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Quality Management of Infrastructure Project Life-Cycle

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***Abstract*—For improving the performance of infrastructure project execution, the quality of construction products is of concern to the government and related stakeholders, especially for Indonesian construction industry is facing the tight competition of national and global construction markets. Therefore, quality assurance at planning, constructing, and controlling of infrastructure project is necessary, to integrate all parties' tasks and responsibilities throughout the project stages. By using two rounds Delphi study, this paper discusses the effectiveness of the implementation of quality management indicators by certified QMS-ISO 9001 Indonesian planning consultants, contractors, and supervising consultants in the three stages of infrastructure project life-cycle. It is found that the quality system indicators are effectively implemented during the planning, constructing, and controlling of infrastructure project execution. These profiles are beneficial in synergizing the construction services providers' roles in the project life-cycle, as well as strengthening their communication and coordination, as an attempt to produce qualified and sustainable infrastructure projects.**

Keywords—quality management, project life-cycle.

I. INTRODUCTION

Indonesian infrastructure development is a part of the national development that can be a driver for local, regional and national economic growth. Successful development of infrastructure and facilities are measured not only by the physical buildings but also determined by their performance, including the proper functioning of the building as well as the benefit to the community. These need to be supported by the government's active role as the project owners, planning consultants, contractors, and supervising consultants throughout the infrastructure project life-cycle.

Improving the quality of providing infrastructure products becomes a challenge, considering the uneven capacity of the Indonesian construction services providers. Currently, the construction service industry is still dominated by large qualification construction companies, which are only about 1% of the total construction business entities. The facts show that large qualified construction companies have benefits both regarding equipment, labor, and access to information technology compared to other qualification construction companies. This condition causes the quality of construction processes and products to be less competitive, while the success of national construction is reflected by the performance of the whole qualification of the construction key-players.

It can be said that from the perspective of the project life-cycle, the success of the construction project depends not only on the performance during the construction stage but also on the planning and supervision processes; in other words, the performance of the construction project should be assessed throughout the project life-cycle. Current conditions on the project sites indicate that there is less integration of tasks and responsibilities among the construction key-players, and between them and the project owners, thus the quality assurance of the project execution is partial. This is an important issue because all parties involved in the construction projects must assure that they meet the expected project performance indicators, such as, quality, cost, time, occupational health and safety, and minimize disputes caused by the possible failure of construction products.

Research studies involving the three main construction key-players altogether are still rare. This paper aims to discuss the effectiveness of the implementation of quality management indicators by the three key-players certified QMS-ISO 9001, they are Indonesian planning consultants, contractors, and supervising consultants, in the three stages of infrastructure project life-cycle. The quality management systems (QMSs) currently being implemented by the highest qualification of Indonesian contractors and consultants are based on the ISO 9001 standard. Holding a valid ISO 9001:2008 certification (this version is applied on this research study) is a requirement for construction companies that wish to be registered in the highest qualifications (B2 and B1), as well as for companies wishing to tender for government projects with a value above USD 100,000. The results of the study benefit the infrastructure project stakeholders regarding strengthening their communication and coordination from the project planning to the construction and controlling stages. Along with the Indonesian government's efforts to improve the professionalism and competitiveness of local and national construction services providers, this study puts forward the issue of the construction services providers' roles and responsibilities in advancing the performance of Indonesian construction industry.

II. INFRASTRUCTURE PROJECT LIFE-CYCLE

The execution of a construction project is such a series of dynamic and particular activities at each stage; this is known as project life-cycle. The stages of the project life-cycle can be defined differently according to the project characteristics and purposes. The project life-cycle consists of initiating process group, planning process group, executing process

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group, monitoring and controlling process group, and closing process group [1]. Although the stages of the project life-cycle are defined differently by various authors [2], the characters of the project life-cycle are commonly recognized in each stage. The initiation process involves project formulation and feasibility study, which is then the results of this process become the basis to provide the technical criteria and specifications designed at the planning stage, and will be implemented in the project realization stage. In the final stage of the project life-cycle, the closure activities include the handover of the project product and completion of administration and finance. In addition, the project life-cycle also emphasizes the process of monitoring and evaluation, that is applicable throughout the project stages. In Indonesian circumstances, the construction project life-cycle for infrastructure project defined by the Ministry of Public Works and Housing comprises planning stage, procurement stage, construction stage, and project handover stage.

An overview of the project life-cycle suggests that the success of the infrastructure project relies on each stage of the project life-cycle, whereas the progress of the previous stage determines the progress of the next stage that in turn determines the progress of the project execution as a whole that eventually determines successful project handover and maintenance. However, this is not as easy as it defines. During the construction project life-cycle, there are many stakeholders involved, who need to share information appropriately to reduce failure costs and to improve overall project results [3]. The nature and characteristics of the construction industry itself cause a fragmentation in terms of (a) clear separation between the project life-cycle phases that may result in lost of information and knowledge while they are delivered to the next phase, (b) project actors who have their goals, tools, and way of working, and (c) uniqueness of the project that has an impact on sharing of information in the project life-cycle [4]. Nonetheless, due to the strong interconnection between the project stages, with active involvement of the project key-players in each stage, the project life-cycle becomes a project management instrument for successful project execution.

To ensure the quality of infrastructure projects, the Indonesian construction services providers are required to consistently develop and implement quality management systems (QMSs), which is currently most possessed is based on QMS-ISO 9001:2008. This regulation mainly applies to large qualification construction services providers undertaking projects, particularly for those that are government related. The ISO 9001:2008 is one of the quality system models that has been widely used as a benchmark for implementation of quality management and process control in the construction industry [5, 6, 7]. This QMS specifies what an organization should do to achieve better quality management and improvement [8]. Therefore, it is necessary to examine the condition of the implementation of QMS-ISO 9001:2008 standards by the Indonesian construction services providers, to have profiles on their quality management implementation according to their roles as planners, constructors, and project supervisors. While research into quality management implementation in construction stage has involved many researchers, there is no critical mass of information specifically related to the quality management implementation altogether in the infrastructure project life-cycle, covering project planning, constructing, and controlling.

III. RESEARCH METHODS

Specific research method has been chosen to utilize the data collection, which is based on the research question: 'what is the level of implementation of quality management indicators in the three stages of infrastructure project life-cycle?'. A survey is a preferred method for this type of question [9], and time available to collect the data is limited [10, 11]. This study then employs two rounds of Delphi questionnaires surveys to obtain a panel of experts' opinions on the research question.

Selection and identification of the panel of experts are crucial for conducting a Delphi study [12]. The experts represent the large qualification of construction services providers, who are working as planning consultants, contractors, and supervising consultants of infrastructure construction projects in the three capital cities in Indonesia, namely Jakarta, Manado, and Denpasar. The experts in Delphi round one consist of 14 planning engineers, 39 contractors, and 19 supervising engineers. The respondents in the Delphi survey can be 15 to 30 experts [13], even three to 80 respondents as needed [14]; as long as they are experts on the research studies. While 49 of them, consist of seven planning engineers, 28 contractors, and 14 supervising engineers, are involved in Delphi round two.

TABLE I. NUMBER OF PLANNING CONSULTANTS WHO PARTICIPATED IN THE DELPHI SURVEY

Organization	**Panel of Experts**		
	Experts criteria	***Round 1***	***Round 1***
Planning Consultant	Team leader	3	1
	Structural Engineers	2	-
	Civil Engineers	7	2
	Environmental Expert	1	-
	Others consultant	1	4
	Total	14	7

TABLE II. NUMBER OF CONTRACTORS WHO PARTICIPATED IN THE DELPHI SURVEY

Organization	**Panel of Experts**		
	Experts criteria	***Round 1***	***Round 2***
Contractor	Directors	3	
	Project Managers	7	7
	Site Managers	3	4
	Superintendent	4	
	Site Supervisors	7	2
	Environmental Expert	2	
	Others contractor	12	15
	Total	39	28

Delphi round one aims to gather the experts' opinions on the research question, and Delphi round two aims to consider the opinions than to approve the results from round one. All data collected were analyzed using descriptive statistics mode to obtain the level of implementation of quality management indicators in the three stages of infrastructure

project life-cycle, and frequencies of the experts' agreements regarding the level of implementation of quality management indicators. The first round was scheduled on 12 to 22 June 2017, while the second round was on 5 to 12 July 2017.

Data collected from the Delphi questionnaires was quantitative data. This data was then processed, analyzed and interpreted by using descriptive statistical techniques to provide the information needed. Quantitative data analysis involves both looking at the general trends in the data and fitting statistical models to the data [15]. The Statistical Package for Social Sciences (SPSS) version 22 was used for the statistical analysis.

TABLE III. NUMBER OF SUPERVISING CONSULTANTS WHO PARTICIPATED IN THE DELPHI SURVEY

Organization	Panel of Experts		
	Experts criteria	*Round 1*	*Round 2*
Supervising consultant	Team leader	2	4
	Structural Engineers	3	1
	Architectural Engineers	2	-
	Civil Engineers	6	3
	Environmental Expert	3	
	Others	3	6
	Total	19	14

In order to find out the level of effectiveness of the implementation of quality management indicators by the three key-players certified QMS-ISO 9001, descriptive analyzes of mode and frequency are used to summarize the general perceptions of the respondents on the subjects of quality management indicators in the planning stage, constructing stage, and controlling stage. The mode is the value that occurs most often, indicating most oven level of implementation of the quality management indicators. In conventional studies, general conclusions achieved generally is based on the descriptive statistical techniques of mean, median, mode, and standard deviation [16].

IV. RESULTS AND DISCUSSIONS

Data collection in regards to the research question was classified into three groups: (1) quality management indicators in planning stage, (2) quality management indicators in constructing stage, and (3) quality management indicators in controlling stage. The measurement was based on unbalanced itemized rating scales [17], which are 5=always implemented completely, 4=always implemented but not completely, 3=often implemented, 2=rarely implemented, 1=never implemented.

Tables IV to VI respectively lists the experts' opinions with regard to quality management indicators in the three stages of infrastructure project life-cycle. Results from these tables show that the quality management indicators in the three stages of infrastructure project life-cycle were rated highly with the mode score of 5. Of the five indicators in Table IV, there is one indicator with the frequency of mode < 50%; this indicates that less than 50% of the respondents agreed with the high level of implementation of the indicator of the need of professional planning engineers (42.90%). As well, there is one quality management indicator in the constructing stage (see Table V), and one indicator in the controlling stage with the frequency of mode < 50% (see Table VI). These indicate that less than 50% of the respondents agreed with the high level of implementation of the indicator of the need to employ qualified sub-contractors and suppliers during the construction stage (48,70%), and the need of management responsibility in controlling project reports (42,10%).

In Delphi round two the experts were asked to review the results of Delphi round one, and to consider the level of implementation by answering "yes" or "no" to respond to the questions. If they felt that it was not at the right level, they were asked to revise the rating. The data analysis for the questionnaire Delphi round two used the frequency of the respondents' similar answer. The consensus can be achieved if the participants provided the identical responses for at least 67% of the time [18]. In the re-evaluation of the level of implementation of the quality management indicators, the agreement response frequency was > 67%, indicating that the experts agreed with the high level of implementation of the indicators. Considering the high level of implementation of quality management indicators in the three stages of infrastructure project life-cycle, it can be said that the three infrastructure project key-players have realized the importance of the indicators in ensuring the process and project results meet project specification and customer satisfaction. The context of an effective quality management implementation is to ensure that work is performed according to specifications from the input to the process of manufacturing, construction, and services, in order to meet customers satisfaction on the results of products and services [19].

From all of the results, the practices of quality management indicators in planning, constructing, and controlling stage are imperative since they are effectively implemented, and most of the respondents agreed and had similar understandings of how the indicators are implemented. In this study, the practices of the quality management in the three stages of infrastructure project life-cycle are measured based on the QMS ISO 9001:2008 standards associated with quality documentation, management responsibility, human resources, product realization, and continuous improvement. Future research shall cover the effectiveness of the implementation of quality management indicators based on the QMS ISO 9001:2015 standards; this new version has started to be adopted in September 2018.

TABLE IV. QUALITY MANAGEMENT INDICATORS IN PLANNING STAGE

Indicators	Delphi round 1		Level	Delphi round 2 % Yes
	Mode	*% Mode*		
Planning documentation	5.00	85.70	High	100
Management responsibility on planning results	5.00	57.10	High	100
Professional planning engineers	5.00	42.90	High	85.70
Communication with project owner	5.00	85.70	High	100
Measurement of planning processes	5.00	64.30	High	85.70

TABLE V. QUALITY MANAGEMENT INDICATORS IN CONSTRUCTING STAGE

Indicators	Delphi round 1		Level	Delphi round 2 % Yes
	Mode	*% Mode*		
Construction reports documentation	5.00	76.90	High	96.40
Health and safety assurance	5.00	66.70	High	89.30
Adequate project resources	5.00	51.30	High	89.30
Comply with the project specification	5.00	79.50	High	96.40
Communication with supervising consultants	5.00	69.20	High	89.30
Employ qualified sub-contractors and suppliers	5.00	48.70	High	82.10
Measurement of construction processes and end-products	5.00	71.80	High	96.40

TABLE VI. QUALITY MANAGEMENT INDICATORS IN CONTROLLING STAGE

Indicators	Delphi round 1		Level	Delphi round 2 % Yes
	Mode	*% Mode*		
Controlling reports documentation	5,00	78.90	High	85.70
Management responsibility on controlling project reports	5.00	42.10	High	85.70
Professional supervising engineers	5.00	52.60	High	78.60
Regular controlling activities	5.00	57.90	High	92.90
Controlling comply with the project specification	5.00	63.20	High	100
Measurement of controlling processes	5.00	73.70	High	78.60

The results from Delphi studies round one and two have also been presented in Figure 1 to 3 respectively, to show the percentage of the agreement obtained from the studies.

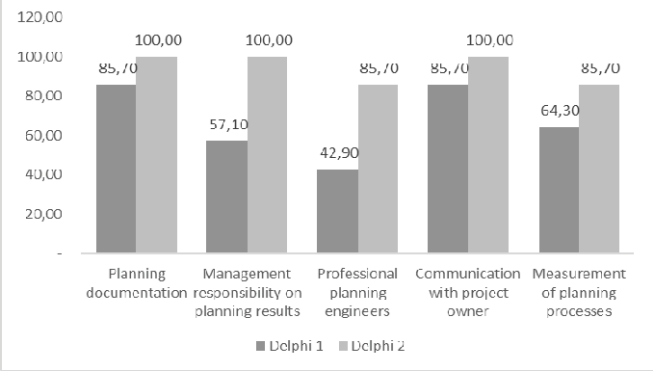

Fig. 1. Delphi studies in planning stage.

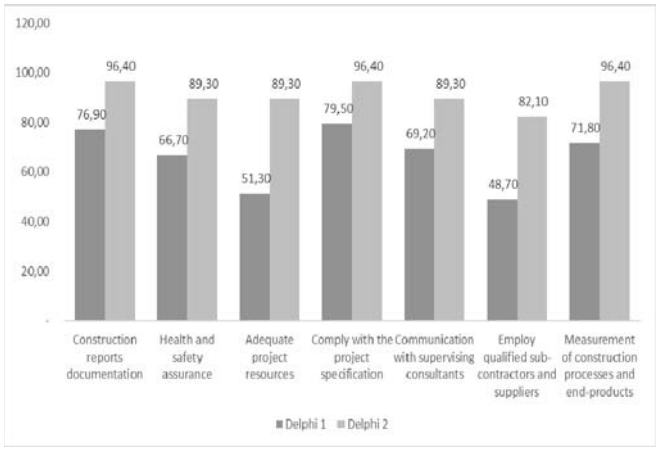

Fig. 2. Delphi studies in constructing stage.

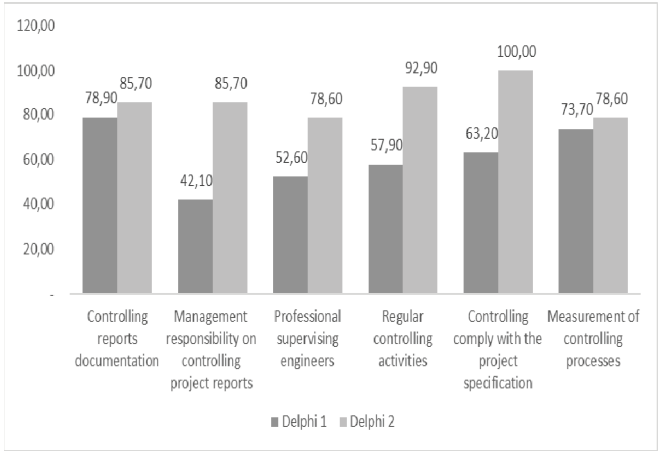

Fig. 3. Delphi studies in controlling stage.

Although the quality management performance of the construction services providers seems effective, this circumstances has remained questionable if it is defined according to their effective roles altogether during the project life-cycle. In fact, the quality management indicators in the infrastructure project life-cycle shall not be partially applied by every consultant and contractor organization. To improve the performance of construction projects there is a need to change hostile relationships and opportunistic behaviours in the practice of the construction industry, conversely increasing the commitment and communication among the project stakeholders to ensure successful implementation of future construction projects [20, 21, 22]. These factors are indispensably required to solve less effective communication and miss-interpretation when proper information is delivered along the stages of project life-cycle, in which the quality management possessed by consultant and contractor organizations plays a comprehensive role. Moreover, several quality management indicators were identified that also need priority to be maintained, such as the following.

Developing a construction (documentation) planning is an essential task in the management of a construction project [23], while the ability to construct a project depends on the result of the planning stage [24]. These authors further explain that the planning stage requires experts and competent planners, especially on what will be built and how to be built, while maximizing project resources [24].

Accordingly, the performance of the contractor is strongly determined by its partner's performance (i.e., planning consultants) in providing project planning documentation, including technical specifications, schedule, and budget.

On the other hand, the role of supervising engineers also contributes to the success of infrastructure project controlling stage. In reviewing the functions of the construction project consultants, the competence of the personnel in the consulting services company is particularly preferred. Research on the role of Project Management Consulting Firms (PMCs) confirms the concept of PMC in a construction project that resulted in substantial improvements in Malaysia's construction industry [25]. This study has confirmed that the construction services providers consider professional human resources, who are involved in the three stages of the infrastructure project life-cycle as one of the critical factors for successful project completion.

Besides the indicators of quality report documentation, management is responsible for assuring if the services are adequately delivered based on specification and contract assignment, and the adequate project resources are available. Also, it is necessary for the construction services providers to undertake a measurement process regarding their services and product realization in each stage of project life-cycle. These ensure that the construction services providers do comply with the QMS-ISO 9001:2008 standards, and most importantly the three main construction key-players understand their respective roles and their mutual interdependences.

Previous research on QMS implementation in construction industry, such as undertaken by Willar et al. [26], Leonard [27], Hoonakker et al. [28], and Shibani et al. [29], showed that the construction industry in fact facing difficulties in implementing their quality systems due to the dynamic characteristics of the construction industry and its project processes. However, in this current study, the results have shown that an improvement had been made by the three key-players certified QMS-ISO 9001, most importantly the contractors, to exist in the tight competition of national and global construction market.

V. Conclusion

Studies on the performance of Indonesian construction services providers during the infrastructure project life-cycle are recognized. All of the quality management indicators to comply with the QMS-ISO 9001:2008 are effectively implemented. The indicators cover the area of quality documentation, management responsibilities, human resources, product realization, and quality improvement during the project planning, project realization, and project controlling. Although these profiles are significant to assure that every construction key-players properly understand each stage of the infrastructure project life-cycle, there is a need to develop strong interdependences among the three main construction key-players that requires commitment and effective communication, as an attempt to produce qualified and sustainable infrastructure product, as well as to minimize disputes and conflict among them.

References

[1] Project Management Institute, A Guide to the Project Management Body of Knowledge (PMBOK Guide) 5th Ed. United States of America, 2013.

[2] J. R. Meredith, and S. J. Mantel, Jr., Project Management A Managerial Approach. Fourth Ed. New York, John Wiley & Sons, 2000.

[3] H. Hoeber, and D. Alsem, "Life-cycle information management using open-standard BIM," ECAM, vol. 23 no. 6, 2016, pp. 696-708.

[4] A. M. Adriaanse, Bruggen bouwen met ICT, 2014.

[5] A. J. Lordsleem, C. Duarte, and B. J. Barkokébas, "Performance indicators of the companies quality management systems with ISO 9001 certification," CIB 2010 World Congress, United Kingdom, 2010.

[6] P. Watson., and T. Howarth, Construction Quality Management. New York, Spon Press, 2011.

[7] D. Willar, B. Trigunarsyah, and V. Coffey, "Organisational culture and quality management system implementation in Indonesian construction companies," ECAM, vol. 23 no 2, 2016, pp. 114–133.

[8] D. Willar, Improving Quality Management System Implementation In Indonesian Construction Companies. PhD Tesis, QUT, 2012.

[9] R. K. Yin, Case Study Research Design and Methods, California, SAGE Publications, 2009.

[10] S. G. Naoum, Dissertation research & writing for construction students. Second Ed. Oxford, Butterworth-Heinemann, 2007.

[11] A. Fink, How to conduct surveys: A step-by-step guide. Fourth Ed. Thousand Oaks, SAGE Publications, 2009.

[12] S. S. Grobbelar, R & D in the National System of Innovation: A System Dynamic Model, Pretoria, University of Pretoria, 2007.

[13] M. J. Clayton, "Delphi: A Technique to Harness Expert Opinion for Critical Decision-Making Tasks in Education," Ed. Psych., vol. 17 no 4, 1997.

[14] G. Rowe, and G. Wright, "The Delphi technique as a forecasting tool: issues and analysis," I nt. J. Frcst., vol 5 no 4, 1999, pp. 353-375.

[15] A. Field, Discovering statistics using SPSS. Third ed. London, SAGE Publications, 2009.

[16] P. Rikkonen, J. Kaivo-oja, and J. Aakkula, "Delphi expert panels in the scenario-based strategic planning of agriculture," J. Future Studies, Strategic Thinking & Policy, vol 8 no 1, 2006, pp. 66-81.

[17] U. Sekaran, and R. Bougie, Research methods for business: A skill-building approach. Fifth Ed. Chichester-UK, Wiley, 2009.

[18] A. V. Alexandrov, P. M. Pullicino, E. M. Meslin, and J. W. Norris, "Agreement on Disease-Specific Criteria for Do-Not-Resuscitate Orders in Acute Stroke," Stroke, vol 27 no 2, 1996, pp. 232-237.

[19] L. R. Beaumont, ISO 9000, The standard interpretation: The international standard for Quality Management Systems. Third ed. Middletown: Simply Quality, 2006.

[20] Y. Ch. Yong, and N. E. Mustaffa, "Analysis of factors critical to construction project success in Malaysia," ECAM, vol 19 no 5, 2012, pp. 543-556.

[21] E. S. Andersen, D. Birchall, S. A. Jessen, and A. H. Money, "Exploring project success," Baltic J. Mgt., vol 1 no 2, 2006, pp. 127-147.

[22] L. D. Nguyen, S. O. Ogunlana, and D. T. X. Lan, "A study on project success factors in large construction projects in Vietnam," ECAM, vol 11 no 6, 2004, pp. 404-413.

[23] C. Hendrikson, and T. Au, Project Management for Construction – Fundamental Concepts for Owners, Engineers, Architects and Builders, Pittsburgh, Prentice Hall, 1989.

[24] C. Allen, and J. Smallwood, "Improving construction planning through 4D planning," J. Eng. Desn. Tech., vol 6 no 1, 2008, pp. 7–20.

[25] P. Nitithamyong, and Z. Tan, "Determinants for effective performance of external project management consultants in Malaysia," ECAM, vol 14 no 5, 2007, pp. 463-478.

[26] D. Willar, V. Coffey, and B. Trigunarsyah, "Examining the implementation of ISO 9001 in Indonesian construction companies," The TQM J., vol 27 no 1, 2015, pp. 94-107.

[27] D. Leonard, "Quality management practices in the US home building industry," The TQM J., vol 22 no 1, 2010, pp. 101-110.

[28] P. Hoonakker, P. Carayon, and T. Loushine, "Barriers and benefits of quality management in the construction industry: An empirical study," TQM, vol 21 no 9, 2010, pp. 953-969.

[29] A. Shibani, R. Soetanto, and E. Ganjian, "Implementation of Total Quality Management (TQM) in the Libyan Construction Industry (LCI)," CIB 2010 World Congress, United Kingdom, 2010.