On Contribution of Construction Waste to Late Project Completion: An Approach based on Consensus Measurement among Construction Professionals

Aqli Mursadin[1,*]

[1]Faculty of Engineering, Lambung Mangkurat University, Banjarmasin, Indonesia 70123

Abstract. As an important indicator of poor project performance, late project completion is a result of delay. While delay itself is caused by numerous factors, their effects that eventually lead to late project completion are realized as waste in term of time. This research investigates how construction professionals agree on what contribute to late project completion based on construction waste. The result should help provide insight into how different types of construction waste affect project performance. For this purpose, respondents consisting of construction professionals in South Kalimantan and Central Kalimantan Provinces were invited to a questionnaire-based survey. They were asked seven questions, each regarding whether a particular type of waste contributes to late project completion. Gwet's gamma coefficient was used to perform a consensus analysis of the answers. A consensus was reached that five out of seven types of waste contribute to late project completion. They include waiting, transport, extra processing, motion, and defects. Implications of the results are discussed and directions for future research are recommended.

1 Introduction

Waste is any form of human activity that consumes resources and produces no values [1]. A significant intensity of waste in terms of extra processing and waiting in several building projects in South Kalimantan has been the focus of several studies [2, 3]. This has led to a further study on how different types of waste and different areas in South Kalimantan influence the generation of material waste [4]. The findings have been in agreement with previous results on causes of material waste in construction [5, 6].

In addition to material waste, late completion can also be seen as an important indicator of poor project performance. Improving this performance requires reducing the likelihood of this indicator to occur. A recent study in several cities and regencies in East Kalimantan has shown that decisions by clients in public projects influence the level of construction waste which may lead to late project completion [7].

[*] Corresponding author: a.mursadin@gmail.com, a.mursadin@ulm.ac.id

The above results, however, have not yet addressed how different project participants perceive the effects of construction waste on late project completion. Some of these participants, in particular, may be considered as construction professionals having specialties or particular skills they bring into the project team. Hence, this work aims at finding out whether there is a certain consensus among these professionals on how each type of construction waste influences late project completion.

As several previously related studies have been conducted in Kalimantan especially in South Kalimantan [2, 3, 4, 7], it is important to gain a deeper look into the behavior of the industry towards waste in this region. The Provinces of South Kalimantan and Central Kalimantan are particularly related in the sense that major cities in both provinces are close to their shared border and connected by the Trans-Kalimantan road. It is expected that common construction practices are shared among professionals in both provinces. A further study in this region is therefore important to help the corresponding construction industry address issues related to waste.

2 Literature review

2.1 Construction waste and late project completion

There are seven types of waste. They include overproduction, waiting, transport, extra processing, inventory, motion, and defects [8]. Overproduction may represent activities such as excessive material order, product finishing beyond the necessary level, and starting some work too early that it requires additional resources to maintain the output. Waiting may range from waiting for work order and instruction to waiting for approval to changes as well as waiting for material or semi-finished products to be available. Transport does take time. It adds to cost but not necessarily to value. Extra processing may occur as correcting work due to production error, disassembling work of an incorrectly erected structure, and unnecessary inspection or supervision. Inventory consumes resources such as the storage space and pieces of equipment required for maintaining the stored material or products. These are resources which would otherwise be saved or allocated for other activities. The motion of both workers and equipment takes energy and time and increases the risk of injury without necessarily adding to the project value. Defects are related to defective materials as well as errors during the production process which may result in a series of rework or replacement. In lean construction, in particular, the main focus is to minimize waste.

Certain types of construction waste contribute directly to material waste generation. Several studies on the relationship between construction waste and material waste have been conducted [5, 6, 9, 10, 11, 12].

In South Kalimantan, a relatively significant intensity of waste in terms of extra processing and waiting in a number of building projects has been reported to occur particularly on work items such as field processing, earthwork, and concrete work [2]. In the same province, a study has also been conducted on late completion at five non-ordinary public building projects. Two causes of the problem have been revealed, namely imperfect design and insufficient funding. Respectively, they can be seen as leading to extra processing and waiting as well.

An investigation of the effects of different types of construction waste as well as different areas in South Kalimantan on material waste generation has been carried out [4]. In particular, different areas show different contributions of construction waste in generating material waste. Construction waste quantification due to decisions by clients has been modeled for two types of areas in East Kalimantan, namely city and regency [7].

According to this result, decisions by clients tend to show relatively significant influence on waste in cities in comparison with those in regencies.

Aziz [13] has developed an extensive list containing 99 causes of delay based on several previous studies and categorized these factors into nine major categories. While delay can result in projects being late in completion, the categorization of these causes does not immediately show how they contribute to this situation.

Types of construction waste can potentially provide such categorization. For example, waiting may be a contribution of a number of factors included in that list [13] such as delay in approving major changes or delay in performing inspections. Hence, the contribution of these factors to the lengthening of the project duration leading to late project completion is partly aggregated in the contribution of waiting. Waiting, in this case, is waste in term of time, and it can potentially lengthen the duration.

2.2 Measurement of consensus

Consensus or agreement between two or more raters on a number of items or subjects is interesting to measure. Quantitative information given by such measurement can show how reliable the raters are compared to each other [14]. The measurement is performed by asking the raters to assign each of the available items or subjects to one of predefined categories. The bigger the number of items or subjects assigned to the same category is, the higher the inter-rater reliability will be.

Another way to look at the resulting information is that it tells which items among many that the raters agree on with each other. A sufficiently high inter-rater reliability means that the raters reach a sufficiently high level of consensus. This quantification enables a choice to be made between several resulting agreements. This is, of course, based on an assumption that those items can be reliably measured using a common scale.

Some measures of consensus that allow the use of many raters on many items with a fixed number of categories are Fleiss' kappa, Krippendorff's alpha, and Gwet's gamma. Fleiss' kappa is an extension of Scott's pi which allows only two raters. It only supports categories given in a measurement scale that can either be dichotomous (e.g., "YES", "NO") or nominal (e.g., "YES", "NO", "MAYBE). On the other hand, Krippendorff's alpha and Gwet's gamma support various scales including nominal and non-nominal.

All these measures are defined as (see, e.g., [14])

$$m = \frac{\pi_a - \pi_e}{1 - \pi_e} \tag{1}$$

where $\pi_a - \pi_e$ and $1 - \pi_e$ indicate the actual level of consensus and the attainable level of consensus, respectively. The three measures above use different ways in defining π_a and π_e.

There are some extreme situations where Fleiss' kappa and Krippendorff's alpha return zero value for $1 - \pi_e$. This, fortunately, does not happen to Gwet's gamma. For this reason, Gwet's gamma will be used here as the only measure of consensus.

A generalized form of Gwet's gamma allows the use of a certain weighting scheme in a form of a square matrix. This can be ignored for a nominal scale, that is, by simply using an identity weighting matrix. Also, the generalized form accommodates the possibility that different numbers of raters rate different items. This means that it accommodates missing data.

Using Gwet's gamma for a nominal scale in a situation where there is no missing data (that is, the number of raters is fixed from one item to another), π_a and π_e are defined as follows:

$$\pi_a = \frac{\sum_{i=1}^{k}\sum_{j=1}^{l} n_{ij}\left(n_{ij}-1\right)}{kn\left(n-1\right)} \tag{2}$$

and

$$\pi_e = \frac{\sum_{j=1}^{l} p_j\left(1-p_j\right)}{l-1} \tag{3}$$

where

$$p_j = \frac{\sum_{i=1}^{k} n_{ij}}{kn} \tag{4}$$

with n_{ij} being the number of raters assigning the i^{th} item or subject of k given items or subjects to the j^{th} category of l available categories, and n the total number of raters. Now, let Gwet's gamma be $\gamma = m$. The maximum value of γ is 1 which implies a perfect consensus. A high value of γ indicates a high level of consensus or simply means a strong consensus. Conversely, a low γ corresponds to a weak consensus.

3 Methods

The approach used in this research is based on the availability of local or regional construction knowledge from construction professionals. Specifically, this is knowledge concerning how seven types of activities which are waste in construction as mentioned previously contribute to late completion. There has to be a significant field experience in construction owned by these experts. This should be reflected in the number of years each of them has spent participating in various projects prior to the study.

Data obtained from this knowledge can then be analyzed to provide the Gwet's gamma coefficient given in (1). The idea of measuring consensus here is *not* to assess how reliable the raters are compared to each other, but rather to obtain a consensus concerning the influence of types of construction waste that future decision making on minimizing the occurrence or the amount of late project completion can be reliably based on.

A questionnaire was developed to comprise seven questions each asking the respondent to indicate whether a type of construction waste contributes to late project completion. The answer was chosen from a three-point nominal scale "YES", "NO", "MAYBE". The assumption is that the measurement of each waste type's contribution can be performed using the same scale as that used for other waste types. The questionnaire was also equipped with a form for the respondent's identity.

A total of 56 construction professionals with a minimum of five years in building construction work experience were approached as the prospective respondents (30 in South Kalimantan and 26 in Central Kalimantan). Their knowledge of construction practice in the corresponding province is considered adequate and valid for providing the required responses. Their names were obtained by following the lists of member construction companies of construction associations in the corresponding provinces. These companies range from contractors to consultants (supervision and construction management) to which the professionals were current employees. This can further be considered as a homogeneous sample.

Results from the questionnaire were summarized. The analysis was carried out as follows. One value of Gwet's gamma is computed for all the seven types of waste (items).

If the resulting consensus is weak, the computation is repeated for each of all seven combinations of six types, that is, by removing one type for each combination. Any types causing the weak consensus should be located by now. Further computation is needed to see the effect of removing these types or any combination of them on the remaining consensus. Here, 0.5 is considered a moderate Gwet's gamma value and, therefore, a consensus reached below that level is deemed to be *not* sufficiently strong.

4 Results

The number of respondents who filled and returned the questionnaire was 47 (26 in South Kalimantan and 21 in Central Kalimantan). Table 1 summarizes the response. It is clear from the big number of "YES" responses that the respondents were likely to agree that each type of waste contributes to late project completion. It is easily understandable that the respondents would agree that each of waiting, transport, extra processing, and defects was practically waste in term of time and could easily lead to late completion. In fact, defects may result in rework which means extra processing. As for motion and overproduction, the difference can be seen from the way the response is distributed between "NO" and "MAYBE". The respondents were more in agreement with each other on motion than they were on overproduction. They, however, could not agree on inventory as much as they did on the other types. Further, it can be seen that the respondents as a whole seemed a little indecisive when it came to overproduction and inventory.

Table 1. Summary of Response

Types of Waste	# of Responses for Categories of Contribution to Late Project Completion		
	YES	NO	MAYBE
overproduction	31	8	8
waiting	36	1	10
transport	33	1	13
extra processing	39	1	7
inventory	27	9	11
motion	31	1	15
defects	36	2	9

The consensus for all types must be achieved at a sufficiently high level. In this case, using (1) and based on data in Table 1, the computed Gwet's gamma is 0.435. It is well below a moderate value of 0.5 and, therefore, the consensus is considered weak, or a sufficiently high level of consensus has not been reached. Such a consensus means two things: the respondents did not necessarily agree with each other on several types, and the consensus itself may not be useful as a basis for further decision making in dealing with late project completion. As mentioned in the previous section, this study is interested mainly in the latter, namely, finding a sufficiently strong consensus among the professionals and the types of waste on which the consensus is made.

One might suggest that the low Gwet's gamma value is due to the response concerning inventory and overproduction for which the respondents were not completely in agreement with each other. This indecisive nature can be seen from the relative similarity in distribution between the "NO" response and the "MAYBE" response for both types. However, this may also be due to the "YES" response for motion which is the same in number as that for overproduction. In addition, for the other four types, the number of responses is distributed in a more convincing fashion of supporting a strong consensus, namely, with a better concentration on one category, i.e., "YES". For this reason, it is worthwhile to investigate the behavior of the resulting Gwet's gamma when certain types are not considered in deriving the consensus.

Table 2 gives Gwet's gamma values for seven distinct combinations of six types. Each combination is obtained by removing one type. It can be seen from this table that removing either overproduction, transport, inventory, or motion results in a six-type combination with a sufficiently high Gwet's gamma (marked with *).

Table 2. Results for Six-type Combinations

Combinations	Gwet's γ
without overproduction	0.519*
without waiting	0.487
without transport	0.501*
without extra processing	0.470
without inventory	0.535*
without motion	0.508*
without defects	0.489

Simply removing inventory immediately results in a six-type combination of 0.535 in Gwet's gamma value. This means that the respondents agreed that apart from inventory all types of construction waste contribute to late project completion. However, overproduction may also be considered to be removed since responses apart from those of "YES" are distributed uniformly (see Table 1). The Gwet's gamma for the six-type combination without overproduction is also the second largest (see Table 2). This suggests that further examination on the effect of removing the above four types needs to be performed, that is, by using six combinations of five types. Table 3 shows the results.

Table 3. Results for Six Selected Five-type Combinations

Combinations	Gwet's γ
without overproduction *and* transport	0.460
without overproduction *and* inventory	0.511*
without overproduction *and* motion	0.472
without transport *and* inventory	0.485
without transport *and* motion	0.446
without inventory *and* motion	0.496

It is clear from Table 3 that removing both overproduction and inventory results in a combination of types that corresponds to a required level of consensus. No other five-type combination can produce such an agreement. This means that construction professionals in both provinces did not agree at a sufficiently high level of consensus that overproduction and inventory are types of waste that contribute to late project completion. In other words, they reached a consensus that apart from overproduction and inventory, the remaining five types of construction waste do contribute to late project completion.

On the other hand, one might try to remove overproduction, transport, inventory, and motion altogether leaving only three types as the basis for the consensus. The resulting Gwet's gamma would be 0.575 which is not particularly higher than 0.511 found by removing only overproduction and inventory. Ignoring two more types of waste which show a clear-cut distribution of responses in favor of a 0.064-point increase in Gwet's gamma difference may not be advantageous in this case.

This result suggests that when faced with the problem of minimizing late project completion, more attention should be paid to waiting, transport, extra processing, motion, and defects than to overproduction or inventory. However, it may not necessarily suggest that overproduction and inventory be excluded as the causes of late completion. While waiting, transport, extra processing, motion, and defects unnecessarily consume additional time in such a way that potentially lengthens project duration; the same is not always true for overproduction and inventory. The latter two may also unnecessarily consume additional resources (which also include time) but in a way that does not necessarily results in longer project duration. In contrast, the study by Mursadin and Isra [2] showed that there is no difference between various types of construction waste in terms of their contribution to material waste. Moreover, it does not rule out the influence on late project completion brought by other factors outside waste.

The resulting consensus also implies that late project completion is not as simple as waste in term of time but also about poor allocation of some other resources which eventually results in unnecessary consumption of additional time. Minimizing the right types of waste should, therefore, lead to reduction in unnecessary use of additional time. As the length of time spent is an important measure of punctuality in projects, minimizing the right types of waste potentially means minimizing late completion.

5 Conclusions and directions for future research

A study has been conducted on consensus concerning the contribution of construction waste on late project completion involving construction professionals with sufficient knowledge of construction in South Kalimantan and Central Kalimantan. It is based on the use of construction knowledge possessed by the professionals and collected using a set of questionnaire. Gwet's gamma has been used as the measure of consensus reached by these professionals.

Of seven waste types, five have been agreed on as those contributing to late project completion at a sufficiently high level of agreement. They include waiting, transport, extra processing, motion, and defects. It does not necessarily mean that the other two, namely, overproduction and inventory are excluded as causes of late completion. Rather, it means that when it comes to late project completion, more attention should be paid to waiting, transport, extra processing, motion, and defects than to overproduction or inventory. All in all, the study underlines an important premise that minimizing the right types of waste potentially means minimizing late project completion.

The study has not explicitly identified types of projects the professionals referred to. A future study should consider more detailed categorization of projects to come up with more accurate depictions of the behavior of waste in influencing project performance. The extension of the study area to cover more regions in Kalimantan is another important issue to address in the future. Finally, an implementation study of the results on real projects should provide a fruitful feedback for methods currently used in handling late project completion through waste minimization.

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