

Print ISSN: 2288-4637 / Online ISSN 2288-4645
doi:10.13106/jafeb.2020.vol7.no11.347

Risk Factors Affecting Equipment Management in Construction Firms*

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Received: August 01, 2020 Revised: September 20, 2020 Accepted: October 05, 2020

Abstract

Mechanization and automation constitute an essential stage in the production and operation of any company, as one of the determinants of increase in labor productivity and decrease in product price, while significantly contributing to shortening of the lead time. Businesses are, therefore, able to quickly put projects into operation, improving economic efficiency, quality, and aesthetics, which speeds up the national economic growth. For the construction industry to be the most effective, modern construction equipment is a necessity. It is one of the five main resources of a construction project. Thus, effective construction equipment management contributes to the success of a project and benefits the relevant construction companies economically. This paper presents the critical risk factors affecting equipment management and proposes suitable solutions. The questionnaire-based survey with experienced experts in the construction sector on the management of the likelihood and consequence of risk factors revealed thirty-two risks for equipment management in construction companies. These factors fell into six groups: (i) site organization-related risks; (ii) management-related risks; (iii) owner-related risks; (iv) supplier-related risks; (v) legal risks, and (vi) site condition-related and external risks. The results showed that management-related factors contributed to the most significant risks and problems for equipment management in construction companies.

Keywords: Construction Company, Equipment Management, Risk Management, Project Management

JEL Classification Code: L74, M11, M19, O32

*Acknowledgements:

This research is funded by University of Transport and Communications (UTC), Vietnam. The authors gratefully acknowledge Ho Chi Minh City Open University, Ho Chi Minh City, Vietnam, for supporting this research. We also would like to thank Dr. Thu Anh Nguyen, BIM Lab Director, and Ms. Mai Tuyet Tran, Master of Construction Management, Ho Chi Minh City University of Technology (HCMUT), VNU-HCM for helping this research.

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1. Introduction

The constant increase in Vietnam's population has contributed to the need to address a series of issues such as the building of infrastructure, urban transportation systems, and the building of houses (P. Nguyen & Nguyen, 2020; Pham, Dao, Cho, Nguyen, & Pham-Hang, 2019; Vu et al., 2020). Also, the recent, widespread increase in the number of high-rise office buildings, commercial centers, and apartment buildings has contributed to the dynamic growth of the construction market in Vietnam. This is both an opportunity and a challenge for construction companies when investing and applying new technology, construction methods, equipment and machines, and optimizing their utilization. Construction equipment can accomplish many more times than what the strength of human power can do. Also, Yeo and Ning (2006) confirmed a large proportion of equipment purchases and hired costs in the total cost of a construction project. The cost of the major equipment may be as high as 36% of the total project construction cost (Prasertrungruang & Hadikusumo, 2009; Prasertrungruang & Hadikusumo, 2007). However, construction companies in Vietnam do not have a strict or optimal equipment

management system. Existing equipment management-related processes for some companies include equipment procurement, supply, maintenance, and transfer only. There has been no optimal way to manage equipment from the beginning of the project and to link these processes into a closed cycle. All these manual and uncontrolled processes are, therefore, prone to risks and losses. This paper provides an insight into the risk factors in creating effective equipment management, and, thus, enable managers to take appropriate actions to improve management efficiency in project success and economic optimization.

2. Literature Review

The emerging Vietnamese economy has grown well in the Southeast Asia region in the recent years (Nguyen & Bui, 2020a, 2020b; Nguyen, Dang, & Ngo, 2019). Thus, an ever-increasing infrastructure demand has developed with a need to construct industrial buildings, residential houses, schools, bridges, roads, ports, hydropower plants, underground structures, etc. (Luong, Tran, & Nguyen, 2018; Sy, Likhitrungsilp, Onishi, & Nguyen, 2017). The demand, therefore, for construction equipment with high productivity and technical specifications has grown commensurately. Equipment includes movable property of diverse and abundant nature. In the construction industry, in particular, the equipment can be repeatedly reused, especially for high-rise building projects or other construction activities. The tendency is for the machinery to become more and more compact and versatile. Depending on how the installation or task is performed, some equipment can become machines with separate parts or include a synchronous machine line. This refers to mechanical, electrical, electronic, and other factors combined to transform energy and materials into specific products for a social life or to the fulfillment of one or more different functions for a project.

Equipment management involves the planning and control of equipment used for supply, import, and export during its life cycle. The goal of the management is to ensure that equipment is delivered on schedule, in the required quantity, quality, and type at affordable costs. Effective equipment management is meaningful for the performance of a project as well as of a construction company (Nugraha & Putranto, 2019). During the implementation phase of the project, the determination of the equipment period of usage and life cycle is vital to ensure the optimal use and to limit equipment downtime to avoid project delays (Randunupura & Hadiwattage, 2013). Besides, equipment also influences overall project costs and profitability (Prasertrunguang & Hadikusumo, 2009).

Equipment can be technically classified by construction phases (Schaufelberger & Migliaccio, 2019): (i) the underground construction phase: where there is a need for

excavators, bulldozers, graders, compactors, pile drivers, rebar bending and cutting machines, concrete pumps, and cranes; (ii) the frame construction phase: steel bending and cutting machines, concrete pumps, concrete mixers, formwork and bracing construction machines, tower cranes, and hoists; and (iii) the finishing phase: mortar mixers, material screen machines, forklifts, material transport vehicles (trolleys and forklifts), tower cranes, hoists, and electric winches, etc.

Equipment management effectiveness include the management of procurement, replacement, operation, repair, and maintenance (Tatari & Skibniewski, 2006). The equipment management process of a construction company usually consists of the following:

(a) Procurement and payment processes: A supervisor first proposes a warehouse keeper who then forwards it to the equipment supervisor. Next, the proposal is submitted to a Manager. After the manager's approval, it is returned to the warehouse keeper, who takes charge of sending the request to a supplier. After that, the supplier makes the delivery which is checked by the warehouse keeper. If the equipment satisfies the requirements, the warehouse keeper will receive it; otherwise, it will be returned to the supplier.

(b) Payment process: Upon the acceptance of the goods, the supplier sends a payment request to the equipment supervisor for inspection. Then, it is submitted to the manager for approval before payment.

(c) Delivery and receipt process: (i) Equipment reception process: Equipment is delivered to a construction site where it is received and checked by the warehouse assistant. If satisfactory, documents will be submitted to the warehouse keeper for signature and goods reception; conversely, if unsatisfactory, the warehouse keeper will return the equipment to the supplier; and (ii) equipment delivery process: Equipment is checked and certified by the warehouse assistant and warehouse keeper. After that, the documents are forwarded to the equipment supervisor for his or her review and signature and finally submitted to the manager. If approved, the document is returned to the warehouse keeper for the fulfillment of procedures and the release of the goods.

(d) Equipment repair process: Damage to the equipment is informed by the supervisor to the warehouse keeper, who then submits the proposal to the manager. If approved, the warehouse keeper makes a delivery request to send the equipment out of the site to a repairer. Once the repair is finished, the warehouse keeper will receive it back and put it in the warehouse.

3. Research Methodology

Based on the review of published literature in coordination with interviews of experienced experts in

construction equipment management, a questionnaire that included 32 risk factors for equipment management was developed as shown in Table 1 (Alaghbari et al., 2007; Assaf & Al-Hejji, 2006; Chan & Kumaraswamy, 1997; Gurmu & Aibinu, 2017; Naskoudakis & Petroutsatou, 2016; Petroutsatou & Giannoulis, 2020; Ramanathan, Narayanan, & Idrus, 2012; Samee & Pongpeng, 2016). Each question in the questionnaire involved two aspects,

namely, the likelihood and consequence of a risk factor (Sy, Likhitruangsilp, Onishi, & Nguyen, 2017). “Likelihood,” also known as the “frequency,” was denoted by the letter “L” while “consequence,” also known as the “impact,” was denoted by the letter “C” (Nguyen & Nguyen, 2020) (See Table 1).

Research methods and techniques used in this study are shown in Table 2:

Table 1: Risk factors for construction equipment management

Risk factors for construction equipment management	
I	Site organization-related risks
R1.1	Out-of-schedule usage period of equipment
R1.2	Planning for equipment earlier than the approval given in the method design document
R1.3	Disorganized arrangement of equipment on sites
R1.4	Damaged equipment during transportation and operation
R1.5	Inappropriate tools for equipment unloading and transportation
II	Management-related risks
R2.1	Insufficient budget for equipment purchase or hire
R2.2	Incorrect breakdown of equipment volume
R2.3	Insufficient knowledge about equipment in use
R2.4	Ineligible supervision skill of site engineers in charge of equipment
R2.5	Difficulties in the documents and procedures for requesting supply equipment from construction sites to companies
R2.6	Difficulties in the documents and procedures for equipment purchase or hire from companies to suppliers
R2.7	Vague and intermittent exchange of project information and plans between sites and companies
R2.8	Vague and intermittent communication between parties at sites
R2.9	Inadequate control of equipment in use
R2.10	Untimely equipment approval by management levels
III	Owner-related risks
R3.1	Unwilling to respond owners' requirements for equipment use
R3.2	Failure to meet equipment use plans due to design modification by owners
R3.3	Failure to meet equipment use plans due to changes in construction methods
R3.4	Failure to meet equipment use plans due to delayed approval of construction methods
IV	Supplier-related risks
R4.1	Incomplete documents on equipment
R4.2	Failure to meet the required production output
R4.3	Improper product quality
R4.4	Improper cooperation with companies

Table 1: Continued

V	Legal risks
R5.1	Equipment's ineligibility to meet the required paperwork for quality and origin
R5.2	Difficulties in equipment verification and testing
VI	Site condition-related and external risks
R6.1	Unfavorable equipment transportation time due to regulations on traffic timeframe
R6.2	Unfavorable equipment transportation time due to regulations on routes
R6.3	Unsatisfied warehouse area at construction sites
R6.4	Improper storage methods at sites
R6.5	Adverse impacts on equipment quality during transportation (from supply places to sites and to internal areas in sites)
R6.6	Security and order at construction sites (theft, fraud, etc.)
R6.7	Adverse weather conditions

Table 2: Research methods and techniques

No.	Research Method	Purpose
1	Data collection	To design questionnaires and to select sample sizes and sampling techniques.
2	Data description	To perform random descriptive statistics; to study according to classification variables (i.e., number of years of experience, types of projects, etc.)
3	Test of statistical assumptions	To assess differences between groups using T-test
4	Means	Frequency of occurrence of variables
5	Cronbach's Alpha	To measure and test Cronbach's Alpha scale reliability
6	Exploratory Factor Analysis (EFA)	To discover the basic structure of a set of interconnected variables that are more meaningful than the original structure.
7	Confirmatory Factor Analysis (CFA)	To analyze and affirm factors to confirm the distinctiveness from and compatibility with the collected data of any model.

4. Results and Discussion

A total of 75 questionnaires were sent to construction equipment management experts. This study was aimed at two types of construction companies: (i) large-size ones (ii) and small-sized ones in Ho Chi Minh City. However, only 67 out of 75 questionnaires were considered satisfactory. Thus, the ratio between the risk factor variables (32 factors) and the number of observed samples (67) was 1:2.1 times, which was acceptable. The survey results showed that the number of respondents with experience of 3-5 years, 1-3 years, 5-7 years, 7-10 years, and over 10 years accounted for 34.3%, 19.4%, 20.9%, 11.9% and 13.4%, respectively which are nearly equal (see Table 3). Fifty-nine point seven percent of respondents had participated in constructing apartment buildings, high-rise office buildings, shopping centers, townhouses, and villa projects at the highest, followed by 29%, 11.9%, 6%, and 1.5%, respectively. And the number

of respondents who had participated in the projects of above VND 200 billion and below <VND 50 billion accounted for 41.8% and 7.3%, respectively. To summarize, the majority of respondents with 3-5 years of experience, had participated in the construction projects worth over VND 200 billion, and had worked primarily in constructing apartment buildings. Each type of project required a variety of equipment, which featured multi-level repetitiveness, turnover, and coordination the respondents were eligible to engage in the survey on risk factors for equipment management (See Table 3).

Testing of the differentiation between two groups of large-sized (A) and small-sized companies (B) in terms of the likelihood and the consequence of risk factors was conducted. The results showed differences in the assessment of the two groups regarding five variables (R2.6), (R3.3), (R1.5), (R2.2), (R4.1), and (R1.4), as shown in Table 4. Therefore, these were no longer under consideration.

Table 3: Sample characteristics

Description	Frequency	Percent (%)
<i>Project type</i>		
Houses	4	6
Villas	1	1.5
High-rise office buildings	14	20.9
Shopping centers	8	11.9
Apartment buildings	40	59.7
<i>Experience</i>		
1- 3 years	13	19.4
3- 5 years	23	34.3
5- 7 years	14	20.9
7-10 years	08	11.9
> 10 years	09	13.4
Total	67	100
<i>Project value (VND billion)</i>		
< 20	2	3
20-100	21	31.3
100-200	16	23.9
> 200	28	41.8

Afterward, testing of the differentiation between the two groups of office staffs and site workers were carried out. The results showed the differences in the viewpoints of the assessment of only variable (R1.4) in terms of its consequence, so this variable was excluded (See Table 5).

After the above six variables were excluded using a t-test, scale reliability testing was conducted. This was essential to develop and verify the scale since it assessed the quality of the questionnaire. The scale reliability was tested in terms of “likelihood” and “consequence.” First, no measurement concepts failed to reach Cronbach’s Alpha of 0.70 and a higher and corrected item-total correlation of greater than 0.3 for the consequence. Second, the first time the scale was tested for “likelihood,” most of Cronbach’s Alpha coefficients were greater than 0.7, except for factor (R3.1) “Unwilling satisfaction of owners’ requirements for equipment use” was < 0.3 (0.258), which meant it was, therefore, no longer considered. The secondary result showed that for each factor group, the Cronbach’s alpha coefficient, and the corrected item-total correlation were ≥ 0.7 and ≥ 0.3 , respectively. Accordingly, the scale is reliable, and subsequent analyses were possible. Then, after the scale was tested to ensure its eligibility, the variables in “consequence” were further included in the EFA. The EFA aimed to reveal the structure of

Table 4: Results of variables in association with testing between the two types of companies

Risk factors		Levene’s Test for Equality of Variances		T-test for Equality of Means
		F	Sig.	Sig. (2-tailed)
<i>Likelihood</i>				
R2.6	Equal variances assumed	1.257	0.266	0.042
	Equal variances not assumed			0.038
R3.3	Equal variances assumed	0.576	0.450	0.044
	Equal variances not assumed			
<i>Consequence</i>				
R1.5	Equal variances assumed	1.210	0.275	0.007
	Equal variances not assumed			0.008
R2.5	Equal variances assumed	0.297	0.588	0.018
	Equal variances not assumed			0.019
R4.1	Equal variances assumed	0.107	0.745	0.036
	Equal variances not assumed			0.036

the scales in the study model. The final EFA results, exclusive of three factors (R2.10), (R2.8), and (R1.3), showed that KMO and the Bartlett test reached 0.790 (> 0.5) and Sig. = 0.000 (<0.05), respectively (see Table 6 and Table 7). It was concluded that the observed variables were interrelated.

Table 5: Results of T-test between office staffs and site workers

Risk factors	Levene’s Test for Equality of Variances		T-test for Equality of Means
		F	Sig. (2-tailed)
R1.4	Equal variances assumed	0.752	0.008
	Equal variances not assumed		0.034

Table 6: KMO and Bartlett’s test results

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.790
Bartlett’s Test of Sphericity	Approx. Chi-Square	930.694
	df	253
	Sig.	.000

Table 7: Total Variance Explained

Component	Eigenvalues			Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.207	35.681	35.681	8.207	35.681	35.681
2	2.943	12.796	48.478	2.943	12.796	48.478
3	1.873	8.145	56.622	1.873	8.145	56.622
4	1.630	7.085	63.707	1.630	7.085	63.707
5	1.105	4.806	68.513	1.105	4.806	68.513
6	1.033	4.492	73.005	1.033	4.492	73.005
7	0.816	3.547	76.553			

At the Eigenvalues value = 1.033 (>1), EFA extracted 6 from 23 observed variables with a total variance of 73.005% (>50%), and no new factors that were not included in the original model were formed. In the framework of EFA, observed variables had factor loads ranging from 0.612 to 0.887 (i.e., greater than 0.5). Thus, after the third EFA, all of these 23 observed variables met the EFA criteria, so no variables were excluded at this stage. Details on the third EFA are presented in Table 8 below.

The new structure generated from the EFA (with 23 factors) for “consequence” was adopted to conduct the CFA on the “likelihood” data which had been examined in terms of differentiation and reliability. The adjustment results of the covariance relationship between the errors of observed variables through MI (Modification Indices) showed that the chi-square/df=1.318 <2, pvalue = 0.002 was significantly statistical, TLI=0.914, CFI=0.927 > 0.9, RMSEA=0.069 < 0.8, and the standardized factor weights of observed variables against those of latent variables were greater than 0.5. These indicators all met the applicable conditions, so it was concluded that the measurement model was consistent with the collected data. The results of the critical CFA tests are shown in Figure 2.

Based on the above tests, this latest structure included factors that were eligible for further analysis in terms of reliability, convergence, and differentiation. The results obtained served

as the basis for the following conclusions on the factors: (i) Factors have not only a high likelihood but also a significant consequence for equipment management. The risk score was equal to the product of the multiplication of means; and (ii) The order of a risk factor group’s consequences for equipment management is calculated using the factor loading-based mean of the group. The summarized results are shown in Table 9:

Regarding likelihood (L), the results showed that the five most frequent factors belonged to group 2 (Management-related risk) and group 6 (Site condition-related and external risks), including (R2.1), (R2.3), (R2.9), (R6.1) and (R2.5). Regarding the consequence (C), the results showed that five risk factors having the most tremendous consequences for equipment management to which construction companies need to pay attention were (R2.1), (R1.1), (R2.9), (R2.7) and (R4.3), which were included in group 1 (Site organization-related risks) and group 2 (Management-related risks). In general, the results showed that the five most important risk factors in equipment management, to which construction companies should pay attention, were (R2.1), (R2.9), (R1.1), (R2.7) and (R2.3), and the factor group with the most significant consequence for equipment management as well as others was group 2 “Management-related risks.” The five risks factors discussed in further detail below to facilitate the recommendations of relevant solutions.

Table 8: Results of the third EFA

	Component					
	1	2	3	4	5	6
R6.1	0.867					
R6.2	0.867					
R6.3	0.799					
R6.6	0.753					
R6.5	0.742					
R6.4	0.740					
R6.7	0.725					
R2.5		0.833				
R2.7		0.809				
R2.3		0.757				
R2.1		0.673				
R2.9		0.647				
R2.4		0.615				
R4.3			0.873			
R4.2			0.795			
R4.4			0.791			
R3.2				0.804		
R3.1				0.730		
R3.4				0.612		
R1.2					0.887	
R1.1					0.738	
R5.2						0.850
R5.1						0.715

a) “Insufficient budget for equipment purchase or hire” (R2.1) is the most significant risk in the equipment management of construction companies (12.349). Indeed, unsound corporate finances, in reality, is a frequent problem. Failure of project-involved plans is inevitable if the financial situation is not sound. It adversely affects not only the execution plans of a project but also equipment purchases or hiring plans. This is particularly true in the construction sector, especially for high-value equipment such as tower cranes and hoists. Moreover, unsound finance, accompanied by inadequate quality equipment from suppliers, results in serious financial loss. It often takes much time to repair or change poor quality equipment, which disturbs equipment management in construction projects. In short, to cope with the financial risks as well as to diminish the initial financial burden on companies and to reduce operating costs of equipment,

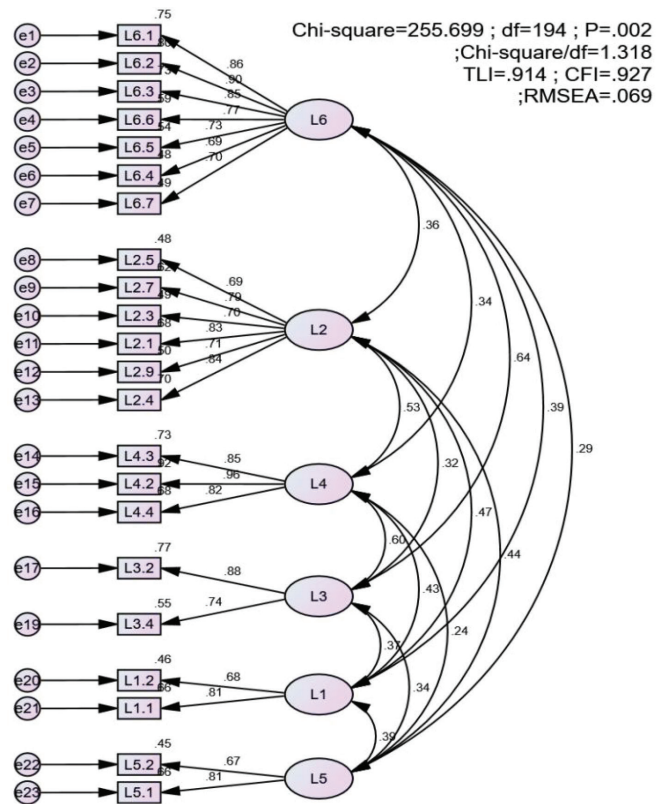


Figure 1: Results of factor analysis to confirm standardized CFA

construction companies can (i) buy used equipment at a lower price but with advanced functionality or technology; (ii) hire or rent equipment out of the regular use to avoid obsolescence; or (iii) purchase new or used equipment in light of the on-hand budget. In particular, the option of “hiring or renting equipment” has some advantages: (i) low initial investment; (ii) good upgradability to remove outdated equipment; and (iii) less concern about damage or loss of value.

b) “Inadequate control of equipment in use” (R2.9) was the second most important factor. Construction projects require diverse types and large quantities of equipment. Therefore, it is difficult to effectively manage without tight control. On the other hand, managers or engineers at construction sites tend to pay more attention to the quality and progress of projects rather than the quality and operation of equipment. Besides, to ensure the proper control following the given procedure, some companies require that all activities from the projects be approved by them, which is another obstacle to meeting demand at the sites. To strengthen the control over equipment, construction companies should use a conventional block diagram model or apply new algorithms such as artificial intelligence and genetic algorithms to optimize the operating time and location of equipment (Haidar, Naoum, Howes, & Tah, 1999; Long, Tran, & Nguyen, 2019; Ramakrishnan, Shabbir, Kassim, Nguyen, & Mavaluru, 2020).

Table 9: Summary of results

N	Factors	C	L	Factor loading	R = CxL	Average
		(1)	(2)	(3)	= (1)x(2)	(2)x(3)/n
I	Site organization-related risks					
1	R1.1	3.522	3.104	0.814	10.935	2.333
2	R1.2	3.254	3.149	0.679	10.248	
II	Management-related risks					
3	R2.1	3.597	3.433	0.828	12.349	2.474
4	R2.3	3.209	3.269	0.697	10.490	
5	R2.4	3.179	3.149	0.836	10.011	
6	R2.5	3.134	3.239	0.693	10.151	
7	R2.7	3.373	3.194	0.791	10.773	
8	R2.9	3.418	3.269	0.709	11.173	
III	Owner-related risks					
10	R3.2	3.090	2.701	0.878	8.346	2.206
11	R3.4	3.030	2.761	0.739	8.366	
IV	Supplier-related risks					
12	R4.2	3.119	2.627	0.960	8.194	2.269
13	R4.3	3.373	2.642	0.854	8.911	
14	R4.4	2.552	2.463	0.824	6.286	
V	Pháp lý					
15	R5.1	2.970	2.597	0.809	7.714	1.975
16	R5.2	3.030	2.746	0.673	8.321	
VI	Site condition-related and external risks					
17	R6.1	3.194	3.269	0.863	10.441	2.438
18	R6.2	3.179	3.194	0.895	10.154	
19	R6.3	3.254	3.119	0.854	10.149	
20	R6.4	3.075	2.910	0.693	8.948	
21	R6.5	2.970	2.821	0.733	8.378	
22	R6.6	3.179	2.970	0.769	9.442	
23	R6.7	3.164	3.015	0.701	9.539	

c) The out-of-schedule usage period of equipment” (R1.1) was the third most important factor. It meant that the management for out-of-schedule implementation faced many difficulties because an essential feature of construction equipment is turnover, which can fail and affect the progress of any project if the given plans cannot be met. Undoubtedly, a construction company should establish the progress of any of its projects under CPM and find its critical path (Lambert & Cooper, 2000). Then, focusing on solving one or more job sequences throughout the project that are important and critical is necessary.

d) “Vague and intermittent exchange of project information and plans between sites and companies” (R2.7) is also an important factor that has a significant impact on the equipment management of companies. The demand for equipment in a project must be approved by a relevant construction company (which, at its discretion, selects the new purchase, rent, or transfer of equipment). Therefore, the vague and intermittent communication between projects or sites and companies will affect the progress and form of equipment supply. This has a significant influence on equipment management in construction projects as well

as in the companies. To cope with this risk, construction companies should: (i) take advantage of the management information system software to make the communication simple, fast, and professional; (ii) make precise and accurate reports and status reports on equipment on a daily or weekly basis; and (iii) adjust the implementation schedule of the projects in case of any unexpected failures of equipment.

e) “Insufficient knowledge about equipment in use” (R2.3) is of equal importance. Currently, there are a number of types of equipment, and the technology of the equipment is so advanced and sophisticated that companies have not used it before (Lee & Xuan, 2019; Li et al., 2020). As a result, inadequate knowledge about the equipment in use becomes a major hurdle. To get rid of this problem, the companies should work in coordination with equipment sellers to organize training sessions under the instruction of the companies’ equipment management department or experienced equipment management experts. Additionally, due to the distinctive features of Vietnam as a country, (Unfavorable equipment transportation time due to regulations on traffic timeframe) (R6.1) is also quite important. The reason is that the majority of respondents work at projects in Ho Chi Minh City, the largest city of Vietnam, where traffic jams frequently and inevitably occur. Therefore, equipment transportation in the prescribed traffic hours or on prescribed traffic routes can have a significant impact on how long it takes to get to the site, which sometimes takes even a whole day for the prescribed transportation.

5. Conclusions

The performance of a project is dependent on the method and procedure of resource management, especially equipment management. Each construction company, regardless of whether it is large, medium, or small-sized, sets up its equipment management procedure. However, these equipment management procedures often are not interconnected or are not an optimal solution, so it is impossible to take the maximum advantage of the features of a particular piece of equipment, and this has a direct influence on the profitability of the project, especially in the case of high-rise building projects. With the construction companies’ desire to respond to risks and difficulties in equipment management and minimize their damages, this study has found 32 most influential factors that reduce the effectiveness of equipment management in Ho Chi Minh City, Vietnam. It also has proposed solutions to the most significant risks. These influential factors fell into six main groups: i) site organization-related risks; (ii) management-related risks; (iii) owner-related risks; (iv) supplier-related risks; (v) legal risks; and (vi) site condition and related external risks. In particular, group 2 (management-related

factors) contributed to the most significant problems for equipment management as well as others.

Also, the study results illustrated five risk factors that have a significant influence on and a high likelihood in equipment management: (i) insufficient budget for equipment purchase or hire; (ii) inadequate control of equipment in use; (iii) use of equipment out-of-schedule; (iv) vague exchanges of project information and plans between sites and companies; and (v) insufficient knowledge about the equipment being used. The author offers the following recommendations based on the results of this study: (i) expand the study scope, sampling scale, and the number of samples to obtain more accurate results; (ii) study and propose an equipment management process that is most appropriate under the conditions in Vietnam; (iii) require that persuasions and proofs are obtained so that the proposed solutions are effective for equipment management; (iv) Based on the findings of the influence factors on equipment management, require that there needs to be an emphasis on equipment plan management, equipment control, and the knowledge about equipment in use; and (v) Further, carry out studies on equipment management in combination with the progress of companies’ in-process projects. This would make the most of the equipment turnover and give the highest benefit to equipment owners.

References

- Alaghbari, W., Razali, A. Kadir, M., Salim, A., & Ernawati. (2007). The significant factors causing delay of building construction projects in Malaysia. *Engineering, Construction and Architectural Management*, 14(2), 192-206. <https://doi.org/10.1108/09699980710731308>
- Assaf, S. A., & Al-Hejji, S. (2006). Causes of delay in large construction projects. *International Journal of Project Management*, 24(4), 349-357.
- Chan, D. W., & Kumaraswamy, M. M. (1997). A comparative study of causes of time overruns in Hong Kong construction projects. *International Journal of Project Management*, 15(1), 55-63.
- Gurmu, A. T., & Aibinu, A. A. (2017). Construction Equipment Management Practices for Improving Labor Productivity in Multistory Building Construction Projects. *Journal of Construction Engineering and Management*, 143(10). [https://doi.org/10.1061/\(ASCE\)CO.1943-7862.0001384](https://doi.org/10.1061/(ASCE)CO.1943-7862.0001384)
- Haidar, A., Naoum, S., Howes, R., & Tah, J. (1999). Genetic algorithms application and testing for equipment selection. *Journal of Construction Engineering and Management*, 125(1), 32-38.
- Lambert, D. M., & Cooper, M. C. (2000). Issues in supply chain management. *Industrial Marketing Management*, 29(1), 65-83.
- Lee, J. W., & Xuan, Y. (2019). Effects of technology and innovation management and total factor productivity on the economic

- growth of China. *Journal of Asian Finance, Economics and Business*, 6(2), 63-73. <https://doi.org/10.13106/jafeb.2019.vol6.no2.63>
- Li, J., Li, H., Umer, W., Wang, H., Xing, X., Zhao, S., & Hou, J. (2020). Identification and classification of construction equipment operators' mental fatigue using wearable eye-tracking technology. *Automation in Construction*, 109. <https://doi.org/10.1016/j.autcon.2019.103000>
- Long, L. D., Tran, D. H., & Nguyen, P. T. (2019). Hybrid multiple objective evolutionary algorithms for optimising multi-mode time, cost and risk trade-off problem. *International Journal of Computer Applications in Technology*, 60(3), 203-214. <https://doi.org/10.1504/IJCAT.2019.100299>
- Luong, D. L., Tran, D. H., & Nguyen, P. T. (2018). Optimizing multi-mode time-cost-quality trade-off of construction project using opposition multiple objective difference evolution. *International Journal of Construction Management*. <https://doi.org/10.1080/15623599.2018.1526630>
- Naskoudakis, I., & Petroutsatou, K. (2016). *A Thematic Review of Main Researches on Construction Equipment over the Recent Years*. Paper presented at the Procedia Engineering.
- Nguyen, H. M., & Bui, N. H. (2020a). Energy consumption - Economic growth nexus in vietnam: An ARDL approach with a structural break. *Journal of Asian Finance, Economics and Business*, 7(1), 101-110. <https://doi.org/10.13106/jafeb.2020.vol7.no1.101>
- Nguyen, H. M., & Bui, N. H. (2020b). Revisiting the relationship between energy consumption and economic growth nexus in Vietnam: new evidence by asymmetric ARDL cointegration. *Applied Economics Letters*, 1-7. doi:10.1080/13504851.2020.1789543
- Nguyen, H. M., Dang, L. A. T., & Ngo, T. T. (2019). The effect of local foods on tourists' recommendations and revisit intentions: The case in Ho Chi Minh City, Vietnam. *Journal of Asian Finance, Economics and Business*, 6(3), 215-223. <https://doi.org/10.13106/jafeb.2019.vol6.no3.215>
- Nguyen, P. T., & Nguyen, C. P. (2020). Risk Management in Engineering and Construction: A Case Study in Design-Build Projects in Vietnam. *Engineering, Technology & Applied Science Research*, 10(1), 5237-5241.
- Nguyen, P. T., & Nguyen, Q. L. H. T. T. (2020). Critical Factors Affecting Construction Price Index: An Integrated Fuzzy Logic and Analytical Hierarchy Process. *Journal of Asian Finance, Economics and Business*, 7(8), 197-204. <https://doi.org/10.13106/jafeb.2020.vol7.no8.197>
- Nugraha, A., & Putranto, L. (2019). *The effect of heavy equipment management on the performance of the construction project and the construction company*. Paper presented at the IOP Conference Series. Materials Science and Engineering.
- Petroutsatou, K., & Giannoulis, P. (2020). Analysis of construction machinery market: the case of Greece. *International Journal of Construction Management*. <https://doi.org/10.1080/15623599.2020.1741491>
- Pham, H. C., Dao, N. N., Cho, S., Nguyen, P. T., & Pham-Hang, A. T. (2019). Construction Hazard Investigation Leveraging Object Anatomization on an Augmented Photoreality Platform. *Applied Sciences*, 9(21), 4477. <https://doi.org/10.3390/app9214477>
- Prasertrungruang, T., & Hadikusumo, B. (2009). Study of factors influencing the efficient management and downtime consequences of highway construction equipment in Thailand. *Journal of Construction Engineering and Management*, 135(1), 2-11.
- Prasertrungruang, T., & Hadikusumo, B. H. W. (2007). Heavy equipment management practices and problems in Thai highway contractors. *Engineering, Construction and Architectural Management*, 14(3), 228-241. <https://doi.org/10.1108/09699980710744881>
- Ramakrishnan, J., Shabbir, M. S., Kassim, N. M., Nguyen, P. T., & Mavaluru, D. (2020). A comprehensive and systematic review of the network virtualization techniques in the IoT. *International Journal of Communication Systems*, 33(7), 01-19. <https://doi.org/10.1002/dac.4331>
- Ramanathan, C., Narayanan, S., & Idrus, A. B. (2012). Construction delays causing risks on time and cost-a critical review. *Construction Economics and Building*, 12(1), 37-57.
- Randunupura, S. N., & Hadiwattege, C. (2013). Plant and equipment management to minimize delays in road construction projects. *Socio-Economic Sustainability in Construction*, 14-15. https://www.irbnet.de/daten/iconda/CIB_DC26728.pdf
- Samee, K., & Pongpeng, J. (2016). Structural equation model for construction equipment management affecting project and corporate performance. *KSCE Journal of Civil Engineering*, 20(5), 1642-1656. <https://doi.org/10.1007/s12205-015-0717-1>
- Schaufelberger, J. E., & Migliaccio, G. C. (2019). *Construction equipment management*. London, UK: Routledge.
- Sy, D. T., Likhitruangsilp, V., Onishi, M., & Nguyen, P. T. (2017). Different perceptions of concern factors for strategic investment of the private sector in public-private partnership transportation projects. *ASEAN Engineering Journal*, 7(2), 66-86.
- Sy, D. T., Likhitruangsilp, V., Onishi, M., & Nguyen, P. T. (2017). Impacts of risk factors on the performance of public-private partnership transportation projects in Vietnam. *ASEAN Engineering Journal*, 7(2), 30-52.
- Tatari, O., & Skibniewski, M. (2006). Integrated agent-based construction equipment management: Conceptual design. *Journal of Civil Engineering and Management*, 12(3), 231-236.
- Vu, T. Q., Pham, C. P., Nguyen, T. A., Nguyen, P. T., Phan, P. T. & Nguyen, Q. L. H. T. T. (2020). Factors Influencing Cost Overruns in Construction Projects of International Contractors in Vietnam. *Journal of Asian Finance, Economics and Business*, 7(9), 389-400. <https://doi.org/10.13106/jafeb.2020.vol7.no9.389>
- Yeo, K. T., & Ning, J. (2006). Managing uncertainty in major equipment procurement in engineering projects. *European Journal of Operational Research*, 171(1), 123-134.