EMPIRICAL RESEARCH APPROACH OF CONSTRUCTION WASTE QUANTIFICATION AND STANDARD TOLERANCE FOR STRATIFIED RESIDENTIAL BUILDING PROJECTS

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ABSTRACT

The construction industry is the major solid waste generator in Malaysia. The extensive building and infrastructure development projects have led to an inclination in construction waste generation. The accurate waste composition and quantity are hardly to be measured, as the construction activity is dynamic in nature. Every construction stage produced different types of waste and amount. Therefore, the pattern of waste generated throughout the construction stages need to be identified. This paper critically reviewed construction waste issue in Malaysia in order to identify the gap in research. Based on literature studied, this paper proposes an approach to quantify the wastage rate and develop construction waste standard tolerance for stratified residential building projects. There are six steps in the empirical research approach. First is identification of the stratified residential construction buildings. Second is characteristics of project analyze is similar for uniform investigation. Third is determination of construction stages. Fourth is quantification of the waste generated in the construction projects studied. The fifth step is conduct structure interview with the authorized person. The last step is summation of the recorded quantity and development of *construction waste standard tolerance. It is expected that the proposed research approach will be practical for construction waste quantification and for future research undertaken.*

Keywords: Construction waste, waste quantification, stratified residential building, standard tolerance, environmental sustainability

INTRODUCTION

Construction waste has placed a heavy burden on sustainable development in a lot of countries or regions and is crucial to the growth of Malaysian economy. With the major infrastructure projects planned construction becomes even more critical (Construction Industry Transformation Program 2016-2020). The efficiency of the construction industry and also environment could be affected by the construction waste generation (Formoso et al., 2002). In Malaysia, the construction industry produces a lot of by-product or construction waste. This was then proved by RM553.5 million of waste management expenditure that has been supplied for year 2013 and RM 189.1 million were allocated for construction activity (Department of Statistic Malaysia, 2013). In order to reduce the impact on the environment, waste management must successfully be implemented.

Waste management and waste minimization effectiveness are the most pressing issue nowadays. A systematic waste management is crucial to be in place at the construction site (Tchobanoglus, 2012). A systematic approach that supported by various decision making tool can initiate an efficient construction waste management (Martinez-Lage et al., 2010) and indirectly will resume the environmental sustainability. One of the tools is a practical construction waste estimation system. Researchers and organizations from all over the world are aware of this issue and have focused on the estimation of construction waste accumulation. Lu, Yuan, Hao, Mi and Ding (2011) agreed that the future challenge of construction waste studies is to establish standardize measurement technique for waste generation in order to improve performance management.

The accurate quantification of construction waste at project level is the need for the authorities to establish appropriate policies, guidelines, strategies and codes of practice for sustainable construction waste management. Later, these law and enforcement can be referred to for the development of optimal waste treatment facilities, reasonable charge for the level of waste and also the appropriate incentives for construction companies to take proactive measures in minimizing construction waste (Li, 2013).

In general, the lacking of reliable and official data from the local governments has encouraged researchers to estimate the construction waste quantification. Researchers from Malaysia has done a few research on construction waste quantification as shown in Table 1 (Mei and Fujiwara (2016); Mahayuddin, Pereira, Badaruzzaman and Mokhtar (2008) and Jalali (2007). However, none of them has generated a standard tolerance for construction waste. This has made it difficult to control and minimize construction waste generation in Malaysia. CITP (2016-2020) also supported that there is a lack of sustainable-rated in construction that shows the high volume of construction and demolition waste dumping. Therefore, there is a need to drive innovation in sustainable construction by reducing irresponsible waste during construction through standard tolerance.

Table 1: Previous Research on Waste Quantification

Author/ year	Area	Method	Outcome
Mei and Fujiwara (2016)	Quantification of construction waste for mixed use development	Structured interview and site observation	Waste generation rate for different construction method.
Bakshan et al (2015)	Methodology for estimation waste generation rates	Field observation at construction site	Framework on how to calculate WGR in Lebanon
Saez et al (2013)	Performance waste management	Construction database	Best practice measures assessment for construction waste management
Yuan (2012)	Performance waste management	Structured interview	Key indicator for assessing the effectiveness of construction waste management

Katz and Baum (2011)	Construction waste estimation	Field observation at construction site	Waste estimation model
Llatas (2011)	Construction waste quantification	Construction database	A model for construction waste quantification
Kofoworola & Gheewala (2009)	Estimation of construction waste generation	Field observation at construction site	Percentage of energy savings from the construction waste recycled
Mahayuddin et al (2008)	Construction waste index for residential projects	Heap survey	Waste index
Jalali (2007)	Quantification of construction waste amount	Building components through component index	Construction waste generation
Bossink & Brouwers (1996)	Construction waste quantification and source evaluation	Construction database and field observation	Percentage, cost and total amount of construction waste

(Source: Mei and Fujiwara (2016), Bakshan et al (2015), Saez et al (2013), Yuan (2012), Katz and Baum (2011), Llatas (2011), Kofoworola and Gheewala (2009), Mahayuddin et al (2008), Jalali (2007) ans Bossink and Brouwers (1996)

LITERATURE REVIEW

Standard tolerance is a convenient reference for an acceptable standard of workmanship in domestic building construction (Victorian Building Authority, 2015). In waste management scenario, standard tolerance acts as a baseline to allow waste generation in a construction project. Generally, building contractor must agree and follow the standard that they consider appropriate to their building project (Vitorian Building Authority, 2015). So far, England and Hong Kong have its own standard tolerance. The standard tolerance for England was produced by Waste Resource Action Program (WRAP).

WRAP is an independent, non-profit company and is con-funded by Defra and the Devolved Administrations (DAs). WRAP conducts research and provides a technical report and gives advice on waste reduction and resource efficiency in England. WRAP has developed a system to record and calculate the wastage rate. The system called Net Waste Tool (NWTool). This system will analyze all the input data and generate a technical report.

The report helps the industry, organization and local authorities in efficiently managing construction waste, raw materials, water and energy.

WRAP uses wastage rate as the quantification method to establish construction waste tolerance. Wastage rates account for the proportion of component that ends up as waste during installation and construction process. Wastage rates are expressed as a percentage by volume of construction materials ordered which becomes waste and are used to calculate the likely or actual proportion of each component wasted (WRAP, 2008).

In addition, wastage rates in WRAP Net Waste Tool (NWT) are applied to all components in the waste classification dataset and exist in two forms, which is standard tolerance and good practice (WRAP, 2008). Tolerance has been made to accommodate best practice wastage rate in future adaptation on construction waste management. The tolerance made of data gathered from Building Research Establish (BRE), Net Waste Tool Consultation Group (NW Consultation Group), Waste Aware Construction and WRAP Net Waste Trial (NW Trial). Net Waste method was put on trial on eight construction waste projects across United Kingdom, involving the collection of wastage rate data for a variety of waste classification based on the various contractor experience (WRAP, 2008). The data have been used for the tolerance establishment.

Table 2 functions to assist project teams quickly identify their major sources of waste and the most significant opportunities to take action (WRAP, 2008). For this purpose, the authorized person in charge on waste management able to over-write data with specific project information such as reducing some cost which appear highly variable and setting their own target wastage rates. Therefore, this set of data aim to be a benchmark, but will inevitably not be corrected depending on the types of construction.

Every construction waste has been classified according to five main waste streams. This is to organize the input data and to ease the authorized person in charge. The five main waste streams are inert, plasterboard, metals, timber and general mixed. According to Hong Kong Environmental Protection Department (EPD) (2015), inert waste is a public fill waste. It includes bricks, concrete, sand, stone, gravel and ceramics which is suitable for land reclamation and site formation. The unprocessed timber in Table 2 refers to softwood and hardwood timber. Meanwhile, the processed timber is the wood based panel products in which wood is pre-dominant in the form of strips, veneers, chipboard and plywood.

Table 2: Construction Waste Tolerance in England

Waste material	**Standard tolerance**	**Best practice**
Inert		
Bricks and blocks	20%	10% (bricks), 5% (blocks)
Aggregates	10%	5%
Surfacing materials	5%	2.5%
Tiles and ceramics	8%	5%
Pre-cast concrete	1%	0%
In-situ concrete	5%	2.5%
Screed	5%	2.5%
Gravel	10%	5.5%
Sand	12.5%	5.5%
Stone	10%	5%
Other inert	10%	5%
Plasterboard		
Plasterboard	22.5%	15%
Metals		
Non-ferrous metal	5%	2.5%
Ferrous metal	15%	5%
Timber		
Wooden pallets	20%	20%
Unprocessed timber	10%	5%
Processed timber	10%	5%
General mixed		
Packaging (paper, cardboard and plastic)	100%	100%
Glass	5%	2.5%
Insulation	15%	5%
Tiled soft-flooring	5%	2%
Roll soft-flooring	20%	10%
plastic	5%	2%
Structural waterproofing	15%	5%
Gypsum products	5%	2.5%

(Source: WRAP (2008)

Meanwhile, standard tolerance in Hong Kong was produced by Poon, Yu and Ng (2001). Hong Kong is one of the countries that also faces problem regarding construction waste management. About 37, 110 tons of construction waste was generated daily in 1999 (Environmental Protection Department, 2000). However in December 2005, a successful Construction Waste Disposal Charging Scheme (CWDCS) has been implemented. After three years of implementation, it shows the effectiveness. The implementation of this charging scheme has effectively reduce the number of construction waste generated in Hong Kong. A 60% of construction waste was able to secure from disposed to landfill (Hao, Hills and Tam, 2008). As a result, it shows that construction waste disposal can be reduced effectively and can help to improve the environment by implementing the CWDCS (Hao, Hills and Tam, 2008).

Besides that, Hong Kong which is a pioneer and leading country in construction waste research has established "A Guide for Managing and Minimizing Building and Demolition Waste". The guide book explains in details on how to estimate, reuse and minimize construction waste on site (Poon, Yu and Ng, 2001). In addition, Hong Kong is also using the same method as WRAP in monitoring their amount of waste produced. Wastage rate has been the most preferable method to monitor and keep track on waste generation in a project.

Table 3 shows the construction waste standard tolerance in Hong Kong. It acts as the baseline for the construction waste generation in the country. It applies only for public housing projects. This standard tolerance is less detail than WRAP standard tolerance. This tolerance was made for a common construction waste such as concrete, timber board, steel bars, bricks, fine aggregates, ready-mix cement, plaster, tiles, sanitary fitting and kitchen joinery.

The actual amount of waste generated will be dependent on the practice, experience of a company and nature of the project. The data gathered will then compared with the norm, to quantify the average performance of the industry. The Hong Kong guide book has prepared two different construction waste tolerance for public housing projects and private housing projects. However, this research will only focus on public housing projects as mentioned in the approach method section.

Table 3: Construction Waste Tolerance in Hong Kong

Waste material	Standard tolerance
Concrete	3-5%
Timber board	5%
Steel bars	3-5%
Brick and block	6%
Fine aggregate	5%
Ready-mix cement	7%
Plaster	2%
Tiles	6%
Sanitary fitting	2%
Kitchen joinery	1%

(Source: Poon, Yu and Ng (2001)

METHODOLOGY

The term empirical was derived from the term empiricism which means, making observation to gain knowledge (Patten, 2017). Basically, all of us make an informal observation of the people and things around us every day. These observations become a basis for making decisions in life. Meanwhile, empirical research is defined as making observations. By following plans order for making observations, a researcher has indirectly engaged in a systematic, thoughtful process that deserves to be called research (Patten, 2017).

Empirical research is based on observation and measured phenomena that derive knowledge from actual experience rather than theory (Patten, 2017). To plan for an observation, a researcher must first plan what to observe, whom to observe, how to observe and when to observe. Empirical evidence can be analyzed either quantitatively or qualitatively. However, the research design varies according to field and the type of questions being investigated. This research implemented the pragmatism research paradigm. Pragmatist researcher starts off with the research question to determine their research framework and ideally working with both qualitative and quantitative data as it allows them to better understand social reality. These substantiate with the principle of empirical research mentioned earlier. In this research, the approach implemented were observation and structured interview as shown in Figure 1.

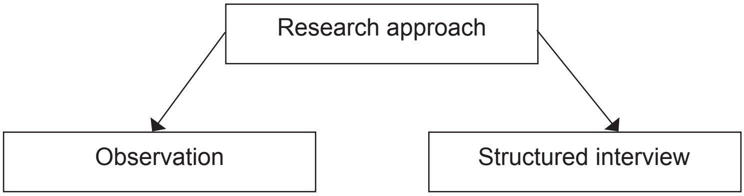

Figure 1: Research Approach

The research would be carried out in six phases.

1. Identification of the stratified residential construction building.
2. Characteristics of the projects analyzed.
3. Determination of the construction stages.
4. Quantification of the waste generated in the construction projects studied.
5. Structured interview with authorized person
6. Development of standard tolerance

Identification of the Stratified Residential Construction Building

The study focused on obtaining data from a stratified residential building construction in Klang Valley, Malaysia. The National Property Information Centre (NAPIC) (2015) reported that stratified properties formed 63.2% (87,913 units) of the total building plan approval (139,189 units). Table 4 shows the stratified property stock comprised of condominium/apartment (44,932 units; 51.1%) and serviced apartment (31,251 units; 35.5%). 44.0% (19,771 units) of the condominium/apartment and 72.5% (22,661 units) of serviced apartment were allocated in Kuala Lumpur. The remaining 36.8% (51,276 units) of the total new residential supply were landed properties comprising of terraced (35,365 units; 69.0%s) and semi-detached houses (10,163 units; 19.8%). To identify this type of construction, data from the Construction Industry Development Board (CIDB) business department for the period of 2015 – 2016 were used. Therefore, in line with current trend, sixteen service apartment projects have been chosen.

Table 4: Stratified Property Stock for Year 2015

Types of property	Stock
Condominium / Apartment	44,932 units
Service Apartment	31,251 units

(Source: NAPIC (2015)

Characteristics of the Projects Analyzed

The scope of this study was limited to the construction type identified in the previous sub-section. The analysis focused on serviced apartment residential projects with similar construction features, materials and techniques in order to obtain comparable results for a precise construction waste analysis.

Table 5: Characteristics of the Construction Projects Analyzed

Characteristics
Type of construction: new construction service apartment
Location: Klang Valley
Use: residential buildings
Number of levels: from 30 to 80 levels
Number of blocks: 2
Stores and/or offices are situated at ground level.
Number of dwellings: 300 to 700 units

Determination of the Construction Stages

The study drew information obtained from the reports and the bill of quantities of the real construction projects analyzed. As the bill of quantities of all the projects analyzed does not follow the same classification of construction stages, it is necessary first, to state a standardized classification, in order to homogenize the construction process and to allow using the data for comparison of future results. The guideline was derived based on the nature of practice in the construction industry.

The guidelines used to define the construction stages are presented here.

1. The bill of quantities should be homogeneous and have a similar structure (by stages) in all the construction projects analyzed, clearly identifying the building stages.

2. The project should be subdivided into elements constructed and activities undertaken.

3. A standardized classification of the construction stages should be provided. In this way, this classification could be extrapolated to other projects with similar characteristics.

Quantification of the Waste Generated in the Construction Projects Studies

Once the bills of quantities have been structured in stages, they will be used together with the database provided by the Solid Waste Management and Public Cleansing Corporation (SWCorp), which provides the estimation, in volume (m^3) of the different types of waste generated per m^2 in each sub-construction stage. In addition, the volume of waste generated in each construction stage or in the whole construction project can be determined.

The steps in planning construction waste quantification for stratified residential are:

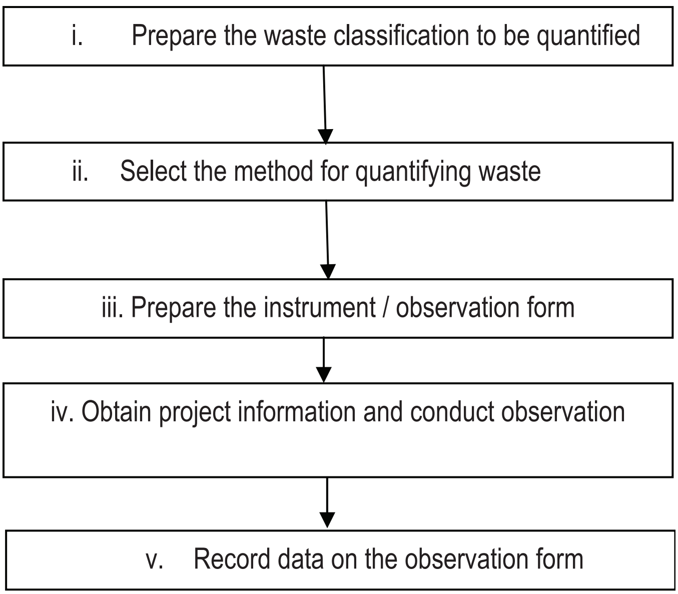

Figure 2: Steps in Construction Waste Quantification for Stratified Residential Building

1. Prepare the waste classification to be quantified

   The construction waste measured in the research was classified based on waste classification by WRAP (WRAP, 2008) for a systematic and adequate quantification. The waste material studied have been classified into six major groups; inert, plasterboard, metals, timber, packaging and general mixed. The data will be recorded according to this classification details. All the expected construction waste was listed in an observation form.

2. Select the method for quantifying the waste

   After waste classification has been determined, it is time to select the best method for waste quantification. According to the literature review, quantification of wastage rate is the best choice. This research will be implementing wastage rate formula generated by Poon et al (2001).

   These are two examples of wastage calculation formula for concrete and reinforcement

Table 6: Example of Wastage Calculation for Concrete and Reinforcement

Concrete	Reinforcement
A. = Quantity ordered B. = Quantity work done C. = Waste = A - B D. = Wastage percentage = (C / B)*100	A. =Quantity ordered B. = Quantity work done C. = Calculated materials on site = (A) –(B) D. = Measured materials on site E. = Waste = C -D F. = Wastage percentage = (E / B)*100

(Source: Poon et al., 2001)

3. Prepare the instrument

   The instrument used in this research is observation form. Basically the observation form consists of date of the observation, element constructed on that day, activity involved on that day and built up area. The observation form is divided into four sections; section A, B, C and D.

Section A is the waste classification derives from WRAP. It consists of six main waste stream with details. The details help the estimator to easily estimate and quantify the specific waste.

Section B is about estimation of waste generation based on project bill of quantity. It consists of ordered quantity for each material and wastage rate prepared by SWCorp.

Meanwhile section C explains the main study, which is the on-site waste quantification using the above formula. The actual data form this section, will then be compared with the norm. In this case, it will compare with the result from section B. At the end, the comparison result will generate the construction waste tolerance, which is the aim of this research.

Section D uses rating scale to measure waste management performance. The rating was derived from Garas, Anis and El-Gammal, (2001). It is based on estimation made by the authorized person in charge on the waste management practices on site. The authorized person in charge will give rating for every waste produced according to the waste management hierarchy; reduce, reuse, recycle, recovery and dispose. The rating are as follows:

Table 7: Rating Table for Construction Waste Management

Rating	Description
1	totally not implemented (0% of the total waste generated)
2	less implemented (1 – 30% of the total waste generated)
3	moderately implemented (31 -50% of the total waste generated)
4	highly implemented (51 – 70% of the total waste generated)
5	most highly implemented (71 – 100% of the total waste generated)

(Source: Garas et al., 2001)

4. Obtain project information and conduct observation

An appointment will be set up with the authorized person in charge on the sixteen selected projects. On the set date, the researcher would first extract the data from the construction database to estimate the construction waste generation. After that, an observation will be conducted on site. Next, construction waste will be quantified and recorded on observation form. To support the quantification, photos will be taken and attached as evidence.

5. Record data on the observation form

   Data gathered through observation and extracted from the construction database (bill of quantity) will be recorded on the observation form. Any evidence or samples data given by the respondent will also be attached with the observation form, to avoid careless and for a proper documentation.

Structured Interview with Authorized Person

After the construction has been estimated and quantified, the next step is to conduct a structured interview with an authorized person in charge of construction waste management on site. A set of questions has been draft regarding construction waste management implemented on site. The questions were drafted according to Deming cycle; plan, do check and act. Deming cycle is a quality improvement model consist of logical sequence for improvement and learning. It suits well with the function of structured interview which is to identify the construction waste management practices on site as a support for the standard tolerance development.

The first in Deming cycle is planning. Questions on future waste management plan has been asked. The plan can be used to analyse and predict the result and record issues that may arise in future. Followed by the second cycle which is do. Do is about the plan execution. The action will be controlled by any circumstances that occur during the execution. Later, the respondents will be asked if they did any checking after the plan execution. It is used to study the result for improvement. Lastly, an action must take place to standardize or improve the plan and process for future implementation to avoid lost.

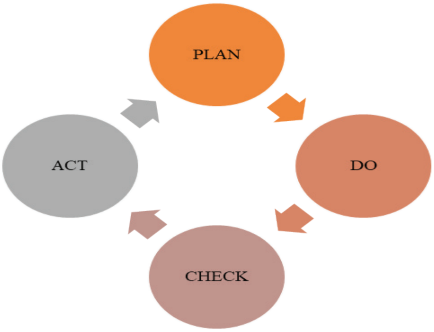

Figure 2: Deming Cycle

(Source: Richard, Elsa and Bruce (2007)

Development of Standard Tolerance

The standard tolerance will be developed by using the results from section B and C. An average of wastage rates from the sixteen projects will be quantified. Then, the results will be compared between the estimated and quantified wastage rates. Results from the comparison will become the standard tolerance. If the value between the estimated wastage rates and the quantified wastages rates is the same, then the value will be maintained as it is. However, if the comparison results for certain waste material is slightly different then an adjustment will be made with justification which means, a new standard tolerance will be set.

CONCLUSION

In conclusion, this is the proposed research approach as a method to quantify the construction waste generation and to conduct an observation. It also will be used for further data collection to achieve the objectives and aim to develop construction waste standard tolerance for stratified residential building projects. It is hoped that t his could help in improving environmental sustainability in Malaysia.

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