The effect of heavy equipment management on the performance of the construction project and the construction company

A S Nugraha¹, L S Putranto¹

¹Tarumanagara University, Department of Civil Engineering Jakarta 11440, Indonesia

*anggriis@yahoo.com; lexy_putranto@yahoo.co.id

Abstract. The appropriate use of heavy equipment will affect the progress of a construction project. An inappropriate choice of heavy equipment will result in low productivity and at the end will incur additional costs. Previous studies have been observing separately the effect of heavy equipment management on the performance of the construction project and the effect of heavy equipment of the performance of the construction company. In this present paper, using structural equation modelling (SEM), both relationships will be studied simultaneously and additionally direct effect of performance of construction project on the performance of construction company will be observed as well. It was found that both relationships were significant and positive.

1. Introduction

According to Tatari and Skibniewski [1], construction equipment management is associated with procurement, retirement, replacement, operation, logistics, and maintenance of the equipment. The business objective of heavy equipment company is to minimize operation, maintenance and repair costs whilst keep maximizing the utilization of the equipment. These responsibilities can be classified into two groups, i.e. operational and strategic. These responsibilities are held by the project manager to determine the equipment requirement within a specific time period.

In Canada, according to Lucko [2], Fan et al [3], and Hendi [4] maintenance, operation, repairaim, and replacements were factors affecting heavy equipment in construction. Gunawardena [5] conducted a study on 22 heavy equipment companies in Sri Lanka to find factors affecting heavy equipment management. The result was equipment choice, equipment finance, equipment maintenance equipment replacement and equipment record. In India Anbhule and Kumthekar [6] developed a design concept of equipment system for toll road construction project. On their system, appropriate design, equipment choice, equipment, installation, operation, and replacement became important factors in construction heavy equipment management.

Performance of construction project can be affected by the characteristics to the stakeholders such as owner, contractor and project managers. These characteristics usually consist of several factors, measurements, and indicators to describe whether construction project performance is going in the right direction. Besides costs, quality and time, according to Yeung et al. [7], Toor & Ogunlana [8], Cha & Kim [9] LaBarre & El-adawaty [10] health and safety of construction workers were also factors affecting the performance of the construction projects. Additionally, according to
Chan & Chan [11], Cheung et al. [12], Ugwu & Haupt [13] and Cha & Kim [9], environment and safety and finally according to Chan & Chan [11], Toor & Ogunlana [8] and Yeung [7] stakeholders satisfactions became important factors to measure the performance of construction projects.

Larsspm et al. [14] examined the importance of hard project management and team motivation in process performance in construction. Hard project management is based on rigorous planning and control. An analysis using structural equation model was conducted, with and without a mediating link between hard project management and process performance, based on data from a survey of 2,175 respondents, representing contractors and clients from 109 Swedish construction projects. The results confirm that hard project management is best executed through teams to improve process performance. “Path analysis,” using the model with the mediating link, verifies that neglecting team motivation can undoubtedly weaken process performance.

This present paper was prepared in order to revealed whether in the Greater Jakarta there were relationships between:

1. The heavy equipment management and the performance of the construction project.
2. The performance of the construction project and the performance of the construction company.
3. The heavy equipment management and the performance of the construction company.

Additionally, we also wanted to reveal whether the performance of the construction project can mediate between the heavy equipment management and the performance of the construction company.

2. Method

The current research was conducted in the Greater Jakarta. We interviewed 104 respondents, consist of project managers, general managers, site managers, equipment managers and competent engineers who were knowledgeable on heavy equipment management. The questionnaires to be used to assist the interview process were consist of 4 parts, the general data, the perception of respondents regarding the level of importance of heavy equipment management, the perception of respondents regarding the level of importance of factors affecting the performance construction project and finally, the perception of respondents regarding the level of importance of factors affecting the performance of the construction company. The general data consist of the name, the age, the position in the construction company, type of construction company (private, state-owned, foreign and others), employment length and education attainment of the respondents.

Questions regarding the level of importance of heavy equipment management consist of four sub- parts, i.e.:

X.1. The choice and ownership of heavy equipment:
1. Choice of the type of heavy equipment used based on the type of project.
2. The plan for heavy equipment choice.
3. The plan of the choice of usage duration of heavy equipment.
4. The plan of the choice of usage of heavy equipment type.
5. The plan of the choice of the number of heavy equipment used.
6. The choice of method of heavy equipment ownership (buy, rent, lease).
7. The project location (seaside, plateau, etc).
8. The field condition at the project.
9. The limitation of heavy equipment choice (traffic regulation, cost, and demolition).
10. The choice of heavy equipment vendor.
11. The final evaluation of heavy equipment choice.

X.2. The maintenance and repair of heavy equipment:
1. The pre-determined schedule of heavy equipment maintenance.
2. The preparation of all required resources to conduct efficient maintenance
3. The maintenance strategy (preventive steps at a heavy equipment maintenance plan).
4. The cost estimate of heavy equipment maintenance (additional costs, additional technicians, etc.).
5. The necessary repair during heavy equipment operation.
6. The experience of technician conducting repair and maintenance.
7. The communication between the technicians, the planners' group and the strategic managers.

X.3. The operation of heavy equipment:
1. The use of heavy equipment according to the project characteristic.
2. The availability of the heavy equipment for the operation
3. Determination of the number of hours of daily use of heavy equipment.
4. The working method of the heavy equipment used.
5. The skill of a heavy equipment operator.
6. The appropriate recruitment of heavy equipment operator.
7. The development of heavy equipment operator through training.
8. The communications between heavy equipment operators

X.4. The Replacement of heavy equipment:
1. The evaluation of overall owned heavy equipment.
2. The justification of the replacement of heavy equipment (inefficient heavy equipment, economical age of heavy equipment has been last.
3. The budget preparation for heavy equipment replacement.
4. The managerial planning for unused heavy equipment.
5. The replacement of obsolete heavy equipment types.

Questions regarding the level of importance of the performance of a construction project:

Y.1.1. Cost factors:
1. The cost control of every construction project which uses heavy equipment.
2. The manpower cost related to heavy equipment.
3. The operation cost related to the heavy equipment (fuel, lubricant, tires, etc.)
4. The cost control towards contingency cost (heavy equipment

Y.1.2. Quality factors:
1. The achievement of the working quality of the heavy equipment used.
2. The number of errors conducted during the heavy equipment operation.
3. The routine heavy equipment quality control.
4. The number of reworks.

Y.1.3. Time factors:
1. The schedule control for each construction work using heavy equipment.
2. The punctuality of the heavy equipment delivery time to the project.
3. The time lost due to a temporary break (heavy equipment repair, accident, etc.)
4. The bad plan of the working schedule.

Y.1.4. The health and safety factors:
1. The number of accidents happens.
2. The number of fatal accidents involving workers.
3. The number of light injury in the accident involving the workers.
4. The number of serious injury in the accident involving the workers.
5. The costs of the accident in the project.
6. The time lost due to the accident.

Y.1.5. The environment factors:
1. The project does not cause air pollution surrounding the project.
2. The project does not cause water pollution surrounding the project.
3. The project does not cause dangerous waste for the environment.
4. The sound level due to the heavy equipment.
5. The project does not cause damage due to the heavy equipment (access road, effects of heavy equipment vibration.)
Y.1.6. Stakeholders satisfaction factors:
1. The owner satisfaction of the construction project.
2. The consultant satisfaction of the construction project.
3. The contractor satisfaction of the construction project.
4. The supplier satisfaction of the construction project.
5. The supervisors' satisfaction with the construction project.

Questions regarding the level of importance of the performance of a construction company:

Y.2.1. Client factors:
1. The number of clients using the service from the construction company.
2. The client satisfaction affecting the construction company performance.
3. The involvement of the clients to the construction company.

Y.2.2. Financial factors:
1. The income of the construction company.
2. The profit of the construction company.
3. The number of assets owned by the construction company.
4. The small and appropriate ratio of company total debt to the income.
5. The policy of the leader of the construction company in managing expenses.

Y.2.3. Manpower factors:
1. The knowledge development through the training to the company employees.
2. The development of technological knowledge to the company employees.
3. The competence of the company employees in understanding heavy equipment management.
4. The attitude of the company employees in servicing the company clients.

Y.2.4. The company internal condition factors:
1. The number of employees in the company.
2. The growth of the number of employees in the company.
3. The increase of the employee incomes in the company.
4. Employee satisfaction in the company.

Y.2.5. The company competitiveness factors:
1. The image and credibility of the company in the eyes of the clients.
2. The innovation or technology advancement used by the company.
3. The appropriate company marketing.
4. The appropriate social relation with the stakeholders.

The collected data were then analyzed using structural equation model.

3. Data Summary
Almost all of the mean of each observed indicators was above 3.00. The only exceptions were Y6.4 (2.94) and Y6.5 (2.88). Even these mean values were still higher than 2.5 (the departure from not important to important). Therefore, in general, in the perception of the respondents, all of the observed indicators were important. The followings were the data summary:
- Mean values of X1 was 3.51 and ranged between 3.03 and 3.89.
- Mean values of X2 was 3.32 and ranged between 3.04 and 3.53.
- Mean values of X3 was 3.34 and ranged between 3.14 and 3.71.
- Mean values of X4 was 3.13 and ranged between 3.03 and 3.28.
- Mean values of Y11 was 3.35 and ranged between 3.17 and 3.61.
- Mean values of Y12 was 3.18 and ranged between 3.06 and 3.33.
- Mean values of Y13 was 3.22 and ranged between 3.11 and 3.27.
- Mean values of Y14 was 3.16 and ranged between 3.09 and 3.34.
- Mean values of Y15 was 3.40 and ranged between 3.09 and 3.70.
- Mean values of Y16 was 3.16 and ranged between 2.88 and 3.51.
- Mean values of Y21 was 3.46 and ranged between 3.32 and 3.58.
• Mean values of Y22 was 3.43 and ranged between 3.12 and 3.79.
• Mean values of Y23 was 3.25 and ranged between 3.05 and 3.68.
• Mean values of Y24 was 3.30 and ranged between 3.01 and 3.62.
• Mean values of Y25 was 3.32 and ranged between 3.01 and 3.75.

4. Results and Discussions
The estimation result of the model is shown in Figure 1. It can be seen that at least there were 2 criteria for model fitness achieved. The $\chi^2=72.22$ (more than 0.05) and root mean square error of Approximation (RMSEA)<0.001 (less than 0.05). This implies that the empirical data fit with the model. All standardized loading factors (SLF) were more than 0.7. This implies that each indicator could reflect the relevant constructs. All of the construct reliabilities (CR) were more than 0.7 reflecting good reliability. All of the average variance extracted (AVE) were more than 0.5, showing adequate convergence. The structural model consists of 2 equations:

\[
\begin{align*}
Y1 &= 0.7545 X \\
Y2 &= 0.5949 X + 0.3618 X
\end{align*}
\]

**Figure 1.** The structural equation model
5. Conclusions and Recommendations

Based on the analysis, it was found that:

- The heavy equipment management (X) was affecting significantly and positively to the performance of the construction project (Y1).
- The performance of the construction project (Y1) was affecting significantly and positively to the performance of the construction company (Y2).
- The heavy equipment management (X) was affecting significantly and positively to the performance of the construction company (Y2).
- The performance of the construction project (Y1) was mediating significantly and positively between the heavy equipment management (X) and the performance of the construction company.

Based on the results, we suggest that the construction company in the Greater Jakarta should pay sufficient attention to the heavy equipment management as it was proved that, it was a significantly and positively related with heavy equipment management, both directly and through the performance of the construction project.

References

[1] Tatari O & Skibniewski M 2006 Integrated agent-based construction equipment management: Conceptual design Journal of Civil Engineering & Management 12(3) 231–6.
[2] Lucko G 2003 A statistical analysis and model of the residual value of different types of heavy construction equipment. Http://Scholar.Lib.Vt.Edu/Theses/Available/Etd-12032003-122642.
[3] Fan H, AbouRizk S, and Kim H 2005 Building intelligent applications for construction equipment management Proceeding of the ASCE International Conference on Computing in Civil Engineering, Cancun, Mexico, 12-15 July 2005 192-9.
[4] Hendi A 2007 Decision support system for equipment selection in construction projects Master Thesis, University of Alberta, Edmonton, Alberta, Canada.
[5] Gunawardena N D 1992 Construction equipment-management practices Annual Transaction of IESL 58-72.
[6] Anbhule Y R & Kumthekar M B 2013 3D equipment management system for highway construction projects: conceptual design IOSR Journal of Mechanical and Civil Engineering, 1(1) 103.
[7] Yeung J Chan, A Chan D Chiang, Y & Yang H 2013 Developing a benchmarking model for construction projects in Hong Kong Journal of Construction Engineering and Management 139(6) 705-16.
[8] Toor S & Ogunlana S O 2010. Beyond the ‘iron triangle’: Stakeholder perception of key performance indicators (KPIs) for large-scale public sector development projects. International Journal of Project Management 28(3) 228–36.
[9] Cha H S & Kim C K 2011 Quantitative approach for project performance measurement on building construction in South Korea KSCE Journal of Civil Engineering 15 1319–28.
[10] Labarre P S & El-adaway I H 2014 Project benchmarking : tool for mitigating conflicts, claims, and disputes through improved performance Journal of Legal Affair & Dispute Resolution in Engineering Construction 6(1) 1–7.
[11] Chan A P C & Chan A P L 2004 Key performance indicators for measuring construction success Benchmarking 11(2) 203-21.
[12] Cheung S O Suen H C H & Cheung K K W 2004 PPMS: a web-based construction project performance monitoring system Automation in Construction 13 361–76.
[13] Ugwu O O & Haupt T C 2007 Key performance indicators and assessment methods for infrastructure sustainability-a South African construction industry perspective Building & Environment 42 665–80.
[14] Larsson J Eriksson P E & Pesämaa O 2018 The importance of hard project management and team motivation for construction project performance *International Journal of Managing Projects in Business* **11**(2) 275-88.

Hendi, A. (2007). *Decision support system for equipment selection in construction projects,*