate potential hazards.                                  |
|                | 11.2 | Manage all safety studies according to the contract.           |
| 12             | 12.1 | Manage quality of Engineering deliverables                      |
|                | 12.2 | Manage material/equipment inspection and testing activities in coordination with QA / QC. |
| 13             | 13.1 | Manage the development of as built documents.                  |
|                | 13.2 | Prepare final report for engineering work.                     |
|                | 13.3 | Manage list of lessons learned in the project.                 |
Manage engineering activities during bidding is very important for EM. Bidding stage is one of the important stage of project life cycle to determine project success [38]. All risk factors happened during bidding stage: misinterpretation bidding documents or poor understanding of scope of work [4], missed during clarification, underestimating material or equipment [4,39], underestimating man-hour that causing shortage of labor [4] and underestimating duration which causing inadequate scheduling [4] are considered as high risk which affecting project success.

Prepare engineering execution plan shall be in line with procurement execution plan and construction execution plan. Inadequate planning or improper planning is considered as one of predominant factors influencing time overruns/delays in a project [4,39,40].

Selecting the right engineering personnel is also very crucial. Poor qualification of the technical staff is considered as one of the factors that causing delays [41]. In O&G project, where new technology has been developed or in high complexity project requires specific skill qualification that must be fulfilled. Lack or inadequate of experience of project type and lack of knowledge of technical staff is also one predominant factor causing time or cost overruns [39,40,42]. According to the survey, wrong personnel selection can lead the project to have issues in quality, time, and cost performance in the future.

Contract documents shall be reviewed properly, otherwise mistakes and discrepancies in the contract document can be the cause of delay [4]. Any design drawings, design data, engineering specification shall be identified carefully to prevent rework and wrong design. Any mistakes in design is one of factor causing time and cost overruns according to [43]. Any design changes in contract shall be informed at the earliest to lead disciplines for further action because design change is considered as main factor causing delays [39].

Risk assessment is important in project management [44,45] and it is also important competency for EM that shall be performed starting from the bidding stage and continue to execution phase. Cost overruns can be occurred when a there is a significant risk that has never been assessed before.

In relation to quality, EM has responsibility for vendor technical evaluation and ensuring all engineering deliverables are in in a good quality. First, selecting the right vendor is important to the success of the construction project [46]. Technical evaluation for vendor selection is performed by engineering team and managed by EM to assist procurement team. Second, EM shall manage all engineering deliverables in a good quality by ensuring the lead engineers have done proper reviewing before submission to client. Quality of engineering deliverables is crucial to determining project success [47].

Finally, safety is also critical as part of the project success. EM shall be responsible in managing engineering team to implement inherent safer design principles in engineering design [48]. Safety in design is not only important for operation and maintenance but also for construction stage during project execution [49].

4. Conclusion
The risk based standard competency for EM in O&G project which developed in this paper hopefully can be used by any PM or any employer when selecting the right candidate for EM in O&G project and also can be used as a basis to develop training module to fill the competency gap for any EM. However, soft competencies are not discussed in this research, which also important for EM.

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