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CONSTRUCTION WASTE ESTIMATION METHODS: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

To date, researchers and governments have paid increasing attention to the zero-waste goal as an effective solution to alleviate the environmental impacts of construction projects towards sustainability. Accurate estimation of construction waste is a prerequisite for an effective waste management plan to achieve zero-waste construction sites. In literature, various methods have been adopted to estimate construction waste generation at the project level. However, there is a lack of an evaluation of existing construction waste estimation methods at the project level in terms of the information that the methods can provide to facilitate construction waste minimisation in a construction project. Hence, a systematic literature review was conducted in this study to bridge the research gap. Twenty-eight papers were selected based on the PRISMA approach and categorised into five estimation methods: area-based waste generation rate, variables modelling method, bill of quantity-based classification system accumulation method, BIM-based classification system accumulation method, and other particular methods. The applicability of those methods to aid practitioners towards construction waste minimisation was analysed based on four aspects: design information requirements, the ability to use in the early design stage, project characteristics, and the ability of waste tracking by material type and construction element.

Keywords: *Construction Waste; Estimation; Review.*

1. INTRODUCTION

Construction industry is one of the biggest waste contributors worldwide with 30-40% of the total solid waste (Islam et al., 2019), including waste generated in new construction, renovation, and demolition of buildings, roads, bridges and other infrastructures (Cheng & Ma, 2013). As a subset of waste generated in the construction industry, waste in the construction phase accounts for more than 10% of the total global waste (Bakshan et al., 2015). This results in adverse environmental impacts, natural resource exploitation, the depletion of landfill sites, increases in project cost and reductions in profits (Ajayi & Oyedele, 2018). Previously, waste generated during the construction stage was considered unavoidable (Tam & Tam, 2006); hence, construction waste estimation methods were established to support the waste treatment plan when construction waste was already generated, such as arranging on-site bins or planning transportation and

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disposal. However, the concept of "zero-waste construction site" has recently emerged in the global construction industry with an ambitious target of no waste produced at the construction sites. This requires a holistic and careful waste management plan from the early planning stage under the 3Rs principles: Reduce, Reuse, and Recycle (Lu et al., 2021). Accurate estimation of construction waste is the most important part of such an effective waste management plan to facilitate waste reduction, reuse and recycling in the construction project (Lee et al., 2016). During the design stage, waste prediction can assess the effectiveness of designing out waste solutions, identify and optimise measures to reduce waste. Contractors can adopt sustainable construction methods and technologies to prevent waste generation. Furthermore, accurate estimation of waste quantity can support the reuse and recycling plan within the project, between projects or across the industry. Therefore, this study conducts a systematic literature review to better understand extant construction waste estimation methods and how they can support waste management plan to achieve zero waste goal at the site level.

The remainder of this paper is structured as follows. Section 2 describes the research methodology for a systematic literature review. Section 3 presents the literature analysis results, including an overview of collected publications, construction waste estimation methods at the project level, and data collection to establish estimation methods. In Section 4, the applicability of existing estimation methods to aid construction waste minimisation is compared and analysed. Section 5 concludes the paper with a summary of the key findings.

2. RESEARCH METHODOLOGY

The study uses the systematic literature review method to systematically describe and analyse all estimation methods of construction waste at the project level since it can identify all research evidence that fits particular topics or research questions and provide reliable findings with minimum bias (Snyder, 2019). The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach was adopted with a 4-phase flow diagram and 27-item checklist to identify the most relevant sample (Page et al., 2021). Figure 1 illustrates the PRISMA flow diagram.

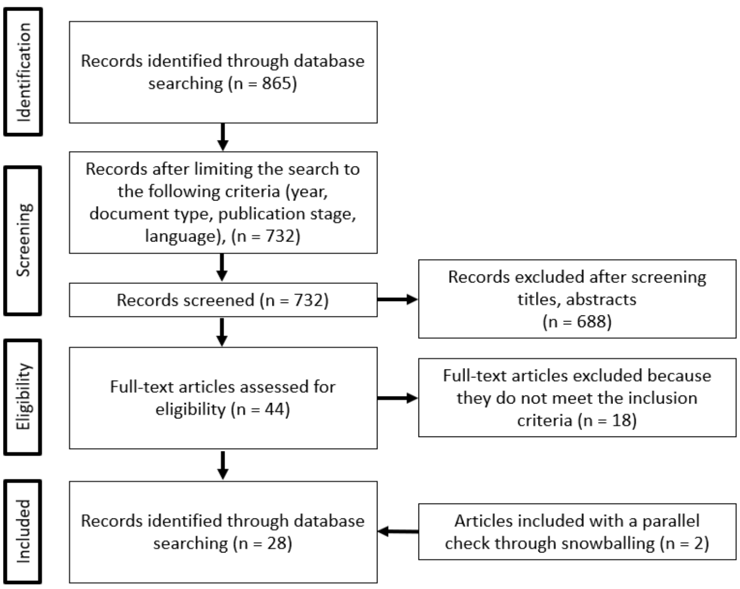

Figure 1: PRISMA flow diagram of the systematic literature review

The keywords used in the identification phase are ("C&D waste" OR "construction waste" OR "Construction and demolition waste") AND ("estimat*" OR "predict" OR "quantification") in the title, keywords, and abstract fields via Scopus database for searching the relevant literature within the scope of the study. Scopus was chosen because Scopus has accurate performance with wider coverage of peer-reviewed journal publications than other databases (Mongeon & Paul-Hus, 2016). The wildcard character * was used to capture relevant variations of the word "estimate*, such as estimation or estimate. Additional filters were used to restrict documents, including peer-reviewed articles and conference papers published in English, over the period from 2000 to February 2023. The papers were initially searched without a limited time span and only a few publications were found before 2000. Then the searching period was set from 2000 to 2023. After filtering, 732 papers were identified from SCOPUS database, and 688 papers were excluded after checking titles and abstracts. As a result, 44 full-text papers were retrieved and read carefully. Next, the journal articles and conference papers whose research objectives do not relate to the estimation method of construction waste at the project level were excluded. For example, research papers on the estimation of demolition waste or at the region level were excluded. Two additional papers were identified by using the snowballing technique. Finally, 28 journal articles were selected for a complete review. First, descriptive statistics were undertaken to provide information about the source of publication, geographical location, and publication year to identify the trends in research on construction waste estimation methods. Following the inductive content analysis approach, the data were coded according to the research focus. Then the emerging codes were grouped and reorganised into themes according to the similarity of their meanings and concepts. This study aims to understand better how extant construction waste estimation methods can support waste management plans towards waste minimisation; hence, the first purpose of data analysis is to analyse different methods used to estimate the amount of construction waste and the information that the methods can provide to support the waste management plan towards waste minimisation. Estimation methods were identified from selected papers and then grouped based on the basis used to estimate the amount of waste. As a result, estimation methods were categorised into five main groups: area-based generation rate (AWGR) method calculated on the construction area, variables modelling (VM) method considering different factors of waste generation, bill of quantity-based classification system accumulation (BoQS) method based on accumulating the waste of all items in the BoQ, BIM-based classification system accumulation (BIMS) method built on BIM model, and other particular methods. In addition, waste tracking themes were identified to indicate the information that the estimation methods can provide to support waste management. Following this stage, five estimation methods are further analysed based on the applicability of those methods to support practitioners to implement waste minimisation from the early design stage, as the zero-waste target requires a management plan from the early plan stage under the 3Rs principles – Reduce, Reuse, and Recycle (Lu et al., 2021). The qualitative analysis software NVivo 12 was used to aid the process of data coding and theme identification.

3. FINDINGS

3.1 OVERVIEW OF PUBLICATION COLLECTION

Overall, the search identified 28 articles distributed over 9 journals. The highest number of publications come from Waste Management journal, accounting for 7 articles. In terms of publishing countries, 28 selected papers were distributed across 10 countries, of which China and Spain are the main contributors with 9 and 7 publications respectively, as shown in Figure 2. Figure 3 indicates the number of publications over the period from 2000 to 2022. The interest in construction waste estimation at the project level started from 2009 and witnessed an overall upwards. This trend can be explained by the fact that according to EU Directive 2008/98/EC in 2008, all EU member states by 2020, have to take necessary actions to reduce 70% of construction and demolition waste by prevention, reuse, recycling and recovery (EC, 2008).

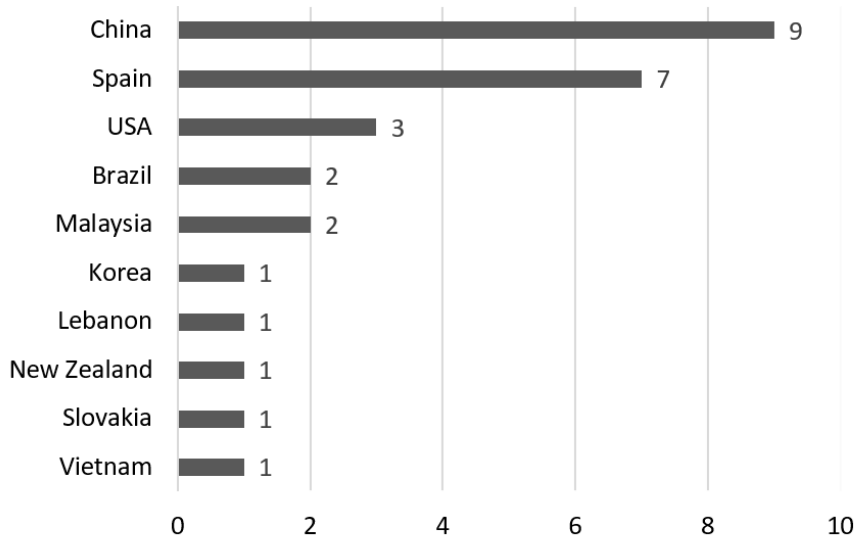

Figure 2: Publishing countries

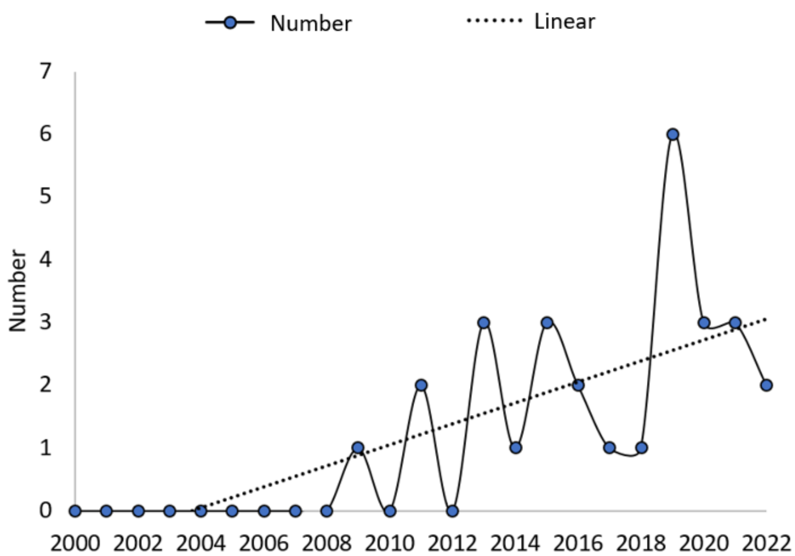

Figure 3: Research trend on construction waste estimation at the project level

3.2 CONSTRUCTION WASTE ESTIMATION METHODS

Selected articles are retrieved and classified into five groups based on the estimation methods (see Table 1). These five waste estimation methods are area-based waste generation rate (AWGR) method, variables modelling (VM) method, bill of quantity-based classification system accumulation (BoQS) method, BIM-based classification system accumulation (BIMS) method, and other particular methods. The ability of waste tracking in each method is analysed since an in-depth knowledge of the type and source of construction waste will enable project managers to select optimal solutions for waste minimisation and to build sustainable waste streams. For example, understanding waste generation in different construction stages (CS) aids project managers in planning for on-site waste management, such as sorting spaces, sorting labour, and waste transportation. The ability to track the waste source based on construction activities or elements (CA/E) will help designers understand the origin of waste; therefore, they can choose optimal design solutions for waste minimisation. Estimating waste by material type (MT) will help project managers develop waste diversion strategies based on the 3Rs principles. Detailed descriptions are given in the following sub-sections.

3.2.1 Area-Based Waste Generation Rate (WGR) Method

The principle of area-based WGR method is based on waste generation rate (WGR) per construction area. The total construction waste can be easily calculated by multiplying WGR by the total area (Sáez et al., 2011). WGR can be classified by individual waste streams according to their recyclability. For example, Wang et al. (2020) calculated WGR per floor area for five waste categories, including inorganic nonmetal waste, organic waste, metallic waste, composite waste, and hazardous waste. Furthermore, WGR by material type is employed by many researchers to disaggregate waste composition, such as concrete, steel, wood, masonry, and tiles (Bakshan et al., 2015; Li et al., 2013). In order to support the waste management plan through the construction phase, WGR for different construction stages is used to support on-site waste management (Bakchan et al., 2019). However, area-based WGR methods do not enable users to track the origin of waste from which construction activities and elements; hence, they hinder waste reduction at source.

3.2.2 Variables Modelling (VM) Method

Construction waste generation is directly impacted by numerous variables, such as total areas, structural types, economic indicators, etc., which are considered in variables modelling methods to provide more accurate waste estimation. These methods are classified into function-driven methods and data-driven methods. Function-driven methods refer to linear regression models and fuzzy set theory. Multiple linear regression analysis is often used to explain the relationship between predictor variables and waste generation (Domingo & Batty, 2021; Islam et al., 2019; Kern et al., 2015; Sáez et al., 2015). Meanwhile, Maués et al. (2020) established a fuzzy logic model with an accuracy of 66.67%. On the other hand, thanks to the development of artificial intelligence, data-driven methods are developed to learn the complex non-linear relationships between factors and the quantity of waste from historical data in order to predict the quantity of waste (Hu et al., 2021; Lee et al., 2016; Liu et al., 2018). Overall, existing VM methods tend to determine the quantity of waste in total without reference to the type and source of waste. Except for the study by Islam et al. (2019), linear regression analysis was adopted to estimate waste by material type; however, this method does not refer to the waste source.

Table 1: Previous studies on construction waste estimation methods at the project level

	Reviewed paper	Estimation method	Data collection	Waste tracking			
				TT	CS	CA/E	MT
1	Sáez et al. (2011)	AWGR	SD	✓			
2	Li et al. (2013)	AWGR	IM				✓
3	Bakshan et al. (2015)	AWGR	IM				✓
4	Noor et al. (2017)	AWGR	DM	✓			✓
5	Bakchan et al. (2019)	AWGR	IM	✓	✓		✓
6	Hoang et al. (2020)	AWGR	DM	✓			✓
7	Wang et al. (2020)	AWGR	DM	✓	✓		✓
8	Kern et al. (2015)	VM	IM	✓			
9	Sáez et al. (2015)	VM	SD	✓			
10	Lee et al. (2016)	VM	IM	✓			
11	Liu et al. (2018)	VM	IM	✓			
12	Islam et al. (2019)	VM	DM	✓			✓
13	Maués et al. (2020)	VM	IM	✓			
14	Domingo and Batty (2021)	VM	DM	✓			
15	Hu et al. (2021)	VM	DM	✓			
16	Solís-Guzmán et al. (2009)	BoQS	DM	✓		✓	
17	Llatas (2011)	BoQS	DM	✓		✓	✓
18	Li and Zhang (2013)	BoQS	UI	✓		✓	✓
19	Liu et al. (2014)	BoQS	SD	✓		✓	
20	Li et al. (2016)	BoQS	IM	✓		✓	✓
21	Lam et al. (2019)	BoQS	IM	✓		✓	
22	Liu et al. (2019)	BoQS	SD	✓		✓	✓
23	Spišáková et al. (2022)	BoQS	IM			✓	
24	Quiñones et al. (2021)	BIMS	SD			✓	✓
25	Quiñones et al. (2022)	BIMS	SD			✓	✓
26	Mercader-Moyano and Ramírez-de-Arellano-Agudo (2013)	Other	SD				✓
27	Bakchan and Faust (2019)	Other	IM			✓	✓
28	Guerra et al. (2019)	Other	IM			✓	✓

Note: AWGR – Area-Based Waste Generation Rate; VM – Variables Modelling; BoQS – Bills of Quantities-Based Classification System Accumulation; BIMS – BIM-Based Classification System Accumulation; DM – Direct Measurement; IM – Indirect Measurement; SD – Secondary Data; UI – User Input; TT – Total Waste; CS – Construction Stage; CA/E – Construction Activity/Element; MT – Material Type.

3.2.3 BoQ-Based Classification System Accumulation (BoQS) Method

In BoQS method, the bill of quantities (BoQ) is used as a classification system, the total waste is determined by accumulating the waste of all items in the BoQ. Solís-Guzmán et al. (2009) adopted the method to estimate the construction waste in Spain projects. Transformation coefficients are used to estimate demolitions, wreckage, and packaging waste of each item. Similar methods were also adopted in China (Liu et al., 2014) and

Slovakia (Spišáková et al., 2022). In these models, the source of waste can be easily tracked based on the BOQ; however, the waste quantity is not disaggregated by material type to assess the potential for reuse and recycling of waste, as each kind of material has different properties and requires different treatment methods. This limitation is addressed in another model developed by Llatas (2011) where the total amount of waste is accumulated from all elements and classified by material type. Later, Liu et al. (2019) used this methodology to estimate construction waste in China. In addition, Li and Zhang (2013) developed an online platform for construction waste estimation which enables users to track the origin of waste; however, material quantity take-off and waste level are entered by users. BoQS method estimates the quantity of waste based on project design, considers the categorisation of waste by material type, and enables users to track the source of waste. However, the method can only be used when the bill of quantities is available; therefore, this does not support waste assessment from the early design stage.

3.2.4 BIM-Based Classification System Accumulation (BIMS) Method

BIMS method is developed based on BoQS method; therefore, the method can also separate waste streams by material type and track the source of waste. The primary improvement is that the estimation model is integrated into BIM, which automatically estimates the quantity of waste and updates any changes during the design stage. Quiñones et al. (2021) developed a BIM-based model to estimate the construction waste from the structural system of a Spanish residential building. The model, later, was used to compare the waste amount generated from a reinforced concrete structure and a steel structure (Quiñones et al., 2022).

3.2.5 Other Methods

Apart from the above estimation methods, another method was established based on the difference between the amount of purchased materials and needed materials (Bakchan et al., 2019; Guerra et al., 2019). The method can only be applied when the purchasing records are available and can estimate the waste due to material losses; however, packaging waste and extracted waste are not quantified. Earlier, Mercader-Moyano and Ramírez-de-Arellano-Agudo (2013) determined the quantity of waste by multiplying the total quantity of consumed material by coefficient of transformation. This method depends on material quantity take-off and the availability of corresponding coefficient of transformation.

3.3 DATA COLLECTION METHODS FOR WASTE ESTIMATION

Database of waste generation is a fundamental part of a waste estimation model and significantly impacts the accurate results. Data collection methods are classified into three types: direct measurement, indirect measurement, and secondary data. Table 1 illustrates the data collection methods chosen in each waste estimation model.

3.3.1 Direct Measurement

Direct measurement refers to the method of quantifying actual on-site waste by sorting and weighting (Hu et al., 2021; Wang et al., 2020) or by heap-survey (Noor et al., 2017). Direct measurement provides the most realistic data to establish an accurate estimation method. However, the method also causes interruptions in site operations, additional health and safety concerns, as well as cost, labour and time intensive (Hoang et al., 2020), especially, when it comes to data collection to calculate waste generation by material type for particular building elements. This explains why researchers tend not to choose direct measurement to collect data in BoQS and BIMS methods.

3.3.2 Indirect Measurement

Compared to direct measurement, indirect measurement provides a quicker way to collect waste data. Project data is used to collect waste data, such as hauling tickets (Bakchan et al., 2019) or purchasing records (Guerra et al., 2019). The estimation model significantly depends on the availability and quality of project data. Furthermore, the material waste rate can be determined by personnel's perception, such as project managers' experience (Li et al., 2013), or contractors' judgment to define the waste percentage allowances (Lam et al., 2019; Li et al., 2016). Compared to direct measurement, indirect measurement may provide less reliable data; however, this method is still employed in many estimation models in order to save resources.

3.3.3 Secondary Data

Secondary data comes from region waste-related statistics or literature sources. Sáez et al. (2011) used national statistical publications to calculate the waste generation waste per built surface of Spanish dwellings. Spanish statistical publications were also used in another study to establish a linear regression model for waste estimation of residential buildings (Sáez et al., 2015). Furthermore, recent BoQS and BIMS models use the waste data in Spain by Solís-Guzmán et al. (2009) and Llatas (2011). The data is out of date and inapplicable in other regions due to different construction characteristics. For example, concrete is the top waste contributor in Hong Kong and Malaysia, whereas timber is commonly used in the New Zealand construction industry (Domingo & Batty, 2021). As a result, using secondary data from literature will impact the accuracy of waste quantity.

4. DISCUSSION

In this section, the applicability of each estimation method to facilitate construction waste minimisation is analysed based on four aspects: (1) design information requirements, (2) the ability to use in the early design stage, (3) project characteristics, and (4) the ability of waste tracking by material type and construction element. Table 2 summarises the comparison of the existing construction waste estimation methods at the project level.

Firstly, design information requirements define when the method can be used to estimate the waste of a construction project. Area-based WGR method only requires the information of construction area; hence, developers and managers can roughly estimate the quantity of waste from the early stage of the project. Apart from area information, VM methods need further information about predict variables to provide more accurate estimation. The variables depend on different models. For instance, Sáez et al. (2015) only considered the number of dwellings and total floor area. More predictor variables were employed in Domingo and Batty (2021) study, such as floor area, number of stories, materials for external and internal walls. BIMS method can apply from the schematic design stage as this method requires a BIM model with the level of development for elements at least equivalent to LOD 200 standard (Quiñones et al., 2021). Therefore, area-based WGR, VM and BIMS methods enable users to estimate the amount of waste in the early design stage. This ability is fundamental to an effective waste management plan from the early design stage (Lu et al., 2021). However, the remaining methods cannot be used until the bill of quantity is available.

Table 2: Comparison of the existing construction waste estimation methods at the project level

Estimation method	Design information requirements	Use in the early design stage	Project characteristics	Material type/ Construction element
Area-based WGR	Construction area	✓		MT
Variables modelling	Construction area and variables	✓	✓	MT
BoQS	BoQ		✓	MT, CE
BIMS	LOD200	✓	✓	MT, CE
Others	Purchasing records & BoQ		✓	MT, CE

Regarding the project characteristics, an individual project has its own features which directly impact the construction waste generation. However, area-based WGR method does not consider project characteristics; therefore, the method is unable to provide the actual amount of construction waste generated in an individual project. Meanwhile, VM method considers design and project parameters to predict total waste generation in a construction project. BoQS and BIMS methods estimate waste generation based on the detailed design of an individual project; therefore, project managers can estimate the waste quantity of the project and assess the efficiency of designing out waste alternatives for further needed improvements. Nevertheless, in BoQS method, the transformation coefficient needs to be aligned with the measurement and item descriptions in BoQ, which depends on the standard method of measurement chosen for the project. This may hinder the widespread use of the model. In addition, only design parameters are considered in BoQs and BIMS methods; meanwhile, qualitative measures such as site management and practices also have a direct impact on waste quantity (Domingo & Batty, 2021).

Considering another aspect, the ability of waste tracking by material type and construction element will provide detailed information for more effective waste management. First, by understanding the composition of the waste stream, project managers can optimise the waste treatment plan under the 3Rs principles and select sustainable materials to replace conventional ones. Although all methods can estimate the amount of waste by material type, VM models tend to limit to waste estimation in total without disaggregating waste by type. Due to the requirement of realistic data for construction waste estimation, gathering realistic waste data by material type is significantly costly and time consuming. BoQS and BIMS methods allow users to estimate construction waste by material type. However, there is a lack of an up-to-date waste database to implement the method. Another advantage of BoQS and BIMS methods is understanding the waste source at the element level; hence, designers can find which elements generate a significant amount of waste to decide whether design alternatives are needed for improvements.

5. CONCLUSIONS

Reliable construction waste estimation is fundamental to an effective waste management plan for the zero-waste construction site. Through a systematic review of twenty-eight papers, existing construction waste estimation methods at the project level are analysed based on how they can facilitate effective waste management in construction projects.

The ability to estimate waste in the early design stage will support waste management from the early planning phase. Considering project characteristics in estimation methods will improve the accuracy of waste quantity since design and project parameters directly impact waste generation. The information on the waste stream composition aids project managers in waste management plans under the 3Rs principles. Furthermore, understanding the waste generation at the building element level helps designers select optimal design solutions for waste minimisation. However, each estimation method has advantages and limitations in supporting effective waste management in construction projects; the selection of an appropriate estimation method depends on the objectives of waste estimation, waste database, and realistic conditions. A reliable and sufficient waste database directly impacts the accuracy of waste estimation. The data collection method should be selected according to the availability of resources and data quality.

6. REFERENCES

Ajayi, S. O., & Oyedele, L. O. (2018). Critical design factors for minimising waste in construction projects: A structural equation modelling approach. *Resources, Conservation and Recycling*, *137*, 302-313. https://doi.org/10.1016/j.resconrec.2018.06.005

Bakchan, A., & Faust, K. M. (2019). Construction waste generation estimates of institutional building projects: Leveraging waste hauling tickets. *Waste Management*, *87*, 301-312. https://doi.org/10.1016/j.wasman.2019.02.024

Bakchan, A., Faust, K. M., & Leite, F. (2019). Seven-dimensional automated construction waste quantification and management framework: Integration with project and site planning. *Resources, Conservation and Recycling*, *146*, 462-474. https://doi.org/10.1016/j.resconrec.2019.02.020

Bakshan, A., Srour, I., Chehab, G., & El-Fadel, M. (2015). A field based methodology for estimating waste generation rates at various stages of construction projects. *Resources, Conservation and Recycling*, *100*, 70-80. https://doi.org/https://doi.org/10.1016/j.resconrec.2015.04.002

Cheng, J. C. P., & Ma, L. Y. H. (2013). A BIM-based system for demolition and renovation waste estimation and planning. *Waste Management*, *33*(6), 1539-1551. https://doi.org/https://doi.org/10.1016/j.wasman.2013.01.001

Domingo, N., & Batty, T. (2021). Construction waste modelling for residential construction projects in New Zealand to enhance design outcomes. *Waste Management*, *120*, 484-493. https://doi.org/10.1016/j.wasman.2020.10.010

European Union. (2008). *Directive 2008/98/EC of the European parliament and of the council of 19 November 2008 on waste and repealing certain directives*. http://data.europa.eu/eli/dir/2008/98/oj

Guerra, B. C., Bakchan, A., Leite, F., & Faust, K. M. (2019). BIM-based automated construction waste estimation algorithms: The case of concrete and drywall waste streams. *Waste Management*, *87*, 825-832. https://doi.org/https://doi.org/10.1016/j.wasman.2019.03.010

Hoang, N. H., Ishigaki, T., Kubota, R., Tong, T. K., Nguyen, T. T., Nguyen, H. G., Yamada, M., & Kawamoto, K. (2020). Waste generation, composition, and handling in building-related construction and demolition in Hanoi, Vietnam. *Waste Management*, *117*, 32-41. https://doi.org/10.1016/j.wasman.2020.08.006

Hu, R., Chen, K., Chen, W., Wang, Q., & Luo, H. (2021). Estimation of construction waste generation based on an improved on-site measurement and SVM-based prediction model: A case of commercial buildings in China. *Waste Management*, *126*, 791-799. https://doi.org/10.1016/j.wasman.2021.04.012

Islam, R., Nazifa, T. H., Yuniarto, A., Shanawaz Uddin, A. S. M., Salmiati, S., & Shahid, S. (2019). An empirical study of construction and demolition waste generation and implication of recycling. *Waste Management*, *95*, 10-21. https://doi.org/https://doi.org/10.1016/j.wasman.2019.05.049

Kern, A. P., Dias, M. F., Kulakowski, M. P., & Gomes, L. P. (2015). Waste generated in high-rise buildings construction: A quantification model based on statistical multiple regression. *Waste Management*, *39*, 35-44. https://doi.org/https://doi.org/10.1016/j.wasman.2015.01.043

Lam, P. T. I., Yu, A. T. W., Wu, Z., & Poon, C. S. (2019). Methodology for upstream estimation of construction waste for new building projects. *Journal of Cleaner Production*, *230*, 1003-1012. https://doi.org/https://doi.org/10.1016/j.jclepro.2019.04.183

Lee, D., Kim, S., & Kim, S. (2016). Development of Hybrid Model for Estimating Construction Waste for Multifamily Residential Buildings Using Artificial Neural Networks and Ant Colony Optimization. *Sustainability*, *8*(9), 870. https://www.mdpi.com/2071-1050/8/9/870

Li, J., Ding, Z., Mi, X., & Wang, J. (2013). A model for estimating construction waste generation index for building project in China. *Resources, Conservation and Recycling*, *74*, 20-26. https://doi.org/https://doi.org/10.1016/j.resconrec.2013.02.015

Li, Y., & Zhang, X. (2013). Web-based construction waste estimation system for building construction projects. *Automation in Construction*, *35*, 142-156. https://doi.org/https://doi.org/10.1016/j.autcon.2013.05.002

Li, Y., Zhang, X., Ding, G., & Feng, Z. (2016). Developing a quantitative construction waste estimation model for building construction projects. *Resources, Conservation and Recycling*, *106*, 9-20. https://doi.org/https://doi.org/10.1016/j.resconrec.2015.11.001

Liu, J., Chen, J., & Tang, K. (2018). A method for estimation of the on-site construction waste quantity of residential projects. In *International Conference on Construction and Real Estate Management 2018* (pp. 225-231). Reston, VA: American Society of Civil Engineers. https://doi.org/doi:10.1061/9780784481738.027

Liu, J., Wang, Y., Yang, B., & Lin, Y. (2014). A Model for Quantification of Construction Waste in New Residential Buildings. *Proceedings of the 17th International Symposium on Advancement of Construction Management and Real Estate* (pp. 1079-1088). Springer Berlin Heidelberg.

Liu, J. K., Liu, Y., Zhao, S. M., & Li, S. M. (2019). Estimation of construction wastes based on the bill of quantity in south China. *Applied Ecology and Environmental Research*, *17*(1), 123-146.

Llatas, C. (2011). A model for quantifying construction waste in projects according to the European waste list. *Waste Management*, *31*(6), 1261-1276. https://doi.org/https://doi.org/10.1016/j.wasman.2011.01.023

Lu, W., Bao, Z., Lee, W. M. W., Chi, B., & Wang, J. (2021). An analytical framework of "zero waste construction site": Two case studies of Shenzhen, China [Article]. *Waste Management*, *121*, 343-353. https://doi.org/10.1016/j.wasman.2020.12.029

Maués, L. M. F., do Nascimento, B. d. M. O., Lu, W., & Xue, F. (2020). Estimating construction waste generation in residential buildings: A fuzzy set theory approach in the Brazilian Amazon. *Journal of Cleaner Production*, *265*, 121779.

Mercader-Moyano, P., & Ramírez-de-Arellano-Agudo, A. (2013). Selective classification and quantification model of C&D waste from material resources consumed in residential building construction. *Waste Management & Research*, *31*(5), 458-474. https://doi.org/10.1177/0734242X13477719

Mongeon, P., & Paul-Hus, A. (2016). The journal coverage of Web of Science and Scopus: a comparative analysis. *Scientometrics*, *106*, 213-228. https://doi.org/10.1007/s11192-015-1765-5

Noor, R., Rahmat, S. A., Endut, I. R., Redzuan, A. R. M., Hassan, A. C., & Jamaludin, A. (2017). Quantification of construction waste generated in residential housing projects via heap survey sampling with the method of visual estimation: A case study in Klang Valley and Pulau Pinang. *Journal of Engineering and Applied Sciences*, *12*, 792-796. https://doi.org/10.3923/jeasci.2017.792.796

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., & Brennan, S. E. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *International Journal of Surgery*, *88*, 105906. https://doi.org/10.1016/j.ijsu.2021.105906

Quiñones, R., Llatas, C., Montes, M. V., & Cortés, I. (2021). A multiplatform BIM-integrated construction waste quantification model during design phase. The case of the structural system in a Spanish building. *Recycling*, *6*(3), 62. https://doi.org/10.3390/recycling6030062

Quiñones, R., Llatas, C., Montes, M. V., & Cortés, I. (2022). Quantification of Construction Waste in Early Design Stages Using Bim-Based Tool. *Recycling*, *7*(5), 63. https://doi.org/10.3390/recycling7050063

Sáez, P. V., Merino, M. d. R., & Porras-Amores, C. (2011). Estimation of construction and demolition waste volume generation in new residential buildings in Spain. *Waste Management & Research*, *30*(2), 137-146. https://doi.org/10.1177/0734242X11423955

Sáez, P. V., Porras-Amores, C., & Merino, M. d. R. (2015). New quantification proposal for construction waste generation in new residential constructions. *Journal of Cleaner Production*, *102*, 58-65. https://doi.org/https://doi.org/10.1016/j.jclepro.2015.04.029

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, *104*, 333-339. https://doi.org/10.1016/j.jbusres.2019.07.039

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. https://doi.org/https://doi.org/10.1016/j.wasman.2009.05.009

Spišáková, M., Mandičák, T., Mésároš, P., & Špak, M. (2022). Waste Management in a Sustainable Circular Economy as a Part of Design of Construction. *Applied Sciences*, *12*(9), 4553.

Tam, V. W. Y., & Tam, C. M. (2006). A review on the viable technology for construction waste recycling. *Resources, Conservation and Recycling*, *47*(3), 209-221. https://doi.org/https://doi.org/10.1016/j.resconrec.2005.12.002

Wang, Q., Chen, L., Hu, R., Ren, Z., He, Y., Liu, D., & Zhou, Z. (2020). An empirical study on waste generation rates at different stages of construction projects in China. *Waste Management & Research*, *38*(4), 433-443. https://doi.org/10.1177/0734242X19886635