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CRITICAL FACTORS INFLUENCING INVENTORY AND PROCUREMENT SYSTEM OF INFRASTRUCTURE PROJECTS

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Abstract. The performance of any construction project is highly influenced by the efficient planning of materials among construction supply chain players. The improper planning for the construction project has been discussed recently in the literature, with a special focus on the logistic and material aspects. Completing a construction project within time and cost constraints is highly affected by the inventory management system. Such evidence proves the big impact of the inventory management system on construction performance. Derived from these arguments, the critical impact of the inventory and procurement system used at the construction site is definite. This research aims to examine the main factors that need to be considered when developing an inventory and procurement management system and classify the most influential and impactful factors. This research adopted a two-steps methodology, which started with an interview with construction experts then followed by a questionnaire survey targeting project managers and engineers from MRT Line 2 Tunneling infrastructure project in Malaysia. Exploratory Factor Analysis (EFA) was used for data analysis as well as the scatter plot of the mean and standard deviation analysis. The most critical factors affecting the inventory and procurement handling are related to the operation and management aspects. The top five impactful factors are communication between labor and management, information sharing, software usage on material tracking, purchasing plan, and construction progress. The research outcomes can be used to develop further mitigation plans in the early stages of infrastructure projects.

Keywords: inventory management, procurement management, logistics, planning, project operation and management, supply chain material.

Introduction

Large-scale construction project performance is directly affected by the efficiency in material inventory management. This is because between 50% to 60% of overall construction costs come from the cost of materials, making managing inventory and procurement a crucial task (Jaśkowski et al., 2018; Lu et al., 2018; Polat & Arditi, 2005). Therefore, investigating inventory and procurement problems is inevitably important. Poor logistic planning, as well as inadequate on-site material management, would lead to the project overdue (Osypchuk & Iwan, 2019). Activities such as lifting materials and components need to be conducted efficiently. Various tasks and actions may seem easy and simple, nonetheless, all these tasks consume time and cost. To illustrate, misallocating the crane parking will result in an increase in the lifting points when moving materials from one place to another, leading to an increase in the time and cost needed for the process.

As construction projects are getting more complicated and complex, it has been imperative for the industry to evaluate and select the best decision on how to manage the material and information flow across the construction supply chain (Pan et al., 2011; Vidalakis et al., 2011a). An analysis of construction hurdles, many of which are associated with function and operation interfaces among

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different supply chain players, is vital too. At an operational level, there is a need to control the information and material flow process in different stages within the supply chain. Moreover, the material and components procurement process is considered a challenging task when managing construction projects (Hsu et al., 2018; Lu et al., 2018).

The operational factors have a high impact on project performance. Since time and cost are the most important indicators for project performance, the delay in material delivery is considered one of the main sources of construction project time and cost overrun (Josephson et al., 2002; Rzepecki, 2019). Consequently, project stakeholders need to take into consideration the early planning of project logistics and material delivery to align the project with the targeted cost and expected productivity (Abdul Kadir et al., 2005). Therefore, a thorough study is needed to investigate the critical factors that influence the inventory management process which subsequently affects the overall project performance.

The inventory and procurement processes importance and impact on the overall project success have been emphasized in the literature (Chen et al., 2021; Sari, 2007; Subramani et al., 2017). Nonetheless, a number of previous studies have focused on logistic process, material consumption, purchasing plan and demand fluctuation (Chen et al., 2021; Hsu et al., 2018; Jaśkowski et al., 2018; Vidalakis et al., 2011a). However, studies focusing on infrastructure projects have rarely been discussed. Hence, the research aims to fill this gap, as infrastructure projects have an enormous impact on the construction industry and the overall country development.

Thus, to achieve the research aim, the critical factors which have a high impact on project performance are investigated, focusing on inventory and material aspects of infrastructure projects. In this study, the first goal is to establish a list of the main factors that would impact the inventory and procurement management system toward an efficient workplace and effective construction performance. Secondly, the study shall examine the level of importance of all the factors identified in managing procurement and inventory in infrastructure projects. Lastly, it shall produce and classify all the factors through an exploratory factor analysis process utilizing Principal Component Analysis (PCA).

1. Inventory and procurement factors

The construction industry projects are unique and complex. Contrary to the manufacturing and retailing industry, the construction supply chain consists of temporary players for every project (Vrijhoef & Koskela, 2000). Reconfiguring the supply chain increases the uncertainty and reduces the benefits of an integrated supply chain. Additionally, the fragmented nature of construction and lack of trust among players are limiting a smooth logistic process among the construction supply chain players.

Main elements of inventory and procurement including material consumption and purchasing, logistic process, vendor managed inventory (VMI) benefits and functions, and allocation policy in the city for the overall supply chain need to be discussed collectively (Hsu et al., 2018; Sari, 2007; Subramani et al., 2017; Vidalakis et al., 2011a, 2011b). The synthesis of the previous research areas has been done and summarized as in Figure 1. Nevertheless, within these interrelated topics, this research has focused on the fundamental elements of material inventory and procurement. The description of the main elements is detailed in the following sections and summarized in Table 1.

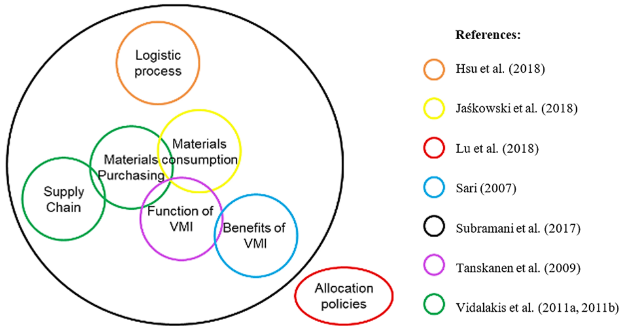

Figure 1. Synthesis of previous studies

1.1. Cost

The price fluctuation of construction materials greatly affects the purchasing plans (Hwang et al., 2020; Subramani et al., 2017). Mass and bulky purchases are highly influenced by fluctuation in demand and price. Undoubtedly, managing disruption in the supply chain and fluctuation in demand and price could help optimize purchasing plans (Chen et al., 2021). As a result, the cash flow of the contractor and/or client will be affected if measures are not taken to control any fluctuation. Furthermore, as construction materials generally are high in volume yet low in value, therefore the cost of transportation could be significant (Vidalakis et al., 2011a).

1.2. Time

Material planning is a critical task throughout the project life. Careful logistic planning can enhance the decision made on material and procurement to the construction site (Lu et al., 2018). In case of deficiency, progress and time performance would be affected. A spike in material cost could happen due to rushing orders from the retailers. Moreover, material planning also could be affected because of progress delay subsequently affecting material demand (Jaśkowski et al., 2018; Tanskanen et al., 2009). Finally, the duration of the project will be extended leading to an increment in the project cost.

1.3. Productivity

Managing material and information flow across project life is critical. A control mechanism is required throughout the successive phases of the supply chain (Vidalakis et al., 2011a). Without a proper work sequence, the planning for

Table 1. Summary of preliminary inventory and procurement management factors

	Main Elements	Factors	Impact Description	Sources
1	Cost	F1: Cost fluctuation of materials affects the purchasing plan.	The cash flow will be affected as fluctuation in material price will impact both contractors and clients.	Subramani et al. (2017); Vidalakis et al. (2011a)
		F2: Transportation costs.	Reaching an integrated transport capability is highly difficult, as a high fluctuation of demand could lead to a sporadic and inefficient delivery service.	
2	Time	F3: Insufficient materials planning.	Time performance or progress would be affected.	Jaśkowski et al. (2018); Subramani et al. (2017); Tanskanen et al. (2009)
		F4: No time to plan or order small items in advance.	A spike in material cost could happen due to rushing orders from the retailers.	
		F5: Delay of progress distorts the materials planning.	The duration of the project will be extended leading to an increment in the project cost.	
3	Productivity	F6: Scheduling plays a role in the seamless flow of activity.	Without a clear work sequence, planning for the upcoming activities is impossible and inaccurate.	Al-Aidrous et al. (2021); Hsu et al. (2018); Subramani et al. (2017)
		F7: The disruption caused by labor	Despite the introduction of automated construction practices, manual operations are still dominant.	
		F8: Quality of weather has a great effect on construction activities	The planning of work would be more accurate by taking into consideration the weather analysis.	
4	Client Satisfaction	F9: The leadership skills of managers are important for clients	Successful delivery of the project would increase the project owner's satisfaction. Moreover, contractors will maintain their reputation of providing good quality projects to the potential clients.	Hsu et al. (2018); Vidalakis et al. (2011b)
5	Construction Waste	F10: Minimizing the total wastage of construction materials	Adopting zero wastage helps in increasing project profit.	Ajayi et al. (2017); Chen et al. (2021)
6	Logistics	F11: Improvement of interactions between suppliers and clients.	Materials delivery to the construction site would be completed with limited disruption.	Hadidi et al. (2017); Hsu et al. (2018); Vidalakis et al. (2011a)
		F12: Restricted site storage capacity	Increase in the transportation and storage cost for using off-site storage and reallocating the materials.	
		F13: Unexpected transportation incident	Without alternative plans, the progress will be directly delayed.	
7	Inventory	F14: Constantly changing production locations	If the location of the supplier is inconsistent that will lead to a decrease in the efficiency of material delivery.	Lu et al. (2018); Sari (2007); Tanskanen et al. (2009)
		F15: No systematic replenishment	Materials not often used or stored and were not used become a cost burden on the cash flow.	
		F16: Uncertainty of construction material demand	This can affect the inventory management system and disrupt the management of all the inventory.	
		F17: Material management and delivery planning	These have a considerable impact on the economic outcomes of the project.	

the upcoming activities is deemed impractical and inaccurate. This could directly affect inventory management. Despite the introduction of automated and industrialized construction practices, their use has been limited to certain parts and components (Al-Aidrous et al., 2021; Lu et al., 2018). Manual operations are still present and dominant in construction. The construction activities are prone to external factors, including disasters, pandemics, and extreme weather in which all have a great effect on the construction progress (Gharouni Jafari & Noorzai, 2021; Liu et al., 2019). Although in the face of external factors limited acts would be available to reduce its impact, the planning of work would be more accurate by considering mitigating strategies such as the weather analysis.

1.4. Client satisfaction

A project is considered successful when completed within time and cost constraints and all stakeholders, especially the client, are satisfied with the project quality (Hsu et al., 2020). According to Díaz-Madroñero et al. (2015), the absolute requirement for managing the supply chain material is the satisfaction of the customer demands. This can be driven by the leadership skills of project managers managing the project (Subramani et al., 2017). Delivering successful projects would undoubtedly increase project owner's satisfaction. Moreover, contractors will maintain their reputation of providing good quality projects to the potential clients.

1.5. Construction waste

Controlling construction waste necessitates close coordination of material and orders coming to the construction site (Chen et al., 2021). Minimizing the total wastage of construction materials and adopting zero wastage helps in increasing project profit (Subramani et al., 2017). Logistic management and lean practices are both crucial strategies to achieve a zero-waste approach (Aziz & Hafez, 2013; Mohammadi et al., 2020). Procedures such as waste generation prevention will lead to efficient material planning. Furthermore, the prudent material estimation will contribute to better control of construction waste (Ajayi et al., 2017).

1.6. Logistics

Well established relationship between clients and suppliers is required to lead to seamless project delivery (Hsu et al., 2018). Strategic interactions between suppliers and clients as well as other supply chain members, including contractors and subcontractors, will help sustain trust and cooperation toward project delivery (Chen et al., 2020). Management of the supply chain is concerned with coordinating different parties across the logistics network to reach the most acceptable strategy for all parties (Sari, 2007; Vidalakis et al., 2011a). Likewise, materials delivery to the construction site would be completed with limited disruption. Nonetheless, an increase in the transportation and storage cost for using off-site storage and reallocating the materials would be incurred. Transportation incidents could occur unpredictably. The planned activity for a certain time will be affected. Alternative plans must be available to reduce any potential progress disruption delaying project progress (Vidalakis et al., 2011a).

1.7. Inventory

Efficient material delivery will depend highly on a cooperative contractor-supplier relationship. If there is a variability of demand, production schedules can be adjusted according to the contractor changing requirements (Chen et al., 2021). Unsystematic replenishment and uncertainty of construction material demand will disrupt the management of all the inventory. As a result, material not used or stored for a long time could become a cost burden and cause cash flow problems. Material management and delivery planning have a considerable impact on the economic outcomes of the project (Rzepecki, 2019; Sari, 2007).

2. Methodology

A quantitative approach was used to address the objective of this research. The process of designing the survey questionnaire has gone through a rigorous methodology. The research methodology consists of three phases. In the first phase, an extensive literature review was conducted to review and collect the critical factors. Overall, the outcome of the literature yielded 17 elements as described in Table 1. In the second phase, a pilot study was conducted after the completion of the first draft of the questionnaire. The pilot study was done by interviewing a total number of three experts of a civil and construction background in Malaysia. The experts were given the opportunities to review and discuss the importance of the factors extracted from the literature review, as well as to add or modify any elements or crucial factors. Some factors were combined such as transportation cost and unexpected transportation incident into transportation impact as well as no systematic replenishment and material management and delivery planning turned to material delivery. As a result, and after reaching a consensus with the experts, the identified 17 elements were rephrased and narrowed down to 15 elements. Then the survey was deemed ready to be distributed to the industry professionals. This pilot study aimed to identify and improve the questionnaire before distributing it to the industry personnel. In the third phase, the industry professionals have assessed the importance of all the elements shortlisted from the second phase.

The questionnaire was disseminated through the Internet using the web-based platform to potential respondents with working experience in large infrastructure projects. Additionally, due to the low response rate and difficulty to reach respondents from infrastructure projects, more printed questionnaires were distributed directly to the industry professionals working in infrastructure projects in Malaysia to increase the response rate. More specifically, this research has surveyed professionals at Escape Shaft 1 located in Kuala Lumpur which is the MRT Line 2 Tunneling project. The targeted professionals included managers, quantity surveyors (QS), designers, mechanical and electrical (M&E) engineers, civil and structural engineers. All the respondents were selected from the Klang Valley area, a name that represents Kuala Lumpur and major parts of Selangor state, the most populated and developed region in the Malaysian peninsula. Before distributing the questionnaires to industry professionals at the site, the online survey was distributed through social media and emails that included a letter explaining the aim and purpose of the research. According to the Centralized Information Management System [CIMS], a total of 1,613 contractors are registered under civil engineering category (CIMS, 2021). From this potential population, 400 survey questionnaires were distributed to participants. The method and sampling technique used in this research is convenience sampling. Convenience sampling is used based on the willingness and availability of the potential respondents to participate in a survey (Olanrewaju & Idrus, 2019). Although convenience sample often lacks generalization, its importance in terms of cutting time and cost cannot be neglected. A mix of respondents' backgrounds was targeted in this research to achieve a comprehensive and inclusive perspective from the industry professionals. The final draft of the questionnaire consisted of 15 factors regarding inventory management systems at construction sites. This survey instrument used a 5-point Likert scale to measure the respondents' point of view and rate the importance of all the 15 factors, where each factor was evaluated by respondents ranging from "strongly disagree" (1) to "strongly agree" (5). According to the collected responses, a number from 1 to 5 was assigned to each factor. Numbers 1, 2, 3, 4, 5 sequentially represent "strongly disagree", "slightly disagree", "neither agree nor disagree", "slightly agree" and "strongly agree".

The questionnaire is consisted of two sections. In the first section, the respondents' background was reported. The second section was used to measure the importance and effects of the factors investigated on the inventory and procurement smooth delivery. The questionnaire survey was conducted to rank the inventory and procurement factors according to their importance. A list of the main factors affecting the whole system for inventory and procurement has been extracted and developed in the questionnaire survey form. The extraction of factors was done through a literature review of recent studies. All the variables used in this research instrument were mentioned in related research in the supply chain literature. Then, a pilot study was conducted to verify and confirm the importance of the collected variables to the infrastructure projects and to the Malaysian context. Additionally, the pilot study first was conducted by interviewing experts from civil engineering backgrounds to improve, verify and comment on the questionnaire's variables and structure. Then after the filtration of the variable, a completed version of the first draft of the questionnaire was prepared. The factors were then inputted into the questionnaire.

In summary, the research flow is described in Figure 2. This work started with a literature review to identify the suitable and important factors from the inventory and procurement literature. After distinguishing possible important factors, a pilot study was conducted in the means of an interview with experts in the field to evaluate the suitability of the identified factors for inventory and procurement in infrastructure projects. Afterward, a survey questionnaire was prepared according to the established factors from the grounded theory prioritizing to identify and prioritize the most important factors for inventory and procurement management, which is the first goal of the survey. A scatter plot of mean and standard deviation was used to prioritize the identified factors for the infrastructure projects in Malaysia. Additionally, exploratory factor analysis using Principal Component Analysis (PCA) was conducted for factor clustering. Consequently, a new categorization is created then discussed with empirical findings from the literature leading to the conclusion and the end of this work.

2.1. Data analysis

A quantitative survey was conducted to rank the factors extracted from the literature and has gone through a verifying process by three industry experts. The factors were ranked according to their importance. A scatter plot was used to describe the mean, standard deviation and demonstrate results from the collected data. Then this study conducted an Exploratory Factor Analysis (EFA), a method that has been used widely in construction studies to identify the importance and similarities of all factors (Ajayi et al., 2017; Wu et al., 2021). Among different factor analysis methods, the Principal Component Analysis (PCA) is the most used method. PCA is a statistical analysis method in which a few, yet significant variables are formed and selected.

The PCA is normally used to find out interrelated links within several factors or variables investigated. The test for measuring the sampling adequacy, KMO or Test or Kaiser-Meyer-Olkin Test and Bartlett Test of Sphericity was carried out before the PCA. The main purpose was to make a comparison of simple and partial correlation coefficients within the studied variables. Normally, the KMO value ranges from 0 to 1. When the coefficient of simple correlation among all variables is very much high compared to the total partial coefficients, then the value of KMO would be closer to 1, indicating a strong and robust correlation within variables, hence, the study is fit for factor analysis. Moreover, according to previous research, KMO value that is higher than 0.5 is sufficient, concluding

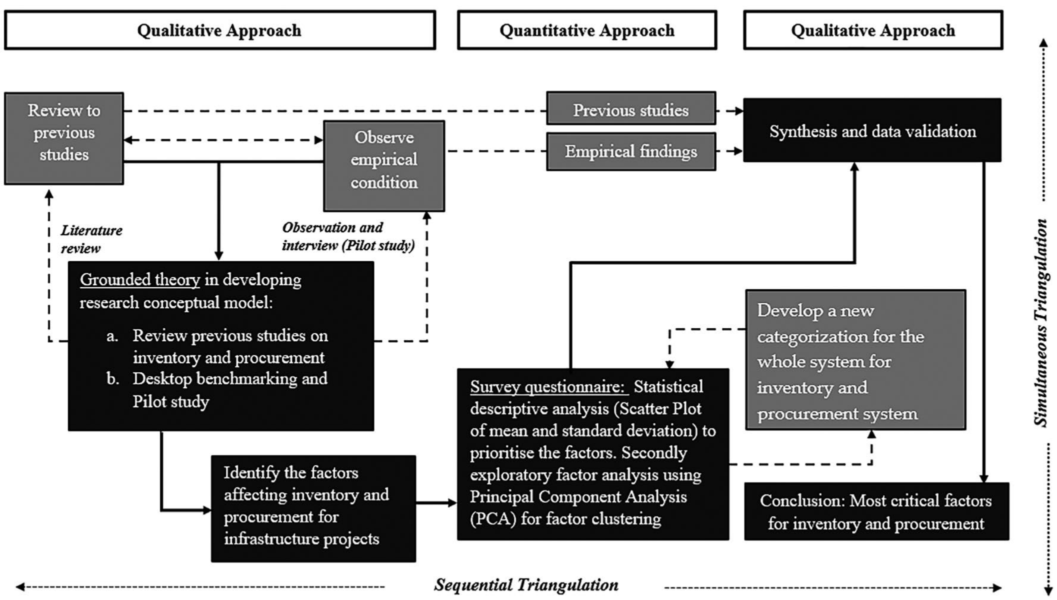

Figure 2. Research flow

that, the questionnaire is valid and the sample collected is considered acceptable for factor analysis (Kaiser, 1970; Vyas & Jha, 2016; Wu et al., 2021). Bartlett's Test of Sphericity was also conducted as a means to verify and test the correlation within the sample's capacities. The p-value of Bartlett's Test should be lower than 0.05, however, if the value is larger, then the collected data is considered not suitable for factor analysis (Yong & Pearce, 2013).

3. Results and discussion

Designing the research overall process has gone through literature review, interview, and survey questionnaire. The questionnaire was the main research method utilized in this study. The questionnaire was distributed to around 400 potential respondents. Nonetheless, the construction industry has a reputation for low response and lack of participation in surveys (Rahmawati et al., 2020; Wu et al., 2015). For example, the response rate in Abdul-Rahman et al. (2006) and Ismail et al. (2012) was 7.4% and 12.4%, respectively. Moreover, Shen and Liu (2003) considered a sample of 36 respondents for exploratory factor analysis. In this study, the response rate is 10%. As a result, only 40 responses were collected from respondents with diverse backgrounds within the construction industry. All the previously mentioned studies clearly show the acceptability of the sample size selected in this study. Mean and standard deviation were used to produce the scatter plot and rank all critical factors. Kaiser-Mayer-Olkin, Bartlett's Sphericity Test, and component matrix were the main tests examined in this study. The respondents' background was from different fields and departments, with a limited number from quantity surveyors (QS) (5%), followed by mechanical and electrical (M&E) (11%), then consultants (14%), and designers (14%) with the majority of respondents from civil and structure specialty (56%). Figure 3 shows the background of the respondents.

3.1. Identifying the most important factors

Based on the survey results, the scatter plot of mean and standard deviation in Figure 4 was plotted manually using Microsoft Excel. The factors were identified in several quadrants then ranked and rated according to the graph. The objective of the scatter plot was to rank and measure the agreement among professionals of the reported factors. The horizontal axis of the scatter plot represents the mean, and the vertical axis represents the standard deviation. After collecting the data, the factors were ranked based on the results of the mean and standard deviation. The factor with higher mean and low standard deviation was ranked the most important.

Mean and standard deviation are the two main descriptive statistics calculated in this study to rank all factors investigated. The 5-point rating scale was used to report the assessment of critical factors for infrastructure projects. There is always a central value for any measured data. It is known as the mean, which is produced by multiplying all the scores of individuals with the frequency and then dividing it by the total number of responses. The formula (1) was used to calculate the mean.

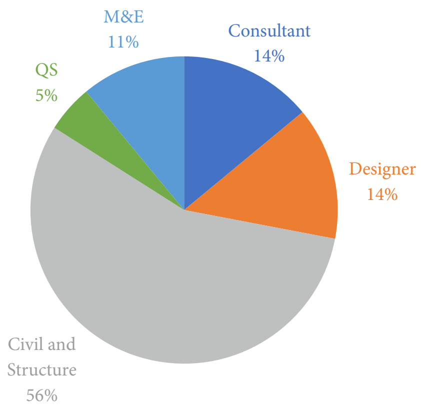

Figure 3. Respondents' background

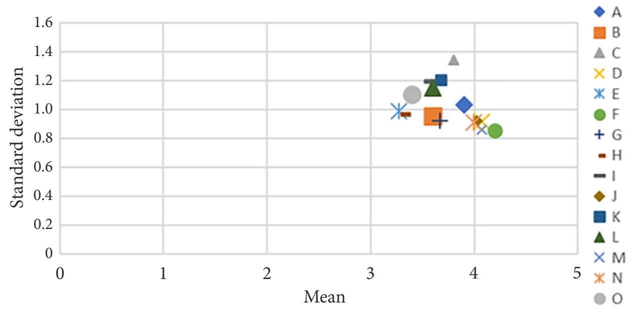

Figure 4. Scatter plot of mean and std. deviation

$$\text{Mean}(\mu) = \frac{\sum(W \times n)}{N}, \quad (1)$$

where W represents the weight given by each respondent using a scale range from 1 to 5, n represents the frequency for each critical factor and N represents the total number of responses in the collected questionnaire. The second descriptive statistic is the standard deviation which is used to measure the agreement among the respondents. The following formula (2) shows the general form in calculating the standard deviation:

$$\text{Standard Deviation}(\sigma) = \sqrt{\frac{\sum(X_i - \mu)^2}{N}}, \quad (2)$$

where N is population size, X_i represents each value of the measured population and μ is the mean of the population. As described in Figure 4, most factors fell under the upper right quadrant of the scatter plot showing higher mean as well as higher standard deviation. A higher value of standard deviation shows that the responses are widely dispersed, indicating high disagreement among participants toward the factor importance. Whereby, lower standard deviation indicates that the responses are concentrated around the means showing high agreement within participants which is considered more reliable (Jiang et al., 2018). So, if the mean is higher and the standard deviation is low, the factor is considered more important and critical as reported in previous studies (Al-Atesh et al., 2021; Jiang et al., 2018; Xian et al., 2021). After collecting the data, the factors were ranked based on the results of the mean and the standard deviation. The factor with higher mean and low standard deviation was ranked the most important. However, if the standard deviation is high, this indicates there is disagreement among different respondents toward the factor importance. There are few potential possibilities that triggered the disagreement including that the questionnaires were distributed to a specific construction site team from different specialties and departments such as safety, civil and structure, quantity survey, mechanical and electrical, etc. The respondents' background and knowledge vary from designing, supervising, and planning. This might prompt the high standard deviation of the response. In conclusion, the factors with lower standard deviation were ranked first. The factor "Communication between labor and management" was ranked the most important with the highest mean of (4.2) and standard deviation of (0.85). On the contrary, the factor "Lean construction (zero waste)" was considered the least important with a mean (3.6) and standard deviation of (1.19). The ranked factors were shown accordingly based on the mean and standard deviation as detailed in Table 2.

Table 2. Ranking of factors

Factors	Mean	Std. Dev.	Rank
Communication between labor and management	4.2	0.853349	1
Information sharing in a construction team	4.075	0.858965	2
Planning changes	4.075	0.916725	3
Software usage on material tracking	4.025	0.919518	4
Delivery schedule	4	0.905822	5
Purchasing plan	3.9	1.032796	6
Construction progress	3.8	1.343551	7
Manpower requirement	3.675	0.916725	8
The fluctuating price of construction material	3.6	0.955416	9
Material demand	3.4	1.104768	10
Weather	3.3	0.966092	11
Different perspectives among stakeholders	3.275	0.986771	12
Material delivery	3.675	1.206553	13
Transportation impact	3.6	1.150251	14
Lean construction (zero wastage)	3.6	1.194002	15

3.2. Principal Component Analysis (PCA)

The plurality of inventory and procurement factors is considered a critical challenge as to find a clear and within reach approach to address all these factors. Therefore, toward a constructive solution for the industry professionals to address the inventory and procurement issues, the Principal Component Analysis (PCA) was used to reduce the number of the variables addressed into a smaller number of components. The originated principal components are considered representative of all the variables. In other words, the variables that are similar or share similar characteristics were grouped into one component. The newly generated components will be considered as the main factors as a result of PCA on the selected data. There will be (n) number of variables represented by (n) number of components. Yet, not all components will be considered as significant or important enough to keep. Hence, from all the components that resulted in the test, only the components that can demonstrate the variance in the data would be selected as principal components. A wide number of related studies in the construction domain have used this method, where several variables are involved, consequently, the PCA will reduce the variables into a smaller number that can be addressed effectively (Ajayi et al., 2017; Karji et al., 2020).

In the first part of the component factor analysis, the Kaiser-Meyer-Olkin (KMO) test was selected to identify the usefulness of this survey being conducted and the detail can be observed from Table 3. The main purpose of the KMO test is to verify whether the data collected is suitable for Principal Component Analysis. Bartlett's Sphericity Test was selected to test the correlation matrix, which is an identity matrix, and indicate the relationship of the variables input in the analysis. Although there is no agreement on a minimum value of KMO to be considered as optimum or appropriate, previous studies mentioned that the acceptable value for the KMO test could be within the range of 0.5 to 0.7 (Wu et al., 2021). Thus, if the KMO value is more than 0.5, then it is considered acceptable, which can be found in a recent study made by Vyas and Jha (2016) where the KMO value is 0.517. Moreover, Shen and Liu (2003) considered a sample of 36 respondents for exploratory factor analysis with a KMO value of 0.524. Whereas Bartlett's Sphericity Test should be below 0.05. For this study, the value of Bartlett's Test was equal to 0.000 which is regarded as satisfactory. Finally, since the KMO value for this research is bigger than 0.5 indicating that the data is suitable for factor analysis.

Table 3. KMO and Bartlett's Sphericity Test result

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.517
Bartlett's Test of Sphericity	Approx. Chi-Square	269.780
	df	105
	Sig.	0.000

The KMO value for this survey is relatively low probably due to the sample size. However, as the value is bigger than 0.5 it is considered acceptable and appropriate for factor analysis. Nonetheless, if the response rate was higher up to 30%, then the sample size collected would reach the most suitable sample size for factor analysis, which is from 3 to 5 times of the variables. That means there should be around 100 respondents to achieve the higher value of the KMO test. All in all, the result from the analysis was regarded as satisfactory.

Based on the component matrix in Table 4, six components were extracted under the Principal Component Analysis explaining the relationship among 15 variables. Two variables, "Planning Changes" and "Delivery Schedule" were excluded as the loading values were below 0.5 across all six components in which all variables were studied to configure the relationship between the components and the variables. The sixth component found in Table 4 does not contain any variable with loading 0.5 and above concerning all variables tested showing low significant and was deleted. Components and variables with weak relationships had to be neglected. Therefore, only five components were classified into a new group of factors. As a result of excluding one component and two variables, the remaining 13 variables were grouped into five components based on the loading value from the component matrix table of the highest value (neglecting the negative indicator). Table 5 shows the second component matrix of the factor analysis.

3.3. Categorizing of new factors

A new categorization was created based on the data extracted from the factor analysis tests. Albeit slightly different from the PCA outcomes, the results of one sub-factor which is software usage on material tracking was moved to the first component to be consistent with the literature. The new categorization comprises five interrelated components or factors. The main factors are, F1: Operation and management; F2: Procurement; F3: Economic influence; F4: External factors; and F5: Sustainable construction. Seven sub-factors were loaded in F1, two sub-factors were loaded in F2, two sub-factors were loaded in F4, and one sub-factor was loaded in both F3 and F5. Operation and management had the highest impact and contain the biggest number of sub-factors. The list of factors investigated are shown in Table 6.

Among the sub-factors related to "operation and management", the communication between labor and management, information sharing in a construction team, software usage on material tracking, construction progress, manpower requirement, material delivery, and transportation impact were ranked the 1st, 2nd, 3rd, 5th, 6th, 11th, and 12th, respectively. This demonstrates the importance of operational issues and the relationship among stakeholders. This in line with Zhu et al. (2017) research, where his study concluded, for the long and strategic growth of construction companies, a clear path of communication between the labor and upper management is needed and will lead to better productivity. Providing clearer and simpler means of communication will facilitate communication between labors and management especially when diverse foreign labors comprise large number in the local construction workers (Abdul Kadir et al., 2005). Sharing information among project players, when implemented, is considered a competitive factor in the construction industry (Lin et al., 2011). A buffer plan for material and manpower is required to ensure that construction progress is within the defined schedule with labor requirements guaranteed (Hwang et al., 2020). Additionally, it is recommended to use software such as Building Information Modeling (BIM) and Primavera P6 to control construction progress. These technologies are useful for controlling project progress so that proactive steps may be taken in a timely manner and delays can be avoided (Zou et al., 2017).

Table 4. The first rotated component matrix

Variables	Component					
	1	2	3	4	5	6
Purchasing plan	–0.13	–0.173	–0.195	0.507	0.644	0.344
The fluctuating price of construction material	0.243	0.128	–0.537	0.665	–0.031	0.089
Construction progress	0.758	0.375	0.154	–0.141	–0.03	0.261
Planning changes	0.288	0.39	–0.246	–0.292	–0.093	0.489
Different perspectives among stakeholders	–0.011	0.711	0.047	–0.284	0.229	0.178
Communication between labor and management	0.63	–0.294	0.154	–0.047	–0.092	0.209
Manpower requirement	0.532	0.322	–0.263	0.264	–0.455	–0.173
Weather	–0.244	0.553	–0.202	0.174	–0.298	–0.406
Lean construction (zero wastage)	–0.319	–0.219	0.731	0.293	–0.165	0.016
Software usage on material tracking	0.427	0.334	0.734	0.065	0.09	–0.137
Material delivery	0.697	–0.501	0.049	0.3	–0.062	–0.103
Transportation impact	0.806	–0.29	–0.005	0.029	–0.261	0.16
Information sharing in a construction team	0.754	–0.006	–0.01	–0.207	0.41	–0.284
Delivery Schedule	0.43	0.407	0.079	0.296	0.45	–0.367
Material demand	–0.203	0.459	0.409	0.558	–0.151	0.363

Table 5. The second rotated component matrix

Variables	Component				
	1	2	3	4	5
Transportation impact	0.806				
Construction progress	0.758				
Information sharing in a construction team	0.754				
Material delivery	0.697				
Communication between labor and management	0.630				
Manpower requirement	0.532				
Different perspectives among stakeholders		0.711			
Weather		0.553			
Software usage on material tracking			0.734		
Lean construction (zero wastage)			0.731		
The fluctuating price of construction material				0.665	
Material demand				0.558	
Purchasing plan					0.644

Table 6. List of main factors and variables

	Main Factors	Sub-Factors (Variables)	Ranking
F1	Operation and Management	Communication between labor and management.	1
		Information sharing in a construction team.	2
		Software usage on material tracking.	3
		Construction progress.	5
		Manpower requirement.	6
		Material delivery.	11
		Transportation impact.	12
F2	Procurement	Purchasing plan.	4
F3	Economic Influence	The fluctuating price of construction material.	7
		Material demand.	8
F4	External Factors	Weather.	9
		Different perspectives among stakeholders.	10
F5	Sustainable Construction	Lean construction (zero wastage).	13

The "Procurement" factor was next in ranking after the operation and management factor. The purchasing plan had a high impact on the inventory smooth process and was ranked fourth. The "Economic influence" related elements were next to the procurement factor. The "Price fluctuation of construction material and material demand" were ranked seventh and eighth. The economic and procurement-related factors have always had a direct effect on the construction performance especially for inventory management (Rzepecki, 2019). Due to the large sum of financial resources and diverse stakeholders involved in infrastructure project, inadequate procurement planning may lead to undesirable outcomes. Finally, the "external factors" with the "Weather" and "Different perspectives among stakeholders" as sub-factors were ranked ninth and tenth then followed by the "sustainable construction" containing "Lean construction" as a sub-factor was ranked thirteenth among all inventory management factors. Regardless of the more interest of recent studies in lean concept and its impact on reducing non-value activity and thereby reducing waste, the infrastructure domain has yet to embrace the concept, explaining the low impact of lean construction in this research. This is supported by recent studies in which expertise in infrastructure domain has yet to implement lean practices and thinking (Mohammadi et al., 2020).

Overall, the top-ranked factors were categorized under operation and management based on the ranking. Most of the construction progress disruption was mainly caused by communication issues (Chen et al., 2020). For instance, the changes of plan due to a particular issue from the required flow process from site team to designers and finally back to site team. According to Hwang et al. (2020) communication and planning are most important elements to improve project productivity. Fortnightly meetings and communication are good strategies for information sharing. In other words, regular meetings among key project stakeholders would minimize coordination issue with timely material delivery (Abdul Kadir et al., 2005). A two-way communication process between labor and upper management would facilitate both negative and positive feedback addressing project difficulties (Hwang et al., 2020). Procurement plans are critical in tracking timely and proper material delivery to overcome shortage issues (Abdul Kadir et al., 2005). This viewpoint is also supported by Hwang et al. (2020) as optimization in purchasing plan at early stage would reduce construction schedule disturbance and allows achievement of project goals. To ensure the construction progress remains on track, regular meetings and tracking of status are needed (Chong et al., 2016). Therefore, key stakeholders, including clients, main contractors, sub-contractors, and material suppliers need to engage in interconnected platform including Building Information Modeling (BIM) and adopt cloud-based system for interactive information sharing (Al-Ashmori et al., 2020; Zou et al., 2017). Supporting technologies such as the Global Positioning System (GPS) and Radio Frequency Identification (RFID) can be linked with BIM to make material tracking more efficient (Chong et al., 2016). Despite the high investment needed, most of the key issues highlighted in this study could be resolved or at least mitigated, whereby all project stakeholders will be able to work collaboratively leading to project success.

Abdul Kadir et al. (2005) recommended establishing purchasing plan for tools, equipment and materials through coordinated project team. It is critical for stakeholders to predict and tackle price fluctuation and material demand collectively. Chen et al. (2021) designed a model that can assist stakeholders alter original orders to suit demand fluctuation. Aziz and Hafez (2013) suggested using lean practices in construction as efficient way to improve performance and reduce waste. Infrastructure projects are highly prone to harsh and unexpected weather conditions, thereby severe weather has potential undesirable consequences affecting construction productivity and overall project goal (Gharouni Jafari & Noorzai, 2021). However, lean construction and transportation ranked at the bottom in this study. A possible explanation is that questionnaire participants were technical engineers from the infrastructure domain, and they were more concerned about the project operation and management than embracing lean practices to reduce waste (Mohammadi et al., 2020). Therefore, the waste and sustainability factors were not crucial for the project's inventory and procurement aspect.

Conclusions

Delay in construction projects occurs regularly, nonetheless, the delay caused by improper management of inventory and procurement system has interrelated consequences and would disrupt the construction supply chain. The finding of this paper is that communication is a key to success in managing the construction inventory process. Besides communication, planning also plays a significant role. Efficient handling of project inventory and procurement not only helps in the budgeting but also improves the reputation of the project stakeholders. There are also inevitable factors related to economics or extreme weather which is beyond stakeholders' control. Price fluctuation of construction material would impact the procurement planning of a project, and it will directly affect the construction activities. This study would assist key stakeholders to develop mitigation plans at the early stages of infrastructure projects. More specifically, clients, main contractors, sub-contractors, and material suppliers need to keep close relationship to monitor operational planning to alleviate adverse consequences. Finally, this study has its limitation as an inherent feature of any research work. The limited number of professionals participating in the administrated survey, due to the difficulty of obtaining high response rate from professionals in infrastructure projects, is considered a limitation of this study. Although acceptable, a larger sample size is required for future studies. Additionally, an in-depth investigation in a form of interview or case study with site visits is desired to provide a valuable detailed analysis which could not be captured using questionnaires. Finally, this study has focused on infrastructure projects, similar studies are needed in other types of projects or sectors with similar layers of supply chains players to identify key factors impacting performance.

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