©2021 International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies

ISSN 2228-9860 eISSN 1906-9642 CODEN: ITJEA8

International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies

http://TuEngr.com

Significant Factors Affecting Productivity of Offshore Pipeline Installation Projects in Malaysia

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Paper ID: 12A9N

Volume 12 Issue 9

Received 30 March 2021
Received in revised form 19 July 2021
Accepted 28 June 2021
Available online 08 July 2021

Keywords:
Factors affecting productivity, Offshore pipeline installation; Construction productivity; Experience and performance factors; Technical factors; Planning and scheduling factors; Project factors; Management factors.

Abstract

The oil and gas (O&G) industry is one of the sectors that contribute to the Malaysian economy. It involves planning, design, construction, and maintenance of upstream as well as downstream of related facilities such as offshore pipeline installation projects. The current standard of practice requires inspection and testing to be carried out to identify defects on welding works due to various factors including poor supervision during the welding process which affects the overall productivity of the pipe laying process. Thus, monitoring productivity is one of the most important aspects during offshore pipeline installation to avoid or minimize project delays. If the factors affecting productivity are not known or managed effectively, they will give impacts in terms of huge losses to the client, contractors, consultants, and other project stakeholders. This study identified significant factors affecting the productivity of offshore pipeline installation projects in Malaysia based on feedback from a survey administered to 100 stakeholders involved directly in the projects. Eighteen significant factors were identified which were grouped under five major components namely; planning and scheduling; experience and performance, technical, project, and management factors. This study brings important insights into productivity factors in the context of pipeline installation to assist the contractors and stakeholders to improve the productivity of offshore projects in Malaysia. It is envisaged that the empirical findings offer valuable information and new knowledge and contribute to the existing literature pipeline installation projects.

Disciplinary: Construction, Oil and Gas.

Cite This Article:

Isa, C. M. M., Zahrim, R. A., Saman, H. M., and Preece, C. N. (2021). Significant Factors Affecting Productivity of Offshore Pipeline Installation Projects in Malaysia. *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies, 12*(9), 12A9N, 1-10. http://TUENGR.COM/V12/12A9N.pdf DOI: 10.14456/ITJEMAST.2021.182

1 Introduction

Malaysia started to venture into O&G production and exploration in the 1970s when the Malaysian government established PETRONAS to own, explore and produce oil and gas in Malaysia under Petroleum Development Act 1974. Since its inception, the O&G industry has expanded to become the country's leading industry and has contributed massively to Malaysian economic growth. According to Malaysia's Gross Domestic Product (GDP) Structure FY2014, 16.7% of total GDP comes from the oil and gas industry alone. As the need for energy continues to grow at a rapid pace in tandem with the country's growth, most of the O&G-related construction activities were initiated such as oil and gas terminals, processing plants, gas pipelines, etc. Several growth and development programs to achieve the production targets are envisaged, consisting of projects for the construction of new surface facilities and up-gradation of the existing installations. This has created vast opportunities for international and national Engineering, Procurement, and Contract (EPC) Contractors to play vital roles in accomplishing these tasks (Khan, 2015).

To meet such demand, productivity in offshore construction plays a major role to meet each of the project goals namely cost, time and quality. However, offshore construction is a complex activity that requires high skill manpower spreading across multiple disciplines. It also typically comes with a tight schedule taking into account the high cost associated with any kind of offshore construction, good weather window, construction barge/vessel availability, worksite constraint, etc. (Fiori, & Kovaca, 2005). Due to the tight schedule, productivity has become a burgeoning factor in deciding the outcome of the project.

The low productivity in gas pipeline projects resulted in domino effects such as contractor and client reputation, delay in project utilization by end-users due to time overrun or schedule stretching, and escalating of cost. In turn, the contractor might need to increase manpower, tools, and equipment to minimize the delay (Enshassi et al., 2007). Thus, this study attempts to study the factors that affect the productivity of offshore pipeline installation projects. A complex offshore construction project involves high-skill manpower across multiple disciplines from a general construction worker, welder, rigger, foreman, diver, tower/vessel operator, vessel master, marine captain, construction engineer, survey engineer, vessel engineer, and many others. At times, the manpower spreading at multiple vessels or worksite locations requires highly coordinated planning and effective communication. Specifically, an offshore pipeline project involves stringent criteria that have to be followed in terms of technical, environmental, and safety. Hence, an offshore pipeline project normally has a different management framework and manpower background compared to typical building construction.

This study focuses on identifying the significant factors affecting the productivity of offshore pipeline installation projects.

2 Literature Review

Productivity can be referred to as the relationship between outputs and inputs (Borcherding, Sebastian & Samelson, 1980). Sumanth (1984) stated that productivity value can be obtained by dividing the output by one of the productivity factors. The inverse of labour productivity in terms of man-hours per unit (unit rate) is also commonly used for labour industry (Cooper, 2004). Productivity can also be referred to as the number of goods and services produced by a productive factor in a specified time unit for the manufacturing or service industry (Horner, Talhouni, & Thomas, 1989). Through a study by Jarkas (2005), the concept of productivity is a knack to produce or a desire to produce.

The construction industry can be defined as labour intensive industry whereby it requires extensive manpower to produce the desired output all through the construction process (Alberta, 2009). Generally, for the construction industry, productivity can be defined as the unit of work performed or produced per unit time preferably in terms of man-hour. There are three main criteria to be followed in order to increase productivity for the construction industry. The first criteria are to have greater resource allocation and human resource efficiency which means to have adequate material, equipment, consumables, and manpower for the specific construction process. The second criteria are effectiveness and engagement all through the construction process whereby all material, equipment, consumables, and manpower has no idle time in between the construction process. The third criterion is to be technologically savvy and innovative as all these years, the construction industry has developed rapidly and in parallel with construction technologies. Alberta (2008) also indicated that improving productivity in the construction industry is not necessarily cost or labour intensive, time-consuming, or difficult in terms of managing all the resources. However, it takes commitment and efficiency in terms of managing the construction process to identify areas for improvement. When the areas for improvement had been identified, productivity can be improved by working toward the improvement and maintaining the improvements over time (Alberta, 2009).

In construction projects, three main elements should be determined and continuously observed in planning efforts throughout the project from proposal preparation to project completion. These interacting elements called "triple constraint" are time, cost, and quality. Here, labour productivity is the key intermediate concept that has the potential to affect all of these elements and should be taken into account in understanding the possible interactions between them (Ulubeyli et al., 2014).

It has been identified from the literature that construction productivity is the main indicator of the performance of the construction industry. Construction productivity is directly related to labour as it is the most crucial and flexible resource used in construction projects. Productivity is influenced by various factors present on the project site. These factors are very difficult to consider during the measurement and estimation of production rates due to the varied and unique nature of every project (Oduba, 2002). Extensive work has been done by the researchers in terms of identifying both the qualitative and quantitative factors influencing the productivity on site such as weather, lack of equipment and material, labour skills, incompetent supervision, incompetent drawing, site conditions, project location, poor communication, number of workers, change orders, late payments, etc. (Arun et al., 2004; Ehshani et al., 2007; Jiukun Dai et al., 2009). Many researchers (Thomas, 1989; Olomolaiy, 1989; Horner & Talhouni, 1989; Christian & Hachey, 1995) studied the relationship of these factors with productivity to evaluate the impact of those factors.

Studies regarding factors contributing to productivity in other industries have been commonly explored decades ago (Borcherding et al., 1980; Sumanth, 1984; Horner et al., 1989; Jarkas, 2005) while some focused on building construction (Alberta, 2009; Ulubeyli et al., 2014; Khan, 2015). However, studies on the productivity of offshore pipeline installation projects subjected to different environments altogether as compared to common building construction are still lacking. In addition, not many significant reports of offshore pipeline installation in terms of productivity level are readily available.

Low productivity can lead to multiple chain reactions not only related to the project itself but can have a negative impact on various stakeholders such as overstretching project schedule, cost overrun, over utilizing of marine spread who may have other job commitments upon project completion and ultimately unable to meet the targeted date of the pipeline utilization by end-user (operator). Any kind of offshore installation involves a vast amount of capital and resources, and mitigating delay has been a top priority. According to a study on the analysis of critical issues of delays in oil and gas construction projects (Khan, 2015), out of 70 factors that have been identified, low productivity factors are at the top 10 of the most frequent factors that cause delay and among them are scope variation, shortage of skilled labour, inadequate planning and scheduling, poor subcontractor performance, lengthy contract awarding process, and construction mistakes.

2.1 Factors Affecting Productivity

There are many factors affecting productivity that have been identified from previous studies in relation to construction projects. To increase the productivity in construction, the identification of the factor that could affect the productivity of construction is vital as it has been a serious issue among the key players of the industry (Motwani et al., 1995). Keeping in mind the end goal to determine approaches to lessen the likelihood of having low productivity and increase the work progress, one must have the ability to distinguish the important factor that influences the productivity in construction. Lim and Alum (1995) studied the factors affecting the productivity of the construction industry in Singapore. Their findings indicated that the most important problems affecting productivity were difficulty with the recruitment of supervisors, difficulty with the recruitment of workers, high rate of labour turnover, absenteeism from the work site, and communication problems with foreign workers.

Based on the literature review, a conceptual framework is established as shown in Figure 1. The independent variables are the factors that may influence the level of productivity of offshore pipeline installation projects. Fifty-two factors were identified from the literature view which is related to clients, contractors, consultants, and other relevant parties. These factors were used in the development of the questionnaire which is further explained in the methodology chapter.

Figure 1: Conceptual Framework on Productivity Improvement for Offshore Pipeline Installation Projects in Malaysia.

3 Methodology

The methodology section describes the rationale of the overall research design that has governed the execution of this study. This study adopted a quantitative research method, where the primary data collection was based on the questionnaire survey distributed to the parties involved in the offshore pipeline installation projects, namely client, consultant, contractors/sub-contractors and suppliers, and other relevant parties. The questionnaire was designed based on the factors that affect the productivity of offshore pipeline installation projects identified through the literature review. The questionnaire was designed into two sections; company background and their opinions on the factors affecting the productivity of offshore pipeline installation projects.

The respondents' background was based on their type of organization, years of working experience in the construction industry, and years of involvement in offshore projects. In general, the respondents comprised four important parties involved in offshore pipeline installation projects in Malaysia, namely clients, consultants, contractors, and subcontractors. The majority of them had more than 10 years of experience in the construction industry and were involved in more than 10 offshore pipeline installation projects. Therefore, the respondents' had the knowledge and technical experience to contribute their point of view, feedbacks, and inputs that are valuable and beneficial for this study to improve the productivity of offshore pipeline installation projects.

4 Result and Discussion

Various factors influencing the productivity of offshore pipeline installation projects have been evaluated by the respondents based on a 5-point Likert scale. These factors were analysed to assess their correlations and establish internal reliability. Factor Analysis using Principal Axis Factorial (PAF) was used to measure the independent variables. PAF is used as the data reduction technique on the 52 items with direct-oblimin with Kaiser Normalization as shown in Table 1.

Factor loadings of greater than 0.5 were retained. In summary, based on the criteria set earlier, a five-factor solution resulted in 20 items with factor loadings above 0.50 with eigenvalues above Kaiser's criterion of 1 and in combination explained 70.892% of the variance. The good Communalities (greater than 0.6) also indicated that the factor analysis was suitable. The Kaiser-Meyer-Olkin (KMO) values verified the sampling adequacy for the analysis, KMO = .723, and all

KMO values for the individual item were well above the acceptable limit of .50. Barlett's test of sphericity χ^2 (190) = 721.103, $p < .001$, indicated that correlations between items were sufficiently large for PAF. In addition, a reliability test using Cronbach's coefficient was conducted to measure the internal consistency of the factors (independent variables). It showed that the component extracted from this analysis indicated high reliability of internal consistency where the value for each component exceeded .60; Planning and Scheduling Factor (α = .654); Experience and Performance Factor (α = .667); Technical Factor (α = .756); Project Factor (α = .632) and Management Factor (α = .656). In addition, the overall items when combined also showed a very good internal consistency (α = .796)

Table 1: Factor Loading Using Principal Axis Factoring (PAF).

Component	Factor Loading					Communalities
	1	2	3	4	5	
1. Planning and scheduling factor	0.794					0.732
Ineffective planning and scheduling of project by contractor	0.763					0.713
Interfering with other project (lack of coordination)	0.647					0.689
Poor site management and supervision by contractor	0.637					0.632
2. Experience and performance factor						
Incompetent welders		0.805				0.795
Lack of training for handling equipment for the welding process		0.796				0.791
Inadequate contractor experience		0.778				0.654
Fatigue due to working long hours		0.687				0.612
Insufficient manpower		0.665				0.613
3. Technical Factor						
Defects on the welding of the pipeline			0.835			0.786
Poor supervision in a welding process			0.833			0.765
Poor supervision in a pipe laying process			0.823			0.763
Delay in performing inspection and testing by the contractor			0.765			0.732
Slow decision making on technical matters			0.754			0.715
4. Project Factor						
Unrealistic contract duration by client				0.720		0.705
Delay in approving major changes in the scope of work by consultant				0.615		0.654
5. Management Factor						
Unavailability incentive for the contactor for finishing ahead of schedule					0.653	0.678
Delay to furnish and deliver the site by the client					0.647	0.634
Fluctuation in material price					0.530	0.612
Eigenvalues	8.07	1.34	1.30	1.05	1.00	
% of Variance	44.86%	7.46%	7.21%	5.81%	5.57%	
Cumulative of variance%	44.86%	52.31%	59.52%	65.33%	70.89%	
Cronbach's Alpha (n)	0.654 (7)	0.667 (9)	0.756 (8)	0.632 (6)	0.656 (4)	
Overall items Cronbach's Alpha	0.796 (34)					

The Skewness and Kurtosis statistics test was performed to meet the assumption of normality. It was found that all variables were normally distributed since the coefficients were in the range of ±1.0. A normal Q-Q plot was used to measure the normality of the variables which revealed that the majority observed values (smaller dots) laid on the straight line of the Q-Q plots, indicating that all factors were approximately normally distributed. The extraction methods commonly used in the published works of literature for both Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) are the Principal Components Analysis (PCA) and Principal Axis Factoring (PAF) (Kaiser, 1970). As suggested by Pallant (2011b), following PCA analysis, PAF should also be conducted for comparison and assessment of best fit. In other words, whichever rotated solution produces the best fit and factorial suitability, both intuitively and conceptually should be used. Hence, in this study, the PAF is empirically found to offer the best fit and is used to analyse the responses of the fifty-two items in the questionnaire. Validity tests (KMO and Bartlett and correlation matrix) have proven that factor analysis is appropriate for this study. Thus, factor analysis using Principal Axis Factorial (PAF) as data reduction technique on the 52 items (Direct-oblimin with Kaiser normalization) has grouped 19 significant loaded factors into five components namely, planning and scheduling factor, experience and performance factor, technical factor, project factor, and management factor.

4.1 Discussion on the Significant Factors Affecting Productivity of Offshore Pipeline Installation Projects

Factor analysis resulted in 19 significant loaded factors that were grouped into five components namely, planning and scheduling; experience and performance; technical; and project and management.

4.1.1 Planning and Scheduling Factors

Four planning and scheduling factors were ineffective planning and scheduling of the project by the contractor, interfering with other projects (lack of coordination), and poor site management and supervision by the contractor. The planning and scheduling were very important since, for every pipe installation project, a progress measurement is created for each activity to monitor the progress or productivity of each work related to the project. When many projects run at the same time, all resources must be properly assigned to ensure adequacy, especially for offshore pipeline installation projects. Thus, good supervision by the contractor or project manager is very important to avoid low productivity or project delay.

4.1.2 Experience and Performance Factors

Five experience and performance factors include incompetent welder, lack of training on handling equipment, inadequate contractor experience, fatigue due to working long hours, and lack of manpower. The offshore pipe-laying process involves many types of equipment such as the automatic welding machine, blasting equipment, bevelling equipment, etc. Thus, the skills in handling the equipment have to be improved through regular training in handling equipment. The process of the offshore pipeline installation project is governed by the welding activity. To have a competent welder on site, it is very important to reduce the downtime of the project due to welding defects. Having competent welders on-site could reduce the risk of project delay.

4.1.3 Technical Factors

Five technical factors are related to defects in the welding of the pipeline, poor supervision in the welding process, poor supervision in the pipe-laying process, delay in performing inspection and testing by contractor, and slow decision making on technical matters. Welding works are one of the activities in the pipe laying process. The current standard practice shows that performing inspection and testing is very important especially in relation to welding works. Through testing and inspection, the welding of the pipes is inspected; thus, a delay in performing inspection and testing will result in project downtime. The survey findings show that the long duration of the welding repair is highly due to the process. However, repair work cannot be avoided. Although the welding activity is carried out by using an automated welding machine, competent welders are needed to supervise it closely.

4.1.4 Project Factors

Two project factors are the unrealistic contract duration by the client and delay in approving major changes in the scope of work by the consultant. According to Kadir et al. (2005) in their study regarding factors affecting construction labour productivity for Malaysian residential projects, unrealistic contract duration and delay in approving major changes in the scope of work by the consultant are listed as the top 5 of the factors listed. Effective project management has to be implemented in order to deal with all the changes in the scope of work in construction. Delay in approving changes in construction will lead to project downtime. Thus, these changes have to be investigated quickly in order to mitigate project delays.

4.1.5 Management Factors

Three management factors are based on the unavailability incentive for contractors to finish the project ahead of schedule, delay to furnish and deliver the site by the client, and fluctuation in material price. Giving an incentive to the contractor for finishing ahead of schedule could boost up the performance of the workers and eventually increase the performance of the project. An incentive may be in the form of sharing the profit gained by cost savings due to finishing ahead of schedule. The procurement department plays an important role in searching for the best vendors when purchasing the materials and equipment in the market. Fluctuation of material price is a common issue and the risks are not as high as the technical issue which seldom contributes to project delay. However, this issue has to be properly addressed to ensure the smooth flow of the purchasing process.

5 Conclusion

Productivity in offshore construction involves complex activities that require high skill manpower that spreads across multiple disciplines and acts as a major role to meet the project goals namely, cost, time, and quality. This study was carried out using a quantitative approach using a survey questionnaire administered to parties involved to identify the factors affecting the productivity of offshore pipeline installation projects. The findings show that planning and scheduling, experience and performance, technical, project, and management factors have significantly affected productivity. Thus, these factors should be managed effectively by the stakeholders, otherwise, they will give impacts in terms of huge losses to the clients, contractors, consultants, and other parties involved in the pipeline installation projects. This study brings important insights on the productivity factors of pipeline installation to assist the contractors and other stakeholders to improve the productivity of offshore projects in Malaysia. It is envisaged that the empirical findings offer valuable information and new knowledge which contributes to the existing literature pipeline installation projects. It is recommended that an in-depth future study is carried out on the effectiveness of offshore pipeline installation processes.

6 Availability of Data and Material

Data can be made available by contacting the corresponding author.

7 Acknowledgement

The authors would like to thank Universiti Teknologi MARA Malaysia for providing the technical support needed and all industry participants involved in this research.

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