4.c. MODELLING THE RELATIONSHIP BETWEEN MATERIAL WASTE GENERATION AND NVAAS

by Aqli Mursadin

Available online at www.globalilluminators.org
GlobalIlluminators
FULL PAPER PROCEEDING
Multidisciplinary Studies for Engineering & Technology Studies
Full Paper Proceeding ETAR-2016, Vol. 3, 157-166
ISBN: 978-969-9948-63-3

ETAR 2016

Modelling the Relationship between Material Waste Generation and Nvaas in Construction Work

Aqli Mursadin [1*], Isra [2]

[1, 2] *Universitas Lambung Mangkurat, Indonesia*

Abstract

Construction material waste is any form of material other than earth material that cannot be used and has to be removed from the site (Ekanayake and Ofori, 2000). Material waste generated during construction work means the loss of material and the requirement for its removal from the site. Aiyetan dan Smallwood (2013) and Fadiya, et al. (2014) quantified contributions from several non-value adding activities (NVAAs) as causes of material waste. A study by Mahamid and Elbadawi (2014) showed the importance of quantitative information on waste and NVAAs. Haryanto (2011) and Bahri (2015) reported that NVAAs commonly occurred in building projects in South Kalimantan. These results, however, have not produced any models that fit data representing the relationship between material waste and NVAAs. This paper presents a work on modelling the relationship. The resulting model will be useful for understanding factors contributing to the relationship and predicting the behavior of material waste generation. The method consists of literature review, model development, data collection using a questionnaire, data analysis, and model fitting. Generalised linear models are chosen with fit measures consisting of residual deviance and log-likelihood. The questionnaire comprises seven questions using a five-point rating scale. Each question is related to waste generated due to a particular NVAA. Respondents include construction professionals from contractor companies randomly selected in Barito Kuala and Banjar Regencies, some with an experience of no less than 20 years in the industry. The resulting models suggest that there is no difference between NVAAs in terms of the amount of generated waste. It was originally thought that the levels of waste generated in relation to some activities were significantly lower than those related to the others. However, different regencies lead to significantly different levels of generated waste. Finally, directions for future research are recommended.

Keywords: Construction Material Waste, Generalised Linear Models, Nvaas, Statistical Modelling

Introduction

Construction material waste is any form of material on the site other than earth material that cannot be used for the intended specific purpose of the project and has to be removed from the site or used for other purposes within the site (Ekanayake and Ofori, 2000). Material waste is produced in various types of construction work from demolition to renovation and new building projects (Nowak, *et al*., 2009). Solis-Guzman, *et al.* (2009) estimated that the construction industry contributes 35 percent of the entire waste produced around the world. According to Hobbs (2011), costs related to material waste include the loss of material and the cost of its removal from the site.

Aiyetan dan Smallwood (2013) studied and ranked a number of factors causing material wastage in construction in Lagos, Nigeria. They included in these factors several construction activities known as *non-value adding activities* (NVAAs). Fadiya, *et al*. (2014) quantified the frequency and the severity of causes of material wastage in the United Kingdom. The majority of these causes can be categorised as or considered directly related to NVAAs. A study by Mahamid and Elbadawi (2014) showed the importance of quantitative information on waste and NVAAs.

NVAAs gain their popularity in the area of lean construction, a construction model with an aim of eliminating or reducing waste (Diekman, *et al*., 2004:60-61). They are among all sorts of human activities that consume resources and yet produce no value (Womack and Jones, 1996).

In particular, the involvement of some NVAAs in construction resource wastage in big building projects in South Kalimantan Province can be examined from studies conducted by Haryanto (2011) and Bahri (2015). The first study, which was on three building projects, identified two NVAAs, namely, extra processing and waiting that have high intensities in work items such as field processing, earth work, and concrete work. This result was confirmed by

*All correspondence related to this article should be directed to Aqli Mursadin, Universitas Lambung Mangkurat, Indonesia
Email: a.mursadin@gmail.com
© 2016 The Authors. Published by Global Illuminators. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)
Peer-review under responsibility of the Scientific & Review committee of ETAR-2016.

the latter on five non-ordinary building projects in the same province. Extra processing in this case is related to product changes, defects, etc. leading to material waste being produced and due to be removed. All this is in addition to materials such as ready-mix concrete being ordered in excess amount resulting in a need to remove the waste.

Apart from that, the relationship between material wastage and NVAAs in this province's construction industry has gained virtually no academic attention. With 13 regencies in the province, each probably with its construction practice and custom, it is important to carry out a further study on this topic in this region. Findings from such a study may reveal how material waste generation in construction behaves from one regency to another. The information, for instance, can be used to compare levels of waste in different regencies and to asses the related risks.

In particular, there is a need for modelling the relationship as mentioned above. This paper presents results from a study performed as part of an effort of developing models representing the relationship between material waste generation and NVAAs in South Kalimantan. By relationship it means any mutual connection, or connecting pattern between NVAAs and material waste generation through which NVAAs contribute, affect, or influence the behaviour of material waste generation.

Literature Review

Relevant Results on Material Wastage and Nvaas

According to Ekanayake and Ofori (2000), construction material waste is any form of material on the site other than earth material that cannot be used for the intended specific purpose of the project and has to be removed from the site or used for other purposes within the site. Such waste is produced in various types of construction work ranging from demolition to renovation and new building projects (Nowak, *et al*., 2009). Solis-Guzman, *et al*. (2009) estimated a 35-percent contribution of construction waste from the construction industry to the entire waste produced around the world.

Construction material waste contributes additional cost significantly to construction (Ekanayake and Ofori, 2000). The total cost of material waste is the sum of the cost of material lost as the waste and the cost of its removal from the site (Hobbs, 2011).

Some of the waste quantification models are based on waste production per unit area or unit volume of product such as those by Hsiao, *et al*. (2002), Fatta, *et al*. (2003), and Zhao, *et al*. (2010). Cochran, *et al*. (2007) based their approach on the amount of waste produced per activity. A procedure was developed by Martinez-Lage, *et al*. (2010) for assessing waste production and composition.

Other studies focused on factors that contribute to the generation of construction material waste. Wimalasena, *et al*. (2010) studied process variables that generate construction waste. A number of factors causing material wastage in construction were studied and ranked by Aiyetan dan Smallwood (2013) in Lagos, Nigeria. Also included in these factors were several construction activities known as *non-value adding activities* (NVAAs). By quantifying their frequency and severity, Fadiya, *et al*. (2014) ranked causes of material wastage in the United Kingdom. The majority of these causes can be categorised as or considered directly related to NVAAs.

In the area of lean construction, NVAAs include seven activities as follows (Diekman, *et al.*, 2004:60-61): overproduction, waiting, transport, extra processing, inventory, motion, and defects. The involvement of some NVAAs in construction resource wastage in big building projects in South Kalimantan Province was reported by Haryanto (2011) who conducted his study on three big building projects in the province. In work items such as field processing, earth work, and concrete work, he discovered that two NVAAs, namely, extra processing and waiting showed high intensities. This finding was later confirmed by Bahri (2015) who performed his study on five non-ordinary building projects in the same province. Extra processing in this case is related to product changes, defects, etc. resulting in material waste being produced and due to be removed. In addition to this, materials such as ready-mix concrete products are being ordered in excess amount leading to a need for the removal of its waste.

When it comes to quantifying the relationship between the generation of waste and its possible causes, previous results indicate the use of frequency and/or severity of contribution of these causes of waste in deriving the relationship. It is possible to turn such numerical results into models for which a variety of statistics are available for measuring both the relationship and the fitness of the models. This, however, was not the case with those of Aiyetan dan Smallwood (2013) and Mahamid arnd Elbadawi (2014). Fadiya, *et al*. (2014) developed single-factor ordinal logistic regression models but did not elaborate their use. A particular concern regarding the results by Mahamid and Elbadawi (2014) is the treatment of the questionnaire response data such as the use of means as statistics computed from the responses as if they were continuous, numerical data while, in fact, they were categorical. Another important aspect, namely, the location where the industry is, was not considered as a factor in the above results.

Modelling Using Generalised Linear Models

A generalised linear model (GLM) is a statistical model having the following general form (see, e.g., Fox, 2008:379):

$$\eta_i = \beta_{i0} + \beta_{i1}x_{i1} + \cdots + \beta_{ik}x_{ik} \quad (1)$$

where x_{ij} is the j^{th} linear predictor or regressor of the random component Y_i, and η_i is the *link function*. These are the three main components of the model. The i^{th} intercept β_{i0} and the slopes β_{ij}'s are the parameter that need to be estimated.

When categorical response data are being modelled, Y_i is usually used to represent the number of responses of the i^{th} category, while x_{ij} can be a function of other variables. The link function

$$\eta_i = g(\mu_i) \quad (2)$$

where $\mu_i = E[Y_i]$ is the expectation of Y_i, can be chosen from a number of functions depending on whether Y_i and the regressors are continuous or discrete. For instance, for ordinary linear regression models (in which, all Y_i and regressors are continuous) an identity function $\eta_i = \mu_i$ is used.

For modelling categorical response data such as data produced using a questionnaire-based survey, the usual choice available for the link function includes, among others, the log function and the logit function (Agresti, 2002). The log function takes μ_i directly as its argument, and the logit function takes as its argument the probability of the i^{th} category being chosen, i.e. $\pi_i = \mu_i/n$, where n is the total number of responses. For some ordinal response data where the categories of response can be ordered (e.g. "very small", "small", "moderate", "big", "very big"), the logit is

$$\text{logit}\,(\pi_i) = \log(\text{odds}_i) = \beta_{i0} + \beta_{i1}x_{i1} + \cdots + \beta_{ik}x_{ik} \quad (3)$$

where $\text{odds}_i = \frac{\sum_{\alpha=1}^{i}\pi_\alpha}{1-\sum_{\alpha=1}^{i}\pi_\alpha}$. This gives $\sum_{\alpha=1}^{i}\pi_\alpha = \frac{1}{1+e^{-(\beta_{i0}+\beta_{i1}x_{i1}+\cdots+\beta_{ik}x_{ik})}}$ and $\pi_i = \sum_{\alpha=1}^{i}\pi_\alpha - \sum_{\alpha=1}^{i-1}\pi_\alpha$. This is also called the cumulative logit. The interpretation of the model is straightforward. The argument $\frac{\sum_{\alpha=1}^{i}\pi_\alpha}{1-\sum_{\alpha=1}^{i}\pi_\alpha}$ is the odds to find a category higher than the i^{th} category. For a unit increase in x_{ij}, this odds multiplies by $e^{\beta_{ij}}$.

Another type of logit commonly used is the baseline category logit which treats categories as nominal even when they are ordinal. For this logit, $\text{odds}_i = \frac{\pi_i}{\pi_*}$ where the subscript "*" indicates a category chosen as the baseline of the model.

It is common to use contingency tables to display relationships between categorical variables (Agresti, 2002). Such tables may be 2-way, 3-way or *n*-way depending on the number of factors considered in the relationships.

A model is called a saturated model if it includes all the main effects and effects of all possible interactions between factors. This model reflects the table structure and fits the data perfectly. A null model is a model that contains only the intercept β_0. According to this model, there is no effect from any factors whatsoever.

It is always desirable to have a simple model that may be found between the saturated model and the null model. A simpler model means fewer parameters to estimate and, therefore, smaller estimation errors. However, it also means less fit between the model and the data. Among several measures of fit that can be used for this purpose is the *deviance* which is based on the log-likelihood ratio, namely

$$G^2 = 2\sum_{j=0}^{s-1}\sum_{i=1}^{r} y_{ij}\log\left(\frac{y_{ij}}{y_{.j}\hat{\pi}_{ij}}\right) \tag{4}$$

where i and j refer to the i^{th} column and the j^{th} row respectively, y_{ij} is the value in the cell ij of the table, $\hat{\pi}_{ij}$ is the estimate of the probability in the cell ij, and $y_{.j}$ is the sum of all y_{ij} of the j^{th} row. Notice that $\hat{\mu}_{ij} = y_{.j}\hat{\pi}_{ij}$ is an estimate of the mean of Y_{ij} whose observed value is y_{ij}. The smaller the residual absolute value $|y_{ij} - \hat{\mu}_{ij}|$ is, the better the model fits the data.

This is a statistic whose null distribution is a chi square distribution with $p - q$ degrees of freedom, where p is the number of parameters that need to be estimated in the corresponding saturated model and q is the number of parameters estimated in the chosen model. This statistic is called the null deviance for a null model and the residual deviance for another model.

Methods

The modelling approach chosen in this study was based on generalised linear models. This allows relationships to be inferred between quantitative values in data in a linear fashion, thoroughly tested, and easily verified and understood. It requires that the models capture the observed behaviour of material waste generation subject to NVAAs, not the presupposed measures of contribution of waste causes such as frequency and severity of the contribution as employed by Fadiya, *et al*. (2014). In fact, waste quantification models are usually based on waste production (Hsiao, *et al*., 2002; Fatta, *et al*., 2003; and Zhao, *et al*., 2010). For this reason, the relative amount of waste generated was chosen to represent the behaviour. By relative amount, it means the amount relative to the size of the project.

For collecting data, the approach used in this study was to gain information on the relationship between material waste generation and NVAAs based on knowledge and perception of individuals directly and currently working in the South Kalimantan's construction industry. Hence, it was carried out based on data collected using a questionnaire. The questionnaire was developed to comprise seven questions each asking the respondent to indicate the relative amount of material waste generated in relation to a particular non-value adding activity in construction.

The relative amount was measured with a five-point scale with the following categories: (1) "extremely small", (2) "small", (3) "moderate", (4) "large", (5) "extremely large". One of the questions is shown in Fig. 1. In addition to these questions, the respondent was also asked to give his/her professional details such as age and length of experience in the industry.

As for the sample, a total of 60 professionals in construction representing companies randomly selected from contractors listed in Barito Kuala Regency and Banjar Regency were approached to become the respondents. The companies they represented are local contractors with local knowledge of construction. They can be considered as a relatively homogeneous sample.

Please indicate the relative amount of material waste generated in relation to OVERPRODUCTION in a project:

☐ Extremely small

☐ Small

☑ Moderate

☐ Large

☐ Extremely large

Figure 1: A Sample Question (*translated*)

These individuals were personally invited to participate in the survey and given the questionnaire. The filled questionnaire was collected directly from each of the respondents. Of this number, 22 in Barito Kuala Regency and 26 in Banjar Regency filled the questionnaire completely. Tables 1 summarises the respondents in terms of their experience in the industry and their roles in the company.

Table 1
Experience and Roles of Respondents

Experience (years)	# Respondents
0 – 10	36
> 10	12
Roles	# Respondents
Director	16
Managers	3
Site supervisor, site engineer	26
Others	3

Data Analysis and Results

Preliminary Tests

Table 2 summarises the responses in a 3-way table. A chi-squared goodness of test (Kottegoda and Rosso, 1997:283-285) was performed on each of the rows in Table 2 against a uniform distribution. If the numbers in a row are uniformly distributed, information in that row can be rendered useless. Table 3 shows the test results. The smaller the probability value in a row of the last column is, the further away the numbers of responses related to the corresponding NVAA in Table 2 will be from being uniformly distributed. It is clear that what was obtained from the survey is indeed potentially useful information and not just random answers.

Table 2
Response on Relative Amounts of Material Waste Generated in Relation to NVAAs

	NVAAs	Areas	Number of Responses by Category				
			1	2	3	4	5
1.	Overproduction	Barito Kuala	4	5	10	3	0
2.	Overproduction	Banjar	4	10	8	4	0
3.	Waiting	Barito Kuala	2	5	11	2	2
4.	Waiting	Banjar	9	14	3	0	0
5.	Transport	Barito Kuala	4	7	6	3	2
6.	Transport	Banjar	11	11	3	1	0
7.	Extra processing	Barito Kuala	3	7	8	3	1
8.	Extra processing	Banjar	5	8	11	2	0
9.	Inventory	Barito Kuala	3	8	8	3	0
10.	Inventory	Banjar	7	10	8	1	0
11.	Motion	Barito Kuala	3	8	6	4	1
12.	Motion	Banjar	6	14	3	3	0
13.	Defects	Barito Kuala	3	7	8	2	2
14.	Defects	Banjar	6	11	3	6	0

Table 3
Test Results on Uniformity

	NVAAs	Test Value, $\mathbf{X}^2$	$P(\mathbf{X}^2 > \chi^2)$
1.	Overproduction	17.417	0.0016*
2.	Waiting	23.458	0.0001*
3.	Transport	19.708	0.0006*
4.	Extra processing	18.875	0.0008*
5.	Inventory	24.500	0.0001*
6.	Motion	24.500	0.0001*
7.	Defects	10.750	0.0295*

* smaller than 0.05

Another preliminary examination which was on the reliability of the results was carried out by measuring internal consistency between responses using Cronbach's alpha method. The higher the Cronbach's alpha value is, the higher the consistency will be. An acceptable range of Cronbach's alpha values is from 0.70 to 0.95 which means sufficiently high consistency.

Together, results from the seven questions gave a Cronbach's value of 0.8493065. Cross validation on each question was also performed by removing that particular question and calculating the value based on six remaining questions. Table 4 shows values obtained by this way. According to this, the internal consistency was sufficiently high.

Table 4
Cronbach's Alpha Results

	Items	If Item Deleted
1.	Overproduction	0.8350917
2.	Waiting	0.8458272
3.	Transport	0.8096026
4.	Extra processing	0.8143725
5.	Inventory	0.8353984
6.	Motion	0.8373137
7.	Defects	0.8177271

The Models

Ordinal logit models were chosen to represent the data. As clear from Eq. (3), this type of model suits very well the ordering nature of the response and the result is easy to interpret. The interpretation is even easier to make than that of probit models, a similar type of model based on normal probability distribution inverse. Log-linear models could be a good alternative but they treat ordinal categories as nominal categories and, therefore, the order becomes unimportant. Ordinal characteristics of a model can improve its parsimony and power (Agresti, 2002:274).

Initially, five possible types of ordinal logit models were available to fit the data:

1. Null (Type 0): $\text{logit}\ (\pi_i) = \beta_{i0}$
2. Independent, NVAAs only (Type 1): $\text{logit}\ (\pi_i) = \beta_{i0} + \sum_{j=1}^{6} \beta_{ij} x_{ij}$
3. Independent, Area only (Type 2): $\text{logit}\ (\pi_i) = \beta_{i0} + \beta_{i7} x_{i7}$
4. Independent (Type 3): $\text{logit}\ (\pi_i) = \beta_{i0} + \sum_{j=1}^{6} \beta_{ij} x_{ij} + \beta_{i7} x_{i7}$
5. Saturated (Type 4):

$$\text{logit}\ (\pi_i) = \beta_{i0} + \sum_{j=1}^{6} \beta_{ij} x_{ij} + \beta_{i7} x_{i7} + \sum_{j=1}^{6} \beta_{i(j+7)} x_{ij} x_{i7}.$$

The values of x_{ij}'s are defined as follows:

$$x_{ij} = \begin{cases} 1 & \text{for the } (j+1)\text{th NVAA and } 1 \leq j \leq 6 \\ 0 & \text{if otherwise} \end{cases},$$

$$x_{i7} = \begin{cases} 1 & \text{for Banjar Regency} \\ 0 & \text{elsewhere} \end{cases}.$$

Here, overproduction and Barito Kuala were taken as the baseline for NVAAs and Areas, respectively. Using a type 1 model, a contribution from extra processing to a category *i* waste relative amount in a cumulative logit, for instance, is realised by multiplying the odds $\frac{\sum_{\alpha=1}^{i} \pi_\alpha}{1-\sum_{\alpha=1}^{i} \pi_\alpha}$ with $e^{\beta_{is}}$.

The probability is estimated as follows:

$$\hat{\pi}_i = \begin{cases} \hat{\pi}_{i\cdot\cdot} & \text{Type 0} \\ \hat{\pi}_{ij\cdot} \text{ or } \hat{\pi}_{i\cdot k} & \text{Type 1 or Type 2} \\ \hat{\pi}_{ij\cdot}\hat{\pi}_{i\cdot k}/\hat{\pi}_{\cdot\cdot\cdot} & \text{Type 3} \\ \hat{\pi}_{ijk} & \text{Type 4} \end{cases}$$

where *i*, *j*, and *k* indicate the categories of responses, NVAAs, and Areas, respectively. The subscript "·" means the probability is marginalised on the corresponding factor (NVAAs or Areas).

The computation to fit the models was conducted using **R** statistical programming language (https://cran.r-project.org). However, the occurrences of sampling zeros in Table 2 might indicate that the sample was not big enough for the survey to get a response for a particular combination of factorial categories. This relatively small size of sample, which was 48, was also prone to producing large standard errors of estimation since the method of maximum likelihood commonly used for fitting models in this type of situation relies on sufficiently large samples for estimating the parameters (see, e.g., Fox, 2008:404). This means that the resulting estimates of parameters might not be reliable.

The pmlr function of **pmlr** package (Colby, *et al*., 2010) in **R** was used to fit the models. This function enables penalised estimation of parameters which can give reliable results even when the sample size is relatively small. The resulting models, however, were baseline category models and had to be rearranged to obtain their cumulative logit equivalence.

Among them, a resulting type 2 model was chosen to represent the relationship. It was preferable to any models of type 1, type 3 and type 4 due to fewer parameters that need to be estimated. The deviance of the type 2 model was 44.88151 with 48 degrees of freedom. This was a good fit based on a chi-square test. A slightly better fit was given by a type 3 model, that is, with a deviance of 21.80625 and 24 degrees of freedom. However, the difference in their deviances which was 23.07526 with 48 – 24 = 24 degrees of freedom was not significantly big based on a chi-square test. This means that the two competing models were not significantly different, hence a simpler one was preferable.

Cumulative logits of the chosen model are as follows:

$$\text{logit}\,(\pi_1) = -1.78432 + 0.753234x_{17},$$
$$\text{logit}\,(\pi_2) = -0.21165 + 1.004051x_{27},$$
$$\text{logit}\,(\pi_3) = 1.48082 + 0.743803x_{37},$$
$$\text{logit}\,(\pi_4) = 2.857146 + 3.050937x_{47}.$$

There is no need to fit any type 1 and type 4 models as they are more complex than a type 2 model. Meanwhile, the null model simply did not fit the data.

Interpretation of the model is straightforward. For instance, $\text{logit}(\pi_2) = -0.21165 + 1.004051x_{27}$ and $\text{logit}(\pi_3) = 1.48082 + 0.743803x_{37}$ mean that in Banjar Regency ($x_{37} = 1$) the probability that the relative amount of material waste generated in relation to any construction NVAA (it does not matter which NVAA) is moderate is

$$\hat{\pi}_3 = \sum_{\alpha=1}^{3} \pi_\alpha - \sum_{\alpha=1}^{2} \pi_\alpha = \frac{1}{1+e^{-(1.48082+0.743803)}} - \frac{1}{1+e^{-(-0.21165+1.004051)}}$$
$$= 0.902439 - 0.688347 = 0.214092$$

With 26 respondents, the estimated average number of responses would be $0.214092 \times 26 = 5.566396$. The actual average from the data was 5.571429.

In Barito Kuala Regency, where $x_{37} = 0$, the two logit functions become $\text{logit}(\pi_2) = -0.2085$ and $\text{logit}(\pi_3) = 1.5041$. Hence,

$$\hat{\pi}_3 = \frac{1}{1+e^{-(1.48082)}} - \frac{1}{1+e^{-(-0.21165)}} = 0.814696 - 0.447284 = 0.367412$$

With 22 respondents, the estimated average number of responses would be $0.367412 \times 22 = 8.083068$. The actual average from the data was 8.142857.

The models can also explain how relative amounts of construction material waste generated in relation to an NVAA behave between different areas. For instance, the bigger $\text{odds}_3 = \frac{\sum_{\alpha=1}^{3} \pi_\alpha}{1-\sum_{\alpha=1}^{3} \pi_\alpha}$ are, the less likely it is to obtain a relative amount of construction material waste generated in relation to an NVAA bigger than "moderate". The ratio between odds_3 in Banjar and odds_3 in Barito Kuala is $e^{0.743803} = 2.103922$. It suggests that finding a "bigger-than-moderate" amount in Banjar is at least twice as hard as it is in Barito Kuala.

Table 5 shows probabilities and odds ratios of categories of waste relative amounts generated subject to different areas.

Table 5
Probabilities and Odds Ratios of Categories

Probabilities and Odds Ratios	Categories of Relative Amounts				
	Extremely Low	Low	Moderate	High	Extremely High
Probability in Barito Kuala	0.1438	0.3035	0.3674	0.1310	0.0543
Probability in Banjar	0.2629	0.4255	0,2141	0.0949	0.0027
Odds Ratio Banjar to Barito Kuala	2.123856	2.729317	2.103921	21.13513	–

The fitness shown by the type 2 models means that variations in the relative amounts of construction material waste generated in relation to NVAAs are not affected by variations in the types of NVAAs. On the other hand, they are affected by variations in areas, that is, regencies of South Kalimantan where construction NVAAs are observed.

Discussion

It is worthwhile to emphasis the difference between approaches taken in this study and in others. Fadiya, *et al.* (2014), for instance, used a logit model for contributions of causes only to compute the probability of each response category. Also, they did not consider locations or locality of the respondents as a factor correlated to material wastage. The study in this paper, on the other hand, considered location as a factor in the models and used the models to explain how a particular factor influences the behavior of material waste generation. In other words, the resulting models capture an important piece of local construction knowledge.

NVAAs do contribute to material wastage in construction, However, there is no difference between them in terms of the amount of generated waste. The above generalised linear models failed to find evidence that variations in types of NVAAs affect how material waste generation behaves in the South Kalimantan construction industry. Data from Fadiya, *et al*. (2014) will be used to show if this is also true for severity and frequency of waste sources as follows.

Because the severity data (Fadiya, *et al*, 2014) only contain one factor (having nine levels, some of which are NVAAs), there are only two types of model: the saturated model and the null model. The null model fits the severity data with a deviance of 41.8972 on 32 degrees of freedom and acceptably small standard errors for parameter estimation. The resulting null model is

$$\text{logit}\ (\pi_1) = -6.1269,$$
$$\text{logit}\ (\pi_2) = -1.2654,$$
$$\text{logit}\ (\pi_3) = 1.0498,$$
$$\text{logit}\ (\pi_4) = 3.3210.$$

This fitness shown by the null model may indicate that variations in types of NVAAs do not affect how material waste generation behaves.

As for the frequency data from the same authors, no reliable models can be obtained. The deviance produced by the null model is 115.7608 on 32 degrees of freedom, which is too large for the model to fit the data. Also, the corresponding saturated model cannot be accepted due to extremely large standard errors. It is worth notice that the Cronbach's values for the frequency data as reported by the authors are well below 0.70. One should question the internal consistency of the results and, therefore, should not rely on any model resulting from the data.

Conclusions and Recommendations

The study has discovered through literature review that non-value adding activities in construction contribute to material wastage. However, through modelling of the relationship between material wastage and NVAAs, it has also discovered that variations in the relative amounts of construction material waste generated in relation to NVAAs are not affected by variations in the types of NVAAs. In other words, there is no difference between NVAAs in terms of the amount of generated waste. On the other hand, the amounts are affected by variations in Areas, namely, regencies of South Kalimantan where construction NVAAs are observed.

The modelling has been based on generalised linear models. The resulting models enable the estimation of relative amounts of material waste generated in relation with NVAAs. They also enable odds ratios of generating waste to be computed between different areas.

It is recommended that this study be extended to include more regencies and cities in the province. This should enable the discovery of local construction knowledge on material wastage in relation to NVAAs. In addition, future modelling should include more factors such as sizes and types of projects.

References

Agresti, A. (2002). *Categorical data analysis (2nd ed.)*. Hoboken, NJ: John Wiley & Sons, Inc.

Aiyetan, O. & Smallwood, J. (2013, October, 23-25). Materials Management and Waste Minimization on Construction Sites in Lagos State, Nigeria. In *Proceeding of the 4th Int'l Conf. on Eng., Project and Prod.* Bangkok, Thailand: *Management (EPPM 2013)*.

Bahri, S. (2015). *Kajian Keterlambatan Pelaksanaan Pekerjaan pada Bangunan Gedung Tidak Sederhana di Provinsi Kalimantan Selatan*. Unpublished MS Thesis, Civil Engineering Master Program, Lambung Mangkurat University, Banjarmasin, Indonesia.

Cochran, K., Townsend, T., Reinhart, D., & Heck, H. (2007). Estimation of regional building-related C&D debris generation and composition: Case study for Florida, US. *Waste Management*, *27*(7), 921-931.

Colby, S., Lee, S., Lewinger, J. P., and Bull, S. (2010). *Package 'PMLR'*. Retrieved from https://cran.r-project.org

Diekman, J. E., Krewedl, M., Balonick, J., Stewart, T., & Won, S. (2004). *Application of lean manufacturing principles to construction*. A Report to the Construction Industry Institute, the University of Austin, Texas.

Ekanayake, L. L. & Ofori, G. (2000). Construction Material Waste Source Evaluation. In *Proc. of the Strategies for a Sustainable Built Environment*, Pretoria, South Africa.

Fadiya, O. O., Georgakis, P., & Chinyio, E. (2014). Quantitative Analysis of the Sources of Construction Waste. *Journal of Construction Engineering*, *2014,* 1-9.

Fatta, D., Papadopoulos, A., Kourmoussis, F., Mentzis, A., Sgourou, E., Moustakas, K., ... & Siouta, N. (2003). Estimation methods for the generation of construction and demolition waste in Greece. *MC Limbachiya, and JJ Roberts. Thomas Telford*, 25-33.

Fox, J. (2008). *Applied regression analysis and generalized linear Models (2nd ed.)*. Washington DC, WA: Sage Publications.

Haryanto, S. (2011). *Non-Value Adding Activities pada Konstruksi Bangunan Gedung Bertingkat*. Unpublished MS Thesis, Civil Engineering Master Program, Banjarmasin, Indonesia: Lambung Mangkurat University.

Hobbs, G. (2011). Developing a Strategic Approach to Construction Waste. Retrieved from https://goo.gl/YocXOC

Hsiao, T. Y., Huang, Y. T., Yu, Y. H., and Wernick, I. K. (2002). modeling materials flow of waste concrete from construction and demolition wastes in Taiwan. *Resources Policy*, *28*(1-2), 39-47.

Kottegoda, N. T. & Rosso, R. (1997). *Statistics, Probability, and Reliability for Civil and Environmental Engineers*. Singapore, Indonesia: McGraw-Hill Co., Inc.

Mahamid, I., & Elbadawi, I. A. (2014). Construction Material Waste: Recognition and Analysis. *Research Journal of Applied Sciences, Engineering and Technology*, *8*(11), 1312-1318.

Lage, I. M., Abella, F. M., Herrero, C. V., & Ordóñez, J. L. P. (2010). Estimation of the annual production and composition of C&D Debris in Galicia (Spain). *Waste management*, *30*(4), 636-645.

Nowak, P. O., Steiner, M., & Wiegel, U. (2009). Waste management challenges for the construction industry. *Construction Information Quarterly*,*11*(1), 5-8.

Solís-Guzmán, J., Marrero, M., Montes-Delgado, M. V., & Ramírez-de-Arellano, A. (2009). A Spanish model for quantification and management of construction waste. *Waste Management*, *29*(9), 2542-2548.

Wimalasena, B. A. D. S., Ruwanpura, J. Y. & Hettiaratchi, J. P. A. (2010, December, 13-14). On-Site Construction Waste Management. In *Int'l Conf. on Sustainable Environment (ICSBE-2010)*, Kandy, Srilanka.

Zhao, W., Leeftink, R. B., & Rotter, V. S. (2010). Evaluation of the economic feasibility for the recycling of construction and demolition waste in China—The case of Chongqing. *Resources, Conservation and Recycling*, *54*(6), 377-389.

4.c. MODELLING THE RELATIONSHIP BETWEEN MATERIAL WASTE GENERATION AND NVAAS

ORIGINALITY REPORT

7%	%	7%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Aqli Mursadin. "An application of statistical modelling on power generating asset performance analysis at the Asam-asam steam power plant of South Kalimantan", E3S Web of Conferences, 2018 Publication	1%
2	Kazaz, Aynur, Serdar Ulubeyli, Bayram Er, Volkan Arslan, Ahmet Arslan, and Murat Atici. "Fresh Ready-mixed Concrete Waste in Construction Projects: A Planning Approach", Procedia Engineering, 2015. Publication	1%
3	Achmad Kusairi Samlawi, Pathur Razi Ansyah, Gunawan Rudi Cahyono. "Technical analysis of biocomposite reinforced with sugar palm (Arenga Pinnata) fiber for jukung materials", IOP Conference Series: Materials Science and Engineering, 2021 Publication	1%

4	Aqli Mursadin. "On Contribution of Construction Waste to Late Project Completion: An Approach based on Consensus Measurement among Construction Professionals", MATEC Web of Conferences, 2019 Publication	1 %
5	Villoria Saez, P., M. del Rio Merino, and C. Porras-Amores. "Estimation of construction and demolition waste volume generation in new residential buildings in Spain", Waste Management & Research, 2012. Publication	<1 %
6	Richard J. Rossi. "Generalized Linear Models", Wiley, 2018 Publication	<1 %
7	Laura Pellegrini, Stefano Campi, Mirko Locatelli, Giulia Pattini, Giuseppe Martino Di Giuda, Lavinia Chiara Tagliabue. "Digital Transition and Waste Management in Architecture, Engineering, Construction, and Operations Industry", Frontiers in Energy Research, 2020 Publication	<1 %
8	Mercader-Moyano, P., and A. Ramirez-de-Arellano-Agudo. "Selective classification and quantification model of C&D waste from material resources consumed in residential	<1 %

building construction", Waste Management & Research, 2013.
Publication

9 Malia, M., J. de Brito, M. D. Pinheiro, and M. Bravo. "Construction and demolition waste indicators", Waste Management & Research, 2013.
Publication
<1%

10 Pengcheng Xiang, Xiaosen Huo, Liyin Shen. "Research on the phenomenon of asymmetric information in construction projects — The case of China", International Journal of Project Management, 2015
Publication
<1%

11 D. J. Pantone. "Herbicide Phytotoxicity Model for Assessing Herbicide Tolerance", Journal of Agronomy and Crop Science, 2/1988
Publication
<1%

12 Stefany Coxe, Stephen G. West, Leona S. Aiken. "The Analysis of Count Data: A Gentle Introduction to Poisson Regression and Its Alternatives", Journal of Personality Assessment, 2009
Publication
<1%

13 Dina A. Saad, Mohamed Masoud, Hesham Osman. "Multi-objective optimization of lean-based repetitive scheduling using batch and
<1%

pull production", Automation in Construction, 2021
Publication

14 Jun-Haeng Heo, J.D. Salas, D.C. Boes. "Regional flood frequency analysis based on a Weibull model: Part 2. Simulations and applications", Journal of Hydrology, 2001 <1%
Publication

15 Jeyaraja Jayamathan, Raufdeen Rameezdeen. "Influence of labour arrangement on construction material waste generation", Structural Survey, 2014 <1%
Publication

16 Majed I Al-Sari, Issam A Al-Khatib, Marios Avraamides, Despo Fatta-Kassinos. "A study on the attitudes and behavioural influence of construction waste management in occupied Palestinian territory", Waste Management & Research: The Journal for a Sustainable Circular Economy, 2011 <1%
Publication

17 Timothy O'Grady, Roberto Minunno, Heap-Yih Chong, Gregory M. Morrison. "Design for disassembly, deconstruction and resilience: A circular economy index for the built environment", Resources, Conservation and Recycling, 2021 <1%
Publication

18	Masudi, Ahmad Firman, Che Rosmani Che Hassan, Noor Zalina Mahmood, Siti Nazziera Mokhtar, and Nik Meriam Sulaiman. "Waste quantification models for estimation of construction and demolition waste generation: a review", International Journal of Global Environmental Issues, 2012. Publication	<1 %
19	Asmanto Subagyo. "Analysis ballistic impact modeling of multicomponent fabrics with jalaba structure", MATEC Web of Conferences, 2018 Publication	<1 %

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		