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Initial PLS Model of Construction Waste Factors

Ismail Abdul Rahman[a], Sasitharan Nagapan[a*], Ade Asmi[b]

[a]*Faculty of Civil and Environmental Engineering,Universiti Tun Hussein Onn Malaysia,86400 Parit Raja, Malaysia*
[b]*Department of Civil Engineering, Universitas Bakrie,12920, Indonesia*

Abstract

Huge amount of construction wastes generate annually and affecting our environment. To reduce this impact, construction practitioners need to determine significant contributory factors of waste generation before engaging with construction works. Hence, this study determines significant factors and groups of factors affecting on construction waste generation. Vigorous literature review identified 81 factors for causing construction waste and clustered in 7 groups of factors namely Design, Handling of Materials and Equipment, Workers, Management, Site Condition and Procurement and External. A structures questionnaire designed based on these factors was surveyed and interviewed among 30 experts in construction industry. Respondents need to ranks the factors and also to conform whether the factors belong to the assigned group. Analysis indicated that all the respondents agreed with the factors assigned with the group and mean rank analysis found that 77 factors are above significant level to Malaysian construction environment. These 7 groups of factors were developed into PLS-SEM model to determine significant level in contributing to construction waste. Outcome from the model identified that Procurement group has highest impact on construction waste generation with path coefficient value of 1.188. This model will be useful to entire construction players and help the country to minimize construction waste generation.

Keywords: Construction industry; construction waste factors; PLS-SEM model

* Corresponding author.: Sasitharan Nagapan Tel.: +60-134033300
E-mail address:sasi81@hotmail.com.

1. Introduction

High demands of infrastructure, new housing & commercial buildings and social amenities generates construction waste resulted from construction activities of these demands (Osmani, 2012; Ying, Yin, & Jing, 2011; Nagapan, Rahman, & Asmi, 2012). Researchers and practitioners indicate waste generates each stage of construction namely during pre-construction, rough construction and post construction (Poon, 2007; Kofoworola, & Gheewal, 2009; Wahab, & Lawal, 2011). According to Ekanayake and Ofori (2000), substantial amount of construction waste generated on site relates to factors in design works, materials handling, and procurement process. Increased amount of waste generated will take more space in the gazetted landfills. Studied shows 26% of landfill space in Netherlands being occupied by construction waste (Bossink, & Brouwers, 1996) and 50% for Singapore situation (Hwang, & Yeo, 2011). Similarly, in Malaysia also needs more space for disposing the increased amount of construction waste generated (Nagapan, Rahman, Asmi, & Adnan, 2013). Since space is scarce, researchers and practitioners need to find ways of minimizing waste generation. The first step in minimizing the construction waste generation is to identify the underlying factors which contribute to construction waste generation.

2. Respondent's Demographic

A questionnaire was developed based on 81 factors of construction waste generation and 7 groups of these factors. The respondents were asked to rank the level of significant based on Likert scale and also to conform whether the factors assigned in the group are true. A total of 30 respondents who are expert in Malaysian construction industry were surveyed and interviewed. The respondents are from 24 agencies or construction companies who are either contractors, consultants or clients. Majority of the respondents are contractors (56.7%), followed by Clients (30%) and consultants (13.3%). All these contractors are from Class A (PKK) or Grade 7 (CIDB). Most of respondents had involved in infrastructure projects and well experienced in construction with 10 to 35 years of involvement. Majority of these experts have a minimum bachelor degree (86.7%) where most of them are engineers.

3. Determine Significant Factors

The gathered data from questionnaires was analysed using Mean Rank approach and found that 77 factors had scored $\geqslant$ 4.00. The most top ten factors are Poor supervision, Lack of environmental awareness, Leftover materials on site, Waste resulting from packaging, Shortage of skilled workers, Lack of legal enforcement, Poor attitudes of workers, Lack of waste management plans, Poor site condition and Lack of experience. The survey also found that all the respondents had agreed with the factors that were assigned in the group as described in the questionnaire.

4. PLS-SEM Model

Seven groups of factors which were agreed by respondents were used to develop into a model using SmartPLS 2.0 software (Henseler, Ringle, & Sinkovics, 2009) as in Figure 1. The model is to identify the level of significance of each group of factors in contributing to construction waste. This model comprises of two parts namely measurement and structural models. The measurement model needs to be assessed to meet certain criteria before final model is achieved.

Measurement model is assessed by checking on each factor reliability and group of factors convergent validity. The first step is to run the model and determine the factor loading for each factor. Any factor that is less than 0.5 has to be omitted and the model has to be run again. This iteration process has to be carried out until all the factors considered in the model have loading factor of ⩾0.5 (Chin, 1998). Once, all of these factors have factor loading >0.5, this measurement model is considered reliable. Then this model is checked for convergent validity for each group of factors. This also needs iteration process until all the parameters for convergent validity reach the threshold value.

For this study, four iterations process were carried out before reaching reliability for all the factors. A total of four factors were deleted (each factor for each iteration) and this left out 77 out of 81 factors that are reliable. This reliable measurement model is checked for convergent validity and found that Average Variance Extracted (AVE) > 0.5, Composite Reliability (CR) > 0.7 and Cronbach's Alpha (Alpha) > 0.7 (Akter, D'Ambra, & Ray, 2011; Aibinu, & Al-Lawati, 2010). This means that the model has achieved the required validity process as shown in Table 1.

Table 1. Convergent validity parameters for each group

Group	AVE	CR	Alpha
Design (DESG)	0.560	0.938	0.929
Handling of Material and Equipment (HAND)	0.614	0.935	0.923
Management (MANA)	0.509	0.942	0.936
Procurement (PROC)	0.633	0.945	0.935
Site Condition (SITE)	0.746	0.959	0.951
Workers (WORK)	0.546	0.943	0.934
External (EXTE)	0.588	0.908	0.892

Once the measurement model has achieved the required criteria, then the model is considered final. This final model can be used to assess the level of significance of each group towards construction waste generation. The assessment is based on path coefficient values for each group and for this study the values are as in Table 2.

Table 2. Path coefficient for each group

Group	Path coefficient, β
Design (DESG)	0.136
Handling of Material and Equipment (HAND)	0.518
Management (MANA)	1.184
Procurement (PROC)	1.188
Site Condition (SITE)	0.328
Workers (WORK)	0.663
External (EXTE)	0.097

From Table 2, it indicates that Procurement group has the highest impact on construction waste generation as compared to other groups with the value of path coefficient, β = 1.188. The External factor group is the least contribution to construction waste generation.

The final stage determines the ability of the structural model in explaining the effect of the entire groups of factors on construction waste generation. The indicator used is the R^2 value of the model where if $R^2 > 0.26$ the model is considered substantial, $R^2 > 0.13$ considered as moderate and $R^2 > 0.02$

considered as weak (Cohen, 1988). For this study, R^2 value for the structural model is 0.648 which means that the model has substantial power of explaining the effect of the entire group on construction waste generation as in Figure 1.

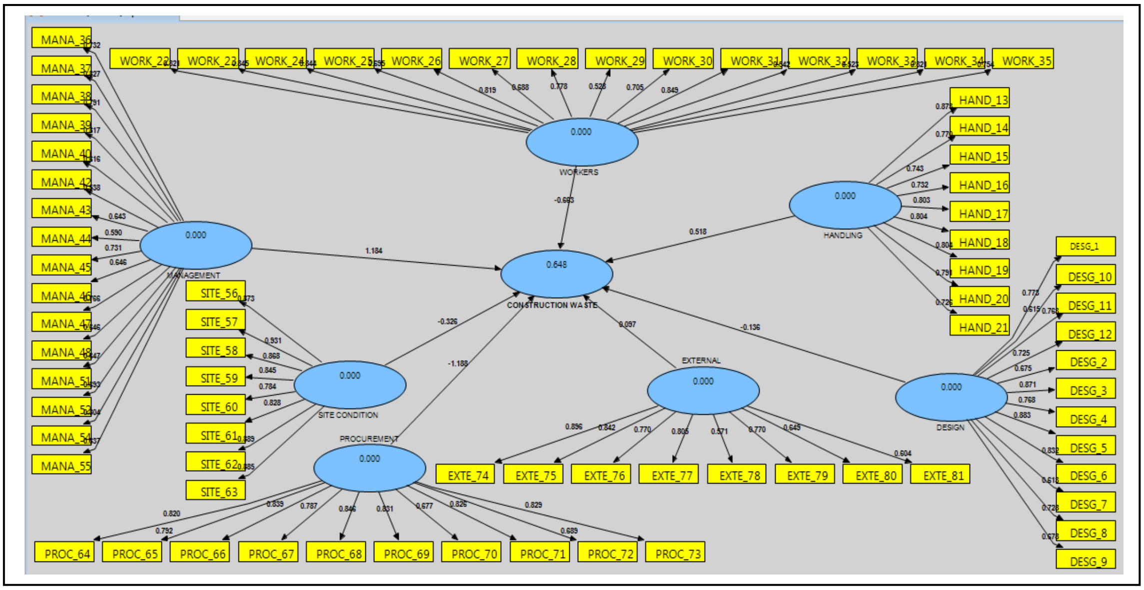

Figure 1. PLS-SEM Model: Construction Waste Generation

5. Conclusion

This study identified 77 significant factors of construction waste generation which are relevant to Malaysian construction industry as Appendix A. These factors are clustered into 7 groups as agreed by all the respondents. PLS model developed from these factors and group's factors identified that procurement's group contribute the most impact to the construction waste generation. The developed model provides an important input in identifying the severity of each factor in contributing construction waste generation in Malaysia. By identifying these factors, will enable to reduce the waste generation from the construction industry and thus, making our development more sustainable in future.

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Appendix A. *List of Construction Waste Factors*

Code	Factors	Code	Factors
DESG 1	Frequent design changes	MANA 40	Inappropriate construction methods
DESG 2	Design errors	MANA 41	Poor information quality
DESG 3	Lack of design information	MANA 42	Late information flow among parties
DESG 4	Poor design quality	MANA 43	Shortage of equipment
DESG 5	Slow drawing distribution	MANA 44	Lack of waste management plans at sites
DESG 6	Incomplete contract document	MANA 45	Lack of resources
DESG 7	Complicated design	MANA 46	Rework
DESG 8	Inexperience designer	MANA 47	Long waiting periods
DESG 9	Error in contract documentation	MANA 48	Non availability of equipment
DESG 10	Too many of interactions between various specialists	MANA 49	Lack of knowledge on construction
DESG 11	Poor coordination between parties during design stage	MANA 50	Lack of influence of contractors to supplier
DESG 12	Last minutes client requirement	MANA 51	Lack of environmental awareness
HAND 13	Wrong material storage	SITE 52	Leftover materials on site
HAND 14	Poor material handling	SITE 53	Waste resulting from packaging
HAND 15	Damage during transportation	SITE 54	Damage caused by poor site conditions
HAND 16	Poor quality of materials	SITE 55	Waiting due to congestion of the site
HAND 17	Equipment failure	SITE 56	Waiting due to lighting problem
HAND 18	Delay during delivery	SITE 57	Difficulties for delivery vehicles accessing construction sites
HAND 19	Tools not suitable used	SITE 58	Unforeseen ground conditions
HAND 20	Inefficient methods of unloading	SITE 59	Interference of others crews at site
HAND 21	Materials supplied in loose form	PROC 60	Ordering errors
WORK 22	Workers' mistakes during construction	PROC 61	Items not in compliance with specification
WORK 23	Incompetent worker	PROC 62	Error in shipping
WORK 24	Poor attitudes of workers	PROC 63	Mistakes in quantity surveys
WORK 25	Damage caused by workers	PROC 64	Supplier errors
WORK 26	Insufficient training for workers	PROC 65	Wrong material delivery procedures
WORK 27	Lack of experience	PROC 66	Over allowances paid lead to over budget
WORK 28	Shortage of skilled workers	PROC 67	Frequent variation orders
WORK 29	Inappropriate use of materials	PROC 68	Inappropriate methods used for estimation
WORK 30	Poor workmanship	PROC 69	Waiting for replacement
WORK 31	Worker's no enthusiasm	EXTE 70	Effect of weather
WORK 32	Inventory of materials not well documented	EXTE 71	Effect of accidents at site
WORK 33	Abnormal wear of equipment	EXTE 72	Stealing at site
WORK 34	Lack of awareness among the workers	EXTE 73	Lack of legal enforcement
WORK 35	Too much overtime for workers	EXTE 74	Vandalism at site
MANA 36	Poor planning	EXTE 75	Damages caused by third parties
MANA 37	Poor controlling	EXTE 76	Festival celebration disturb works at sites
MANA 38	Poor site management	EXTE 77	Unpredictable local conditions
MANA 39	Poor supervision		