ATLANTIS PRESS

Advances in Engineering Research, volume 187

Third International Conference on Sustainable Innovation 2019 – Technology and Engineering (IcoSITE 2019)

Correlation Model of Construction Waste Cause Factors to Cost and Time in Infrastructure Project

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***Abstract*—Construction industry has been developing rapidly around the world. One of the problems in construction management is construction waste. It has major impact on cost, time and quality of construction management. The aim of the study was to examine the correlation model of construction waste cause to cost and time that impacts infrastructure project. The variable of cause construction waste was identified from interviews, observation and some references about construction waste causes. The variable of cost and time was generated from Supply Chain Operations Reference (SCOR) Model approach. A survey was carried out through a structured questionnaire. The respondents were experienced people in the area of construction and management of building projects. In this initial study, questionnaires were completed by 383 respondents. Data were then analyzed with Structural Equation Model (SEM) with statistical package, *Analysis of Moment Structures (AMOS) as an analytical tool.* The results indicated that the cause factors of construction waste were correlated to cost and time both cost and time had a correlation shown by the coefficient value of 0.51, significantly α = 0.05. It indirectly impacted on quality of infrastructure project system. The finding was expected to help construction practitioners reduce construction waste cause factors and to give better understanding to improve the infrastructure project in a sustainable way.**

Keywords—Construction, Waste, Management, Time, Cost, Infrastructure

I. INTRODUCTION

Infrastructure development in Indonesia has seen an increase in recent years. However, several problems of construction were found in some parts of this country such as poor productivity, unskill labor, time and cost overruns and poor construction management. These are associated with considerable waste present on construction sites. An important step towards elimination of waste is to measure the amount of waste which exists in Indonesian construction sites. This is because construction wastes have become a pressing issue in many developing countries and have adverse effects on environment, economy and social aspects [1]. Many of the problems, or research issues, in construction engineering and management involve the measurement of concepts that are not easily quantified. Project scope definition, management capability, project complexity, and past contractor performance are concepts that previous research has proven to be critical to construction project success but difficult for researchers to measure [2]. There has been a trend toward the use of multivariate regression techniques to measure these concepts. Structural Equation Modeling (SEM) analysis can be considered as an extension of standardized regression modeling that explicitly deals with poorly measured independent variables

Structural equation models are suitable for many research issues dealing with construction engineering and management [3]. This paper examines the application of SEM to the problem of construction waste. The causes of construction waste stem from multiple factors, which are not all directly measurable (termed latent variables). The SEM analysis offers a method for modeling latent variables by explicitly including errors of measurement brought about by surrogate variables, thus providing insight into the factors that can be used to understand the cause factors of construction waste to cost, time and quality of construction management.

A. Construction Waste

Construction waste is defined as the remaining material from the comparison between the amount of material which is sent, received at project site and used appropriately in the work plan, it is call the non-add value [4]. Construction waste factors are highly recognized yet they receive less controls from professionals. In general, project managers define the term waste as physical construction waste rather than real concept of waste. Thus, they tend to accept a permissible level of waste in their construction site rather than finding solutions to reduce or eliminate the wastes. Waste in construction has been classified as material, quality, labor and equipment. Material waste includes scrap waste generated in the sites and waste originated from excessive inventory kept in the storage. In Quality costs, only cost due to rework in construction is considered for quantification. Inefficiencies in utilization of labor and equipment are further categorized into non value adding activities such as waiting, idle, transportation, excess processing and excess movement [5]. The performance of construction waste management is affected by the role of such factors as waste factors, system of waste management, technology, knowledge of waste management through training, investigation and training of waste management. Therefore, it can be said that construction waste management is an important part in strategy to reduce construction waste both physical and non-physical [6].

In addition, construction waste can be devided into two types namely physical waste and non physical waste. The physical waste is formed from material loss during the construction stage and non-physical waste may be caused by poor management such as time overrun and cost overrun. The classification of construction waste is outline in Fig. 1 [7].

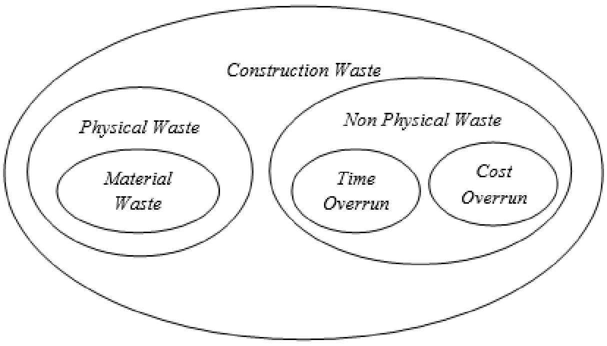

Fig 1. Classification of Construction Waste [6]

One of the affect performance cost is waste factors, which has not been attended much in construction industry especially in developing countries. This is because the new concepts of wastes are not only related to resource but also related to time and effort. Five components, namely 'resource plan and storage', 'resource distribution and usage', 'working procedure', 'communication and transport', and 'worker's rest', were mean of value 56.7% [8]. On other hand, the index of construction waste caused from value of mean were design changes value of 3.97 and construction methods value of 3.86, indicating that the design is a major factor in the construction waste [9].

B. *Indicators of Supply Chain Operations Reference (SCOR)*

The Supply Chain Operations Reference (SCOR) Model released by Supply Chain Council (SCC) in 1996 has been widely studied and used in research and industry [10]. The Supply Chain Operations Reference model (SCOR) is the product of Supply Chain Council (SCC) a global non-profit consortium whose methodology, diagnostic and benchmarking tools help organizations make dramatic and rapid improvements in supply chain processes [11]. The performance section of SCOR consists of two types of elements: Performance Attributes and Metrics. A performance attribute is a grouping of metrics used to express a strategy. An attribute itself cannot be measured; it is used to set strategic direction. Table I show the attribute and Metrics of SCOR Mode [12].

TABLE I. THE SCOR LEVEL-1 METRICS [12]

Attribute	Level-1 Strategic Metric
Reliability	Perfect Order Fulfillment (RL.1.1)
Responsiveness	Order Fulfillment Cycle Time (RS.1.1)
Agility	Upside Supply Chain Flexibility (AG.1.1)
	Upside Supply Chain Adaptability (AG.1.2)
	Downside Supply Chain Adaptability (AG.1.3)
	Overall Value At Risk (AG.1.4)
Costs	Total Cost to Serve (CO.1.001)
Assets	Cash-to-Cash Cycle Time (AM.1.1)
	Return on Supply Chain Fixed Assets (AM.1.2)
	Return on Working Capital (AM.1.3)

SCOR model is used in manufacture as assessment indicators system supply chain in the production of a product in conform to the customer reservation. In the context construction industry, supply chain is defined as the process of construction that is essentially different from the supply chain of manufacture industry. The difference of both is manufacture industry takes place in a closed room with products move toward workers and the construction industry took place in an open space with products do not to move toward workers but workers toward the objects and products various.

C. *Structural Equation Model*

Structural Equation Model (SEM) is very general 'statistical modeling technique', which is widely used in the behavioral sciences. It can be viewed as a combination of factor analysis and regression or path analysis. The interest in SEM is often on theoretical constructs, which are by the latent factors. Correlation between the factors are the primary concern of this model. The structural equation model implies a structure for the covariance between the observed variables, which provides the alternative name covariance structure modeling. Although SEM models can be checked in some different ways, all structural equation model is consist of three types [13]:

- multiple estimation and relevant with correlation
- Capable to describe of concepts observation in the correlation and analysis for error of measurement in the estimation process
- Interpret a model to describe the whole sequence of correlation

Model Goodness of Fit (GOF) measures are an important part of any statistical model assessment. Fortunately, there are a large number of GOF criteria available for assessing the fit of SEMs. Table II shows various GOF measures for the final model [13].

TABLE II. GOODNESS OF FIT MEASURES [13]

GOF	Description of Test
Number of parameters	Parameters estimated
RMSEA	< 0.05 indicates very good fit
P-close	p-value for hypothesis test that RMSEA is 0.05
GOF index	0 (no fit) to 1 (perfect fit)
Adjusted GOF index	GOF index adjusted for degrees of freedom
Akaiki information criterion	0 (perfect fit) to positive value (poor fit)
Tucker-Lewis index	0 (no fit) to 1 (perfect fit)
Normal fit index	0 (no fit) to 1 (perfect fit)

Reliability is also an indicator of convergent validity. Considerable debate centers around which of several alternative reliability estimates is best. Coefficient alpha remains a commonly applied estimate although it may understate reliability. Different reliability coefficients do not produce dramatically different reliability estimates, but a slightly different Construct Reliability (CR) value is often used in conjunction with SEM models. It is computed from the squared sum of factor loadings (Li) for each construct and the sum of the error variance terms for a construct (ei) as in (1).

$$CR = \frac{(\sum Li)^2}{[(\sum Li)^2 + \sum(ei^2)} \quad (1)$$

Where, Li denotes the Standardized Loading and ei as 1-Li. The rule of thumb for CR is that it should be 0.6 or higher, and ideally 0.7 or higher to mean that reliability is good with internal consistency [13].

II. RESEARCH METHOD

The purpose of research was to find out construction waste cause factors related to cost and time that impacted the quality of management project. The variable correlation level was expected to be employed as references for improving the construction waste management. These were mainly used as contribution variable for improving every factor of activity in the sustainable infrastructure project. This research was carried out in three major stages. The first step was finding indicators of factor that caused construction waste. Next, finding indicators of time and cost with SCOR model was done. The last step was analyzing model of construction waste cause factors to cost and time that impacts quality of management project using Structural Equation Model (SEM) by AMOS application for windows. The information was received through field survey and interview using questionnaire instrument by project practitioners. The variables and indicators were then derived based on the site survey. In the instrument, the construction waste cause factors were provided so that the practitioners could choose the indicators measured in Likert Scale showing the range of 1 and 5 in terms of their relative importance. Score "1" represents "not influence" to the cause factors of construction waste whereas score "5" represents "very large influence" to the construction waste cause factors. Research method is outlined in Fig. 2.

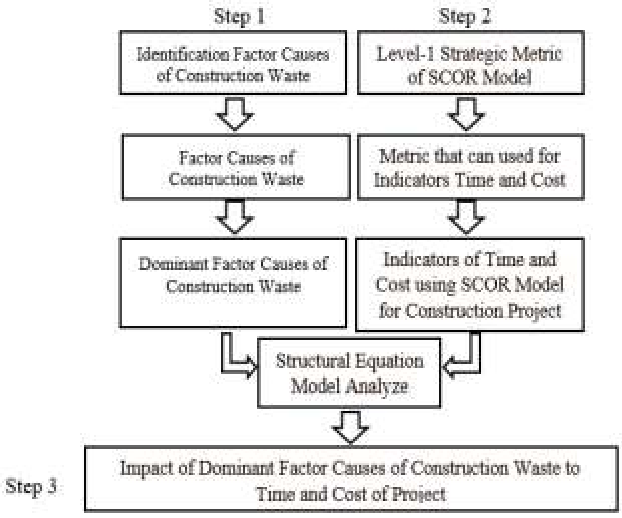

Fig 2. Research Method

The dominant aspect of construction waste cause factors was generated from those investigated with the past 5 years and from the observation. The variable of cause factors is shown in Table III.

TABLE III. THE VARIABLE OF WASTE CAUSE FACTORS

No	Variable	Code
1	Change/repair of work	CW1
2	Installation/repair of equipment	CW2
3	Slow labor / unskilled	CW3
4	Waiting for instruction	CW4
5	Placement of facilities is not optimal	CW5
6	Change of work schedule	CW6
7	Poor Weather	CW7

The indicators of cost and time employed SCOR model. It has been validated by site construction so that it can be used as measurement of cost and time in the construction context. The variable of measurement for cost and time is shown in Table IV.

TABLE IV. THE VARIABLE OF COST AND TIME

No	Variable	Code Cost	Code Time
1	*Perfect Order Fulfillment (POF)*	C1	T1
2	*Order Fulfillment Cycle Time (OFCT)*	C2	T2
3	*Upside Supply Chain Adaptability (USCA)*	C3	T3
4	*Overall Value at Risk (VAR)*	C4	T4
5	*Total Cost of Serve (TCS)*	C5	

The variable of waste cause factors and the variable of cost-time analysed with Structural Equation Model (SEM).

D. Result and Discussion

The implied and observed variance-covariance matrices were compared to determine where the model might be changed to improve the overall fit. For instance, some questions initially thought to reflect certain latent variables were found to better reflect other latent variables or were not good indicators for any of the latent variables. In addition, some presumed direct influences were better modeled as indirect or merely correlative, resulting in a better fit between implied and observed variances and covariance. The final model of correlation between Construction Waste and Cost-Time (CWCT) using standard SEM terminology and graphical notation is illustrated in Fig. 4.

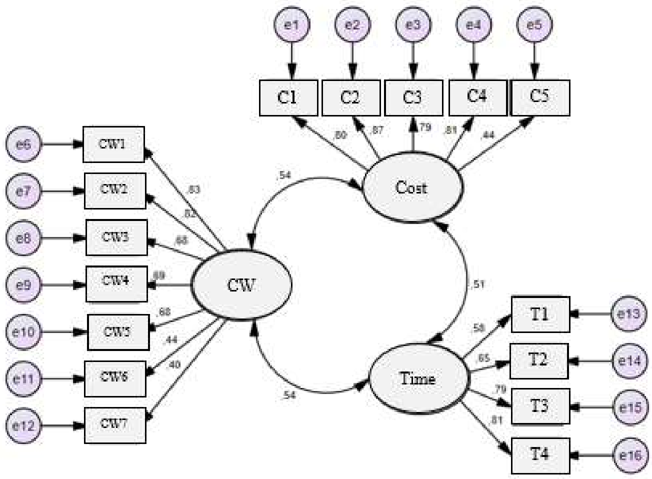

Fig. 4. The Model of CWCT

Fig. 5 shows the coefficient estimates indicating the bias introduced by the normal data for all indicators in the final model. It can be seen that the coefficient of the loading factor of construction waste cause factor indicators as shown in arrows has a significant level showing high enough and qualified > 0.5. The value of construction waste cause factor influence to cost and time is 0.54. It can be said that such value has relationship of 54%. The value of cost and time influence is said to be mutual influence of 0.51. This implies that such value has relationship of 51%. This indicates that the latent relationship between initial waste factors was significant because its variance was greater than 50% as the rule of thumb.

Based on the analysis of SEM-AMOS, goodness-of-fit measures showed that the model of construction waste cause factors to cost and time that impacts quality of management project was considered as fit. The result of structural model fit is presented in Table V.

TABLE V. STRUCTURAL MODEL FIT INDICES

Goodness-of-fit Measures	*Estimates*	CUT OFF VALUES BASE
CMIN/DF	3.61	< 5
GFI	0.89	0 to 1
RMSEA	0.08	≤ 0.08
AGFI	0.86	0 to 1
TLI	0.89	0 to 1
NFI	0.88	0 to 1
PRATIO	0.84	0 to 1
PNFI	0.74	0 to 1
PCFI	0.76	0 to 1

Table V highlights that the model of construction waste cause factors has been qualified as "goodness-of-fit" so that the model can be said to be fit. Furthermore, the Construct Reliability (CR) test performed on each component indicators were analyzed using Equation 3. CR was later analyzed based on the value of Standardized Loading from AMOS output. The model can be said fit if the value of the specified eligible CR is above 0.7. Standardized Loading (*SL*) and *CR* value is shown in Table VI.

TABLE VI. ESTIMATED OF CONSTRUCT RELIABILITY OF SEM

Variable	SL	SL²	1-SL²	CR
CW	0.404	0.163	0.837	
	0.440	0.194	0.806	
	0.677	0.458	0.542	
	0.689	0.475	0.525	
	0.677	0.458	0.542	
	0.825	0.681	0.319	
	0.833	0.694	0.306	
Σ	4.545		3.877	0.842
Cost	0.873	0.762	0.238	
	0.793	0.629	0.371	
	0.805	0.648	0.352	
	0.436	0.190	0.810	
	0.798	0.637	0.363	
Σ	3.705		2.134	0.865
Time	0.579	0.335	0.665	
	0.810	0.656	0.344	
	0.787	0.619	0.381	
	0.646	0.417	0.583	
Σ	3.494		1.972	0.802

Table VI shows the estimate of construct reliability. Based on column of *SL*, the bias is introduced by the normal data for all indicators in the final model. It can be seen that the coefficient of the loading factor CFCW model shown in arrows for each indicator has a significant level of high enough and qualified > 0.5.

According to Khanh and Kim [7] the causes of construction waste mostly consist of five components including resource plan and storage, resource distribution and usage, working procedure, communication and transport, and worker's rest that have impact to cost and time with value of 56.7% of significant value α=0.5. On other hand, the index of construction waste was designed from the value of mean of 3.97 and construction methods value was 3.86. This indicates that the design was a major factor in the construction waste [8]. The result of this study consisted of seven components of construction waste dominant namely change/repair of work, installation/repair of equipment, slow labor/unskilled, waiting for instruction, non-optimal placement of facilities, change of work schedule and weather. They were different from Khanh and Kim [7] because of the construction project have different problems and site condition. Furthermore, the result of this study disclosed the main construction waste cause factor was change/repair of work with mean value of 3.67. Change/repair of work was carried out based on design change, and it was similar with Satishkumar et al. [8] result of study. The identification cause factors of construction waste helped project manager to get better understanding of this factor. The project manager could control the waste construction on the production process to obtain better construction. It can be concluded that the construction project success can be achieved by understanding the causes of construction waste so that it can be improved in the future so that the final result of construction project is better.

E. Conclusion

Significant levels of the Cause Factors of Construction Waste (CFCW) that affected the construction waste time and cost was 0.54 which means that the variable of CFCW was at 54% of the cost and time. The variables of cost and time had mutual influence of 0.51 pointing out that time and cost were influential at 51% with a significant level (α) of 0.05. Furthermore, the impact of CFCW indicators having highest score was poor weather at 0.833 of significant level. Cost indicators indicated the highest impact is Perfect Order Fulfillment (POF) at 0.873 of significant level. Time indicators that showed the highest impact was Order Fulfillment Cycle Time (OFCT) at 0.810 of significant level. Based on the of result of the present study, it can be said that cause factors of construction waste impacted on cost and time of construction project. It is then said to have indirect impact on quality of construction management. To reduce the construction waste cause factors, it is necessary to improve the construction waste management sustainability.

ACKNOWLEDGMENT

The writer is grateful to the university for supporting this paper to be published and the contractor for providing access to collect data in construction waste.

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