Article

A confirmatory Framework PLS-SEM for Construction Waste reduction as part of achieving Sustainable Development Goals of a building

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Abstract: As a result of rapid population growth, an exponentially growing human population, and industrial expansion, it has become increasingly difficult to manage municipal solid wastes throughout the world. Decentralized waste management systems have created difficult situations in developing countries such as Malaysia. Wastes generated in the country, due to various cultural, social, and religious activities, organic and contributing to environmental pollution (air, water, and soil) and human health troubles. A questionnaire survey was participated by 220 construction professionals in Malaysia using structured and semi-structured methods. The framework was assessed using A partial least square structural equation modeling (PLS-SEM) to target sustainable development goals (SDG). Statistical analysis results indicate a significant effect between SCW management, since$(r(270) = .687, P < 0.001)$. Improving factors has strong relationship with SCW management, since$(r(270) = .723, P < 0.001)$. The mediation results also suggested a significant indirect positive effect of improving factors drivers on SCW management through policy-related factors since $(\beta = 0.688, t = 8.254, P < 0.001, 95\%\ \text{CI for}\ \beta = [0.536, 0.866])$. Finally, policy-related factors construct has a strong relationship with SCWM) management, since $(r(270) = .811, P < 0.001)$ With the R Square of 0.787 and 0.785. The developed framework can improve construction waste management in the construction industry and enhance construction waste management to achieve global sustainable development goals. The findings show that one of the most critical issues of enhancing profitability is using preventive policies to reduce construction waste. This study could guide construction industry stakeholders in identifying the different waste management features during a building project's construction and design stage

Keywords: Effective Construction; Waste Reduction; achieving Sustainable Development Goals; partial least square structural equation modeling (PLS-SEM).

1. Introduction

The construction industry generated 16.6 million tonnes of waste in 2007, comprising 38% of destruction (2019), and 43% of those wastes sent to landfills [1, 2]. The amount of

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waste generated is enormous in the processes of construction and demolition (C&D). In 2020, C&D waste was reported to account for about 26% of Malaysian solid waste [3]. The problems associated with C&D are increasingly becoming a nightmare to practitioners and researchers [4, 5]. Furthermore, the amount of C&D waste continues to rise rapidly and is not entirely managed in most countries [6]. Therefore, the Architectural, Engineering, and Construction (AEC) industry should seek to minimize and manage C&D waste more efficiently [7, 8]. Many previous studies have suggested strategies for reducing C&D waste by reusing and recycling it [9]. Construction waste reduction is the first step in minimizing C&D waste. This is achieved by mitigating the root causes of waste [10, 11]. Design defects left unattended during the construction process will need to fix through renovation works and or reconstruction after project completion. This renovation or reconstruction may demand changing or demolition of some of the structural elements, leading to the accumulation of waste [9]. Improper design and unexpected design changes have been considered the fundamental causes of waste generation in construction [12, 13]. The inappropriate design has significantly led to an unexpected increase in construction waste total volume to about 33%. [14]. With an integrated building design, the causes of construction waste can be minimized and prevented where necessary., design problems and improvements, thereby reducing the volume of waste generation [15, 16]. In the work of Leemans, et al. [17], In Malaysia, residential and non-residential buildings use approximately 7.6% of total primary energy and emit about 6.0% of total (equivalent) carbon dioxide emissions as all direct and indirect contributions are listed for all major industries MILLHONE and Transfer [18]. The construction industry generated 16.6 million tonnes of waste in 2007, comprising 38% of total waste (2019) and 43% of those sent to landfills. In most of the countries, solid wastes are being dumped into the landfill sites. However, there will be risks of economic loss as well as environmental pollution as a result of doing so[19]. Sludge (35 percent waste) is also generated by the pulp and paper industries, and it can be divided into three categories based on the level of contamination and the method of treatment [19].

These steps reduce the electricity use and CO2 emissions of a building's life cycle [20]. Initially, now there are significant costs incurred. Nevertheless, the expense of lowering the carbon emissions of a house is control by long-term gains in energy conservation, not to mention the ever-increasing energy prices [21]. As a consequence, the idea of low-carbon buildings and, eventually, the carbon-free building developed. Globalization and demographic changes, and rising income levels since the 1970s had influenced the Malaysian housing provision system. Since the 1970s, Malaysia has experienced rapid economic growth with rising per capita income and rapid urbanization. The important green policies such as the utilization of renewable energy (RE), the adoption of energy efficiency (EE), and the promotion of green technology (GT) for sustainable development and towards the construction industry. However, currently lack the profound management devices to assist in the robust evaluation and execution of CWM by constructing configuration stages [22].

However, Environmental systems have been contaminated due to a lack of proper waste management practices, which have had negative effects on living creatures (including humans) and have also contributed to the current economic crisis [23]. Hence, its management has become a global concern. Solid wastes can be divided into five major categories: municipal solid waste (MSW), construction and demolition debris, electrical waste, sludge, and food waste. MSW is the most common type of solid waste. This challenge of increasing MSW magnitude seems inevitable as it is a byproduct of human activities that is growing alarmingly faster than that of urbanization [24].

Furthermore, even though MSW contains a high proportion of recyclable materials, incineration or illegal dumping are common practices due to a lack of land for new landfill construction[24]. As a result, time must be given to developing appropriate waste management strategies, inviting all relevant stakeholders. Many developing countries have

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made significant strides in improving their solid waste management systems [24]. However, because of the varying nature of solid waste, it is difficult to manage solid waste in developing countries such as Malaysia, the world's second-most populous country[25]. Open dumping of waste or any organic waste and construction waste can cause many environmental problems, as its decomposition will promote the genesis of pathogens. On the other side, its proper management can produce many helpful resources such as biochar, fragrance, compost, natural colors, etc., and reduce the pressure on the environment. However, at the global level, Stakeholders for proper waste management (NGOs ¼ Non-Governmental Organizations, CIDB, WUCM, and Municipal Corporations. Murgia, et al. [26] explained construction waste is generated directly or indirectly through construction operations. A percentage of the plasterboard waste, for example, is hazardous and may have an impact on the affected areas. Although Malaysia has regulatory policies for managing the waste generation, such as Standard Specifications, it is still a developing country.

Local Government; Environmental Quality Act 1974 (EQA), governed by the Ministry of Environment and Climate Change. Malaysian Natural Resources and Environment Act 1994, as well as the Pembinaan Malaysia Act 1994 (PMA) These rules, however, do not completely cover all of the features of CIDB [33], which is why Construction waste management is a broad term. For example, the PPSPPA is more concerned with domestic issues. Rather than construction waste, instead of construction waste Furthermore, to keep track of the work of contractors and The CIDB plan, the Solid Waste Management, and Public Cleansing Corporation, and other activities in the future [33, 34], to develop a guideline for the management of construction waste. Zuofa and Ochieng [27] Sustainability and resilience Green Growth." Before that, the Malaysian development industry's primary controlling body, the (CIDB), pushed the Construction Industry Transformation Plan (CITP) for 2016-2020 to engage and strengthen the development industry. CITP developed to rely on four (4) main thrusts: efficiency, health and professionalism, and environmental sustainability. It is proposed that a study be conducted to close the knowledge gap by gathering or collecting empirical data from relevant professionals who are knowledgeable about the problems mentioned above. This paper investigates the factorial validity for effective construction waste management through an extensive literature review and questionnaire to achieve the sustainable development goal for more efficient construction waste management. The study's findings are expected to encourage practitioners, especially in small and medium construction firms, to utilize effective construction waste management for achieving sustainable development goals in the Malaysian construction industry.

Hence, effective construction waste management for achieving sustainable development goals in various regions of the world and Malaysia. This is being presented to the scientific Community to extract valuable products from waste to achieve this goal. To steer the construction industry in the right direction, all relevant parties should work together to ensure that waste is minimized by fully implementing waste material reduction, reuse, and recycling. This paper is organized as follows. The next section presents a literature review, explicitly focusing on effective construction waste management for achieving sustainable Development Goal benefits in construction waste minimization**;** the third section offers a brief description of the study's methodology. And the fourth section gives a detailed analysis and explanation of the data obtained. Finally, the last section presents the conclusion of the review and possible recommendations for future research.

2. Overview and concept of waste reduction

The key reason for waste management is to manage waste. Nonetheless, in particular, minimization of waste at the source is important for efficient waste management [28]. The Sixth Environment Action Plan identifies waste minimization as the main objective of the Community's waste program, and this concurrent focus of the recycling and disposal strategy results in a shortage of specific meanings of keywords [29]. According to Begum,

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et al. [30], waste minimization comprises several activities (including waste reduction, re-use, and recycling) that reduce waste entering the environment. In particular, waste minimization in the construction sector includes the processes, including but not restricted to: improvements, adjustments in inventory management, product design, material changes, changes in operation and maintenance methods, replacement or improvement of infrastructure, and re-use or recycling of waste materials [31]. While the exact language used to define the concept and its scope may vary among regulatory bodies, all definitions highlight the significance of avoiding the creation of waste rather than focusing on the management of residuals after they are generated.

Furthermore, waste minimization requires reducing or removing waste production at the source and environmentally sustainable recycling strategies when source mitigation is not economically sustainable. Waste minimization does not require waste treatment, i.e., any method designed to change the physical, chemical, or biological design or quality of hazardous waste or treatment of waste. For instance, pacification, dilution, compacting, and incineration are not waste minimization practices [32]. The strategy and process for reducing waste imply mitigating waste production at the environment and the specific stage. The broader aspect of the purpose related to waste management is generally known as a waste hierarchy. Thus, the continuation of constructing waste disposal facilities is not a good idea, and building and operating new disposal facilities is very costly. It could only lead to a higher refuse disposal fee [33].

2.1 Root causes of construction waste

The root causes of construction waste obtained from the primary sources are Architects' failure to enforce waste management strategies during Osmani and Sciences [34]. Mohammed, et al. [35] stated that construction waste generation by design. Numerous project stakeholders contribute directly or indirectly in a waste generation which includes last-minute client demands (resulting in rework); lack of expertise of planners in assessing building methods and the order of construction activities (leading to specification errors causing work to be modified or terminated); Lack of expertise of planners in assessing building methods and the order of construction activities (leading to specification errors causing work to be modified or terminated); Lack of expertise of planners in assessing building methods and the Uncertainty in the design (producing in off-cuts); Lack of design knowledge (resulting in over-ordering of materials due to decisions made by contractors and subcontractors);, studies or laws, and regulations) Osmani, et al. [36] and Ghafourian, et al. [37]. Osmani, et al. [36] stated that waste produced during the design process is mainly due to: 'poor teamwork' which leads to errors and defects; and ''Overlapping design and construction adds to the complexity of managing the design process and raises waste mitigation issues to the top of the priority list.. Osmani, et al. [36] identifies "the shortage of designers' expertise in evaluating construction techniques and the schedule of construction processes" as a significant cause of design variations during the construction phase.

Furthermore, the interpretation is the origin of waste production. It examines the causes and impacts of the numerous stated elements on the management of construction waste. The categories include design, labour management, procurement site condition handling, and external factor set. The list of the selected construction waste factors is shown in the Table. 1.

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Table 1: Causative Factors for Construction Waste Generation

Group	Causes of Construction Waste	References
Design		Migilinskas, et al. [38], [39, 40]
	Last-minute client requirements	
	Frequent design changes	
	Design errors	
	Frequent design changes	
	Errors in contract documentation	
	Lack of design information	
	Poor design quality	
	Poor coordination of parties during the design stage	
Procurement	Waste resulting from packaging	[40, 41]
	Poor site condition	
	Interference of other crews at the site	
	Congestion of the site	
Management Factors	Lack of coordination amongst parties	Migilinskas, et al. [38]
	Lack of influence of contractors	
	Poor planning	
	Late information drift amongst parties	
	Rework	
	Lack of knowledge about construction	
	Poor quality information	
	Inappropriate methods of construction	
	Lack of environmental information	
	Communication problems	
Construction Operation/ Project Management	Poor workmanship	[40, 42, 43]
	Improper project planning	
	Poor supervision	
	Poor site conditions	
	Reworks Due to Errors	
	Leftover from cutting and shaping	
	Inadequate knowledge	
	Materials off-cuts	
Site Condition	Unforeseen ground conditions	Wijesiri, 2011
	Difficulties accessing the construction site	
	Leftover materials on site	
	Poor site condition	
	Waste resulting from packaging	
	Lighting problem	
Handling	Poor Materials Storage	[44, 45]
	Poor Materials Handling	

2.2 Current Practice of Waste Management Construction in Malaysia

Development in the standard of living led to rapid growth in the construction industries, and the demand for infrastructure projects, shifts in utilization patterns, and population growth contributed significantly to waste generation [46]. Construction waste consists of delays. [47, 48] mentioned that building waste might be hazardous, such as asbestos produced during the demolition of existing structures. It is, therefore, necessary to have a proper and well-defined policy and technology used in the management of waste produced from construction activities to reduce the adverse effect that may have on environmental, social, and economic aspects.

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2.3 Construction Waste Management Policy

With the advancement in sustainable improvements as a new norm, the construction industries have started to understand its harmful effects on the environment [47]. It is known that by nature, construction is not an environmentally friendly activity. The Negative Impact of the construction activities has been compressively reviewed by the researchers, including waste generation, resource depletion, land deterioration, and different forms of pollution [49-52]. In response, the Government of Malaysia has developed a Construction Industry Development Board (CIDB) agency to transform the industry by improving its environmental performance [53]. CIDB has produced a Master Plan for the Construction Industry to enhance sustainability awareness among the construction key players. In conjunction with this, the government of Malaysia has established Standard Building Works Specifications (SBW) governed by the Ministry of Works. At the same time, the 1994 Pembinaan Malaysia Act (PMA) is also governed by the CIDB). SBW's goal is to ensure twice a week garbage and construction clearance and send into landfill while PMA is to avoid and decrease pollution caused by building waste. All the policies and acts established by government bodies demonstrate the desire to manage building waste properly. Construction practitioners do not follow all policies implemented, however, and a more holistic policy is needed to ensure that economic, social, and environmental aspects can be protected.

2.4 Waste Management Technologies

Researcher Fercoq has indicated that the most environmentally sound measure for the waste management hierarchy should start with waste minimization, waste reuse, recycling, and ultimately composting. The adoption of waste minimization in the construction industry has shown its importance [47]. Minimization of waste involves reducing supply, which reduces waste generation at origin, and recycling, which reflects a recovery to recycling waste material [54]. Malaysia is moving towards adopting the Industrial Building System (IBS), which can control waste generation in construction activities and is environmentally friendly [55]. IBS is defined as a construction system that is built using a prefabricated component [56]. However, Mohammad and Sciences [57], due to higher initial costs, hinder construction professionals from adopting this method, although IBS may be one of the great ways to minimize on-site waste.

2.5 Factors for improving waste management practices

The interpretation on factors for improving waste management to mitigate the shortcomings of (CWM). C&DW management hierarchy, including reducing, reuse, and recycling strategies, is discussed, after which the most essential contributing factors to C&DW management are introduced. After determining the factors that impact C&DW management, this study classifies those that help to further sustainable C&DW management into four categories, which are the framework for sustainable C&DW management, construction, management factors, and industry policy factors. Tables 2 and 3 illustrate some of the major contributing factors to the management of C&D waste. The interpretation on drivers and factors for improving waste management to mitigate the shortcomings of (CWM) via application of 3r. The interpretation of drivers and factors for improving waste management to mitigate the shortcomings of (CWM) via 3r.

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Table 2: Factors for Improving Waste Management

Group	Factors for Improving Waste Management	References
Man-power Factors	The commitment of the contractor's representative at the site Appointment of laborers solely for waste disposal Contribution & cooperation of subcontractor Waste management organizations broken-down t structures. Consistency in the language and manner used to describe the details Drawing documents are free of errors that could otherwise lead to reworks	[57, 58]
	[59, 60]	

Table 3: Factors for Improving Waste Management to Mitigate 3R

Group	**Factors for Improving Waste Management (CWM)**	**References**
Management Factors	[59, 60]	
Industry Policy Factor	Obligatory cost estimation for the quantity of waste treatment a bill Adequate training to gain required competencies and experience Supervising waste management by a residential officer Additional tender premiums where waste initiatives to implemented Feasibility studies of waste estimation techniques Simplifying legal prosecutes to install waste treatment equipment	[59, 60]

2.6 Construction waste Determinant for Sustainable Attributes

Construction waste management techniques have been used for specific applications, methods, equipment, and final products through construction waste sources. For instance, techniques such as aggregate crushing, powder grinding, polishing, and ash burning would be used to control glass waste[47]. In tackling construction waste sustainably, The technique should be chosen from the possibilities based on its lengthy viability. Sustainable qualities contribute to long-term Development while also balancing environmental, social, and economic factors. Economic features address the financial benefit or expense of dealing with unique construction waste. Environmental qualities are used to assess the influence of waste management technology on the environment.

Nonetheless, Recently, social considerations have been imposed on building projects, requiring contractors to consider social aspects such as local jobs and neighborhood quality of life while selecting appropriate waste management strategies. It indicates that the criteria for assessing waste management activities differ from time to time. In this regard, it is important to establish an integrated system for choosing the preferred CWM method based on up-to-date, sustainable attributes.

Construction & Demolition waste is a term that refers to the process construction Environmental Protection Agency (EPA) defines waste as "waste materials generated in the design, remodeling, or demolition of structures and roads." Materials resulting

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from natural calamities are also included [61]. Sustainable construction is also a critical strategy that can be regarded for sustained Development through deliberating on environmental, social, economic, and cultural issues. The need to uncover the balance between the economic, environmental, and social elements of the design, construction, and use of buildings is a more substantial meaning for sustainable construction. Indeed, sustainable construction is seen as a significant sub-component to drive sustainable development [62]. For example, Umar, et al. [63] highlight the benefits of high-performance C&D waste management for a smooth building process while decreasing environmental impacts. It adheres to the two pillars of construction sustainability: resource conservation and pollution abatement [64]. As shown in Figure 1, sustainable construction mainly depends on waste management [65]; sustainable construction would have affected the evaluation of CWM performance. It is commonly agreed that the outcomes of the CWM are affected by environmental sustainability, social sustainability, and economic sustainability variables [66-68].

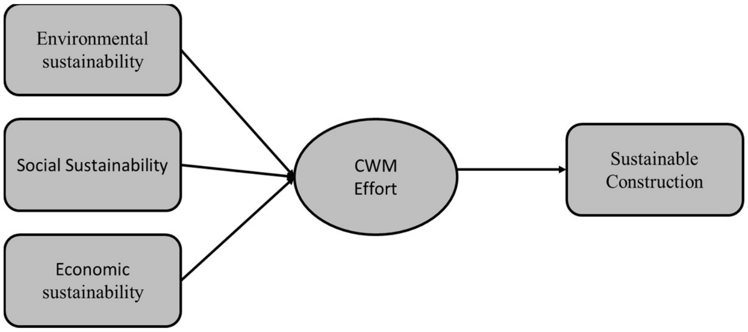

Figure 1. Novel and model for sustainable CWM

3. Menials and Methods

The proposed study applied two stages of analysis methods, namely variances-based structural equation modeling (PLS-SEM). A survey research strategy was used to collect data, including a questionnaire and walkthrough observational procedures. The Methodology questionnaire was adapted and used in the Malaysian construction industry. Before conducting the field survey, the questionnaire was pretested, and a pilot survey was conducted to ensure that it was accurate. Improving the questionnaire before the pilot survey, the pretest was conducted by discussing the questionnaire with colleagues[69].

A total of 220 questionnaires were administered to the respondents the local consultants and contractors registered with the Construction Industry Development Board (CIDB), out of which 131 representing 79 percent were retrieved of which 122 representing 74 percent of the total questionnaires distributed were considered valid for the analysis as recommended by Aziz, et al. [70] and [71] and a population of about 1000 for the field survey. According to the pilot study's findings, positive feedback was received in response to the questionnaire's design and presentation. It was refined in response to the pilot results to improve the questionnaire's face validity. The Statistical Package for Social Science (SPSS) version 21 was used in the preliminary analyses, was used for the Analysis. The data were screened to ensure univariate and multivariate normality as required [72]. The descriptive analysis of the categorical items was also carried out to determine the normality of the data. The mean, standard deviation, skewness, and kurtosis of the categorical items were used to determine the normality of the data. Later, factor analyses were conducted to determine the reliability and validity of using the factors in measurement models for evaluating public housing performance. These analyses included reliability, exploratory factor analyses, and confirmatory factor analyses.

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3. Results

Data collection was carried out by employing a questionnaire survey. It has been undertaken to demonstrate existing theories and reinforce research findings with previous research views and conclusions. Pretesting was carried out by discussing the questionnaire. It also entailed having the questionnaire evaluated by professionals in the same subject to ensure that the questions were relevant and that the questionnaire was simple and eligible. After collecting the data from the study area, the questionnaires were coded and posted into SPSS and subsequently transported to PLS-SEM. The analysis was carried out using frequency to identify missing data and wrong postings. Data were screened before using them for further analysis. That was important in ensuring that data used in analysis meet the criteria of normally distributed Parr, et al. [73] and was free from missing data. The questionnaires were of two different kinds. Variables used to develop the first questionnaire were obtained from the literature and other studies by Heberlein and Baumgartner [74]. Survey respondents include civil engineers, architects, quantity surveyors, and others (building designers and interior designers). The reliability and validity of using the variables in measurement models for effective CW management for assessment were then determined using reliability, exploratory, and confirmatory factor analyses. The following analysis discussed as follows.

3.1. Profiles of respondents

Following the data screening, the sample's demographic profiles with 122 instances were presented. The gender distribution indicated that about 85% of the respondents were males, and 15% were females. The data showed that more than 90% of the respondents were married and aged between 30 years to 60 years. Even though more than 73% of the respondents were civil servants, about 42% reported mostly at private companies. This probably indicated a significant number of the respondents are from construction companies in Malaysia.

3.1.1. *Data Reliability and validity of the Measurement Models*

A reliability test for all the constructs was carried out using Cronbach's alpha, as suggested by Taber [75]. Even though the recommended level is 0.7 Wong [76], The purpose of the reliability assessment is to test whether the consistency of the data in the questionnaire is consistent or not to obtain the correct results of the study. C and I received acceptable values of 0.882 and 0.815, respectively, in the first repetition of field data. The value of the P construct is 0.889. Also, the variables under the S had a value of 0.889. A similar study by Eisinga, et al. [77] on BIM achieved the alpha value of 0.71.

Table 4: Cronbach's Alpha

Constructs	No. of items	Cronbach's alpha
C	122	0.882
I	122	0.815
P	122	0.889

In this regard, the validity of the instrument used for this study is shown in the following Equation:

Validity (v) $= \sqrt{\alpha}$

Equation 4.1

Where: α is the reality alpha value.

Therefore, Validity (v) = $\sqrt{0.882} = 0.9391$

The results obtained indicate excellent validity.

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3.1.2 *Causes of construction waste generation in Malaysia.*

This section contains the Malaysian construction industry's causes and practices to manage and control sustainable construction waste management strategies in this study. Table 5: illustrates the results obtained from the respondents. The results are arranged from the highest mean to the lowest. The five most significant factors among all stakeholders were; Lack of Design and documentation (RD1) as the most critical factors that cause prevalent practices adopted by the Malaysian construction industry to manage and control the sustainable construction wastes management strategies and ranked first having a mean value of 2.90 and SD of 0.856 which is higher than all the remaining factors within the group. Transportation problem (RD2) ranked second, having a mean and S.D values of 2.88 and 0.845, respectively. Incorrect Procurement (RD3) was ranked third with a mean and S.D values of 2.87 and 0.756. Furthermore, the Lack of design standards for reducing C.D.W. (RD4) has a 2.83 mean with an S.D of 0.845. Low cost for C.D.W. disposal (RD5) ranked fifth, having a mean and S.D values of 2.82 0.761, respectively.

Table 5: First mean ranking of causes of waste generation

Code	N	Constructs	Mean. V	Std.Deviation	Rank
RD1	266	Lack of Design and documentation	2.90	0.856	1st
RD2	266	Transportation problem	2.88	0.845	2nd
RD3	266	Incorrect Procurement	2.87	0.756	3rd
RD4	266	Lack of design standards for reducing CDW	2.83	0.832	4th
RD5	266	Low cost for CDW disposal	2.82	0.761	5th

Table 6 shows the causes of construction waste generation and Malaysian practices adopted by many professionals in the Malaysian construction industry, which indicates that (CDW). The reduction is significant. Most of them have no idea how to reduce C.D.W. in the design process. According to the results obtained and supported by Gouldson, et al. [78]. Lack of guidance for effective C.D.W. collection and sorting (RU1) has 2.92 mean with S. D of 0.845 and ranked first among the causes of low the Malaysian construction industry practices while Lack of knowledge and standards for reused (CDW). (RU2) having a mean value of 2.90 with an SD of 0.861 and ranked second among the causes of low practices. Also, an accident due to negligence (RU3) has a 2.89 mean value and SD 0.848 as part of the factors causing low the Malaysian construction industry practices and ranked third. Equipment malfunctioning (RU4) has a 2.73 mean value and an SD of 0.940. Lastly, in the group, Time pressure (RU5) has a 2.68 mean S.D of 0.979 and ranked fifth.

Table 6: Second mean ranking of causes of waste generation

Code	N	Constructs	Mean	Std.Deviation	Rank
RU1	266	Lack of guidance for effective C.D.W. collection and sorting	2.92	.845	1st
RU2	266	Lack of knowledge and standards for reused CDW	2.90	.861	2nd
RU3	266	Accident due to negligence	2.89	.848	3rd
RU4	266	Equipment malfunctioning	2.73	.940	4th
RU5	266	Time pressure	2.68	.979	5th

Moreover, Table 7. Illustrated the respondents' results indicating the under-developed market for recycled CDW. Products In Malaysia (RC1) is the most significant factor with a mean value of 2.94 with an SD of 0.845. Immature recycling market operation (RC2) ranked second has 2.91 with an SD of 0.856. Green recycling technology (RC3), with a mean value of 2.90 and SD of 0.848, is the third-ranked factor among the causes of low practices adopted by the Malaysian construction industry.

Table 7: Third mean ranking of causes of waste generation

Code	N	Constructs	Mean	Std. Deviation	Rank
RC1	266	The under-developed market for recycled CDW products In Malaysia,	2.94	0.845	1st
RC2	266	Immature recycling market operation	2.91	0.856	2nd
RC3	266	Immature recycling technology	2.90	0.848	3rd
RC4	266	Damage during transportation	2.89	0.845	4th
RC5	266	Difficulties for delivery vehicles accessing construction sites	2.31	0.832	5th
RC6	266	Inefficient method of unloading	1.68	0.979	6th

The summary of less significant factors was shown in Table8; the result showed that Damage during transportation (RC4) has 2.89 mean and SD of 0.848 and ranked fourth, while difficulties for delivery vehicles accessing construction sites (RC5) ranked fifth, has 2.31 mean. SD: 0.832 and Inefficient method of unloading (RC6) has a mean value of 1.68 and SD of 0.979 selected as less significant factors that cause standard practices adopted by the Malaysian construction industry to manage and control the sustainable construction wastes hence these factors chosen for further analysis.

3.1.3 *Barriers to Implementing Effective Construction Waste Management*

This section presents the barriers that impede effective construction and demolition waste management strategies in the Malaysian construction industry. The ranking of the 15 identified barriers is shown in Table 9.

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Table 9. The barrier to Implementing Effective Construction Waste Management Strategies

Barriers	Mean	S.D.	Rank
Lack of attention to waste management in current regulations	4.56	0.89	1st
Lack of attention to designing buildings according to requirements of waste management	4.36	0.96	2nd
Lack of awareness among contractors about the waste management	4.23	0.66	3rd
Lack of regulations to make waste management an obligation	4.04	1.22	4th
Lack of incentives from regulatory authorities	4.03	1.02	5th
Lack of culture in favor of waste management	4.01	0.98	6th
Lack of support from owners and stakeholders	3.91	0.95	7th
Lack of attention to waste management from the Community	3.87	0.67	8th
Lack of economically viable facilities for waste management	3.71	0.15	9th
Lack of waste management necessities within the national building codes	3.65	0.88	10th
Low costs of sending materials to landfill	3.47	0.88	11th
Lack of budget for managing waste	3.45	0.56	12th
Low prices of building materials (waste management is not economically justified)	3.41	0.74	13th
Lack of support from building supervisors	3.21	0.79	14th
Tight scheduling of construction projects	3.01	0.61	15th

Table 9 shows the barriers to implementing effective construction and demolition waste management strategies in the Malaysian construction industry. As a result, using mean ranking, There is a lack of attention to waste management in current rules; there is a lack of attention to designing buildings according to waste management needs. There is a lack of attention to waste management in current regulations. Lack of waste management awareness among contractors; a lack of rules making waste management mandatory; and a lack of regulatory incentives, respectively having mean values of 4.56, 4.36, 4.23, 4.04, and 4.03, are the 1st to 5th major barriers against the implementation of effective construction and demolition waste management strategies in the Malaysian construction industry.

Lack of waste management culture; Lack of support from owners and stakeholders; Lack of community attention to trash management; Lack of environmentally suitable waste management infrastructure; and The Lack of waste management requirements in national building codes was found to be the 6th to 10th biggest barrier to implementing efficient construction waste management strategies in Malaysia, with mean values of 4.01, 3.91, 3.87, 3.71, and 3.65.

The factors that were considered the least barriers to implementing effective construction and demolition waste management strategies in the Malaysian construction industry and ranked 11th to 15th were low costs of sending materials to landfill, Lack of budget for managing waste, low prices of building materials (waste management is not economically justified), Lack of support from building supervisors, and tight scheduling of construction projects as indicated by mean values of 3.47, 3.45, 3.41, 3.21 and 3.01 respectively.

3.1.3 ***Descriptive statistics and multiple correlations***

Table 10 shows the results of descriptive statistics derived for the selected constructs. The mean (M), standard deviation (SD), and coefficient of variation (CV) are the three statistics in question.

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Table 10. Descriptive statistics for the selected constructs

Construct	Mean	SD	CV
Design Factors	3.366	0.836	24.83%
Design Development Stages / Lean Construction	3.159	0.872	27.62%
Construction & Site Management	3.007	0.919	30.54%
External and Workers / Handling factors	3.094	0.884	28.58%
Planning And Design Factors	2.905	0.937	32.26%
Management Practices	2.929	0.893	30.50%
Construction Factors	3.018	0.897	29.71%
Waste Minimization Measures	2.881	0.933	32.40%
Effective to Improve CWM Factors	2.841	0.873	30.73%
Waste Management Policy Factors	2.906	0.939	32.33%
Industrial Factors	2.820	0.869	30.81%
Environmental Factors	2.865	0.880	30.70%
Economic Factors	2.836	0.889	31.36%
Social Factors	4.029	0.853	21.17%
Current Practices / Generation	3.156	0.772	24.46%
Improving Factors Drivers	2.915	0.788	27.05%
Policy Related Factors	2.863	0.869	30.34%
Sustainable Construction Waste Management	3.244	0.671	20.70%

The descriptive statistics for the independent variables were as follows: for Current Practices / Generation, we have $(M = 3.156, SD = 0.772, CV = 24.46\%)$ and for Improving Factors Drivers, we have$(M = 2.915, SD = 0.788, CV = 27.05\%)$. The descriptive statistics for the mediator variable "Policy Related Factors" were as follows$(M = 2.863, SD = 0.869, CV = 30.34\%)$. Finally, the descriptive statistics for the dependent variable "Sustainable Construction Waste Management" were as follows$(M = 3.244, SD = 0.671, CV = 20.70\%)$.

Table 11. Pearson Multiple Correlations

Construct	**Current Practices / Generation**	**Improving Factors Drivers**	**Policy Related Factors**	**Sustainable Construction Waste Management**
Current Practices / Generation	1	.815***	.685***	.687***
Improving Factors Drivers		1	.850***	.723***
Policy Related Factors			1	.811***
Sustainable Construction Waste Management				1

P < 0.05; **P < 0.01;P < 0.001**

Table 11 shows the matrix of Pearson correlation coefficients between all variables in the study. The correlation coefficients suggest a significant positive (moderate to strong) correlation among all variables. Pearson product-moment correlation coefficient was calculated and found that there is a moderate positive relationship between Current Practices/Generation and Sustainable Construction Waste Management, since $(r(270) = .687, P < 0.001)$. Improving Factors Drivers construct has a strong relationship with Sustainable Construction Waste Management, since$(r(270) = .723, P < 0.001)$. Finally, the

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Policy Related Factors construct has a strong relationship with Sustainable Construction Waste Management, since$(r(270) = .811, P < 0.001)$.

3.1.4 *Structural Equation Modeling*

In this study, the researcher has applied structural equation modeling (SEM) for the model analysis. The SEM is a broad strategy to test hypotheses and determine the relationship between exogenous and endogenous variables. A partial least square analysis of SEM (PLS-SEM) is followed in this study. The first stage of this technique is about specifying the structural model, while the second stage is about defining the measurement models. The third stage focuses on collecting and examining the data. These three stages have been implemented in (Ch.). The fourth stage involves PLS-SEM path model estimation, while the fifth stage requires assessing the measurement model's results. The sixth stage is for assessing the results of the structural model. The final stage is making final interpretations of the results and conclusions.

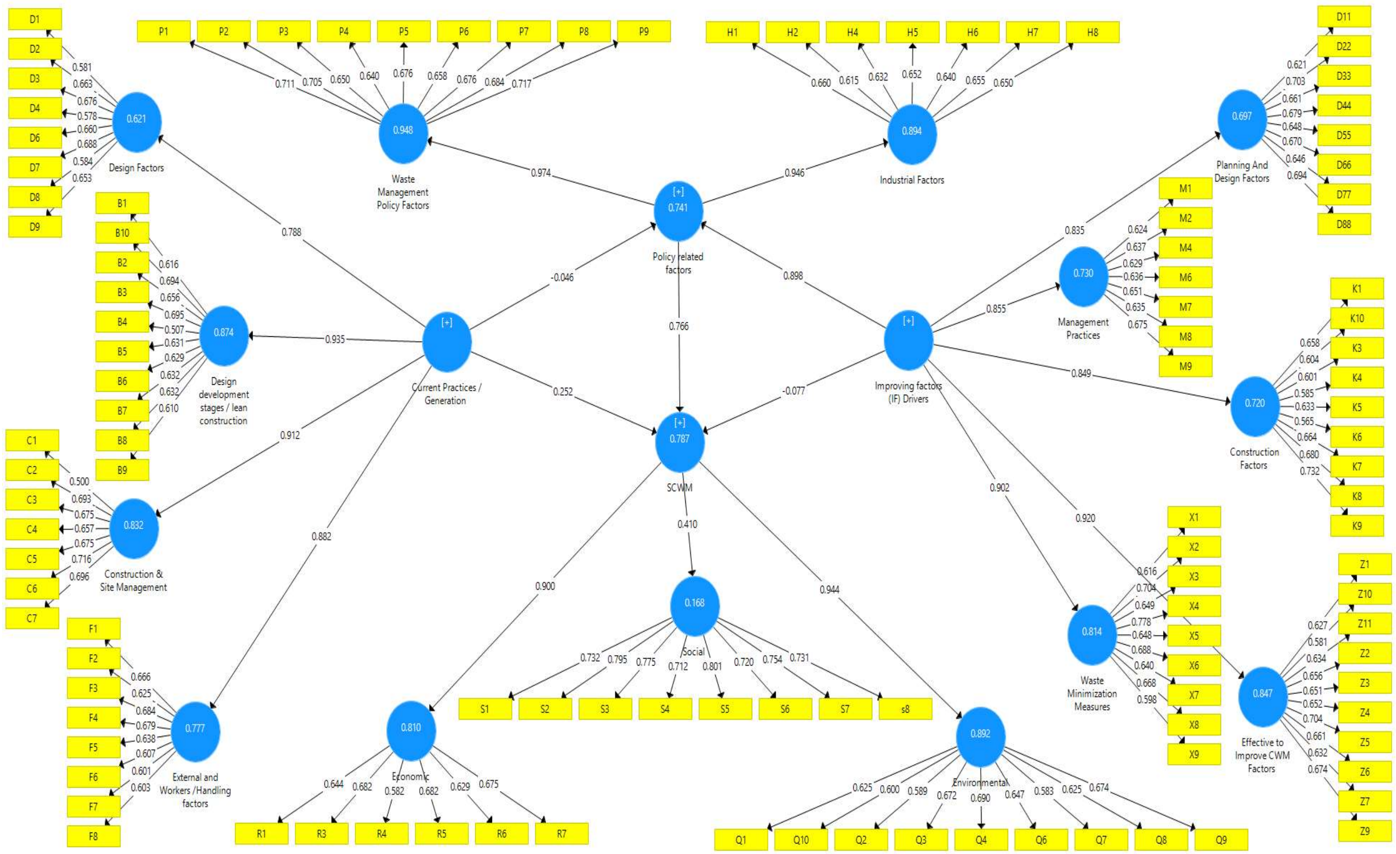

Figure 2, Output loading factor research mode

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3.1.5 Assessing the Measurement Model

The assessment of the reflective measurement models in PLS-SEM requires evaluating the internal consistency reliability, convergent validity, and discriminant validity. Fig (4.1) shows the measurement model of the current study. Once the reliability and validity of the measurement model have been established, the structural model will be assessed. The following subsections will discuss the reliability and validity of the measurement model.

3.1.6 Internal reliability and convergent validity

The internal consistency reliability examines whether all of the indicators associated with a constructed measure it [79]. There are different ways to measure internal consistency. Cronbach's alpha is a statistical measure that is the most commonly used for this purpose.

Table 12: Internal reliability and convergent validity

Construct	Cronbach's Alpha	rho_A	CR	AVE Initial	Modified
Design Factors	0.79	0.793	0.845	0.366	0.406
Design Development Stages / Lean Construction	0.831	0.834	0.869	0.4	0.4
Construction & Site Management	0.783	0.79	0.844	0.438	0.438
External and Workers / Handling factors	0.792	0.794	0.846	0.408	0.408
Planning And Design Factors	0.82	0.821	0.864	0.443	0.443
Management Practices	0.762	0.763	0.83	0.369	0.411
Construction Factors	0.816	0.82	0.86	0.392	0.407
Waste Minimization Measures	0.843	0.847	0.878	0.445	0.445
Effective to Improve CWM Factors	0.846	0.848	0.878	0.386	0.42
Waste Management Policy Factors	0.854	0.855	0.886	0.463	0.463
Industrial Factors	0.764	0.764	0.832	0.378	0.414
Environmental Factors	0.814	0.816	0.858	0.388	0.403
Economic Factors	0.725	0.727	0.814	0.334	0.422
Social Factors	0.891	0.894	0.913	0.567	0.567

Cronbach's alpha provides the average correlation between all of the indicators that belong to one construct. The accepted value of Cronbach's alpha is 0.7; all weights of Cronbach's alpha in Table (4.18) were above 0.7. Despite its popularity, Cronbach's alpha is criticized for assuming that all of the indicators have equal outer loadings [80] and that the number of indicators influences the calculation of Cronbach's alpha in that fewer items produces lower value, especially in scales with items fewer than 10 [80].

Due to the limitations of Cronbach's alpha, researchers are advised to use other measures of internal consistency such as composite reliability (CR) and rho [81]. Jöreskog rho measure is a better reliability measure than Cronbach's alpha in structural equation modeling. It is based on the loadings rather than the correlations observed between the observed variables [81]. Composite reliability measures the internal consistency while considering that each indicator has a different outer loading. Following the previous rules, the reliability of each construct was assessed using the calculations provided in Smart - PLS. The results in Table (4.18) show that all constructs had reliability (Cronbach's Alpha, rho, and Composite Reliability) scores of more than 0.70. Figures (4.18) present the results of the internal consistency reliability. Those findings provide evidence of the high reliability and sufficient internal consistency of the constructs. The convergent validity evaluates the correlation between the variables that measure one construct. The convergent validity of reflective measurement models is usually evaluated using the outer loadings of the items and the average variance extracted (AVE).

3.1.7 Discriminant Validity

Discriminant validity examines how much a construct differs from other constructs. Discriminant validity is usually established using the Fornell-Larcker criterion, cross-loadings, or Hetrotrait-Monotrait (HTMT) ratio. The Fornel Larcker criterion, the square root of AVE, is compared against the construct's correlations. The square root of the construct's AVE should be higher than any of the construct's correlations with other constructs; the results of the Fornell-Larcker criterion were reported in Table (13). HTML is "the ratio of the between-trait correlations to the within-traits correlations. The HTMT value in Table (13) should be lower than 0.9 [361]. Following these guides, the results reveal that the discriminant validity is agreed. The third method, the cross-loading criterion, has also been used in this study to determine discriminatory validity. This method attempts to determine that the loading of indicators on a given latent construct should be higher than the loading on all other constructs by row. In other words, the loading of the indicators (items) of their constructs should be higher than the loading of another construct. Table 4.20 showed that the loading of all indicators of the allocated latent construct is higher than the cross-loading on other constructs (by row). The result showed a substantial degree of unidimensionality for each construct.

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Table 13. Item Loading

Current Practices / Generation				Improving Factors Drivers				Policy Related Factors				Sustainable Construction Waste Management			
	Items	Initial	Modified		Items	Initial	Modified		Items	Initial	Modified		Items	Initial	Modified
Design Development Stages / Design Factors	D1	0.562	0.581	Planning And Design Factors	D11	0.62	0.621	Waste Management Policy Factors	P1	0.712	0.711	Environmental Factors	Q1	0.607	0.625
	D2	0.661	0.663		D22	0.703	0.703		P2	0.704	0.705		Q2	0.597	0.589
	D3	0.668	0.676		D33	0.66	0.661		P3	0.649	0.65		Q3	0.664	0.672
	D4	0.597	0.578		D44	0.679	0.679		P4	0.641	0.64		Q4	0.681	0.69
	D5	0.513	Deleted		D55	0.648	0.648		P5	0.677	0.676		Q5	0.558	Deleted
	D6	0.623	0.66		D66	0.67	0.67		P6	0.657	0.658		Q6	0.641	0.647
	D7	0.676	0.688		D77	0.648	0.646		P7	0.677	0.676		Q7	0.579	0.583
	D8	0.567	0.584		D88	0.693	0.694		P8	0.682	0.684		Q8	0.623	0.625
	D9	0.634	0.653	Management Practices	M1	0.627	0.624		P9	0.719	0.717		Q9	0.663	0.674
	D10	0.523	Deleted		M2	0.613	0.637	Industrial Factors	H1	0.593	0.66		Q10	0.603	0.6
Lean Construction	B1	0.615	0.616		M3	0.509	Deleted		H2	0.621	0.615	Economic Factors	R1	0.616	0.644
	B2	0.656	0.656		M4	0.616	0.629		H3	0.541	Deleted		R2	0.512	Deleted
	B3	0.695	0.695		M5	0.567	Deleted		H4	0.592	0.632		R3	0.634	0.682
	B4	0.509	0.507		M6	0.613	0.636		H5	0.688	0.652		R4	0.587	0.582
	B5	0.632	0.631		M7	0.636	0.651		H6	0.609	0.64		R5	0.636	0.682
	B6	0.628	0.629		M8	0.613	0.635		H7	0.66	0.655		R6	0.655	0.629
	B7	0.63	0.632		M9	0.657	0.675		H8	0.618	0.65		R7	0.608	0.675
	B8	0.633	0.632	Construction Factors	K1	0.654	0.658		H9	0.599	Deleted		R8	0.577	Deleted
	B9	0.609	0.61		K2	0.571	Deleted						R9	0.293	Deleted
	B10	0.694	0.694		K3	0.601	0.601					Social Factors	S1	0.732	0.732
Construction & Site Management	C1	0.502	0.5		K4	0.592	0.585						S2	0.793	0.795
	C2	0.692	0.693		K5	0.611	0.633						S3	0.774	0.775
	C3	0.675	0.675		K6	0.588	0.565						S4	0.715	0.712
	C4	0.656	0.657		K7	0.649	0.664						S5	0.801	0.801
	C5	0.675	0.675		K8	0.682	0.68						S6	0.721	0.72
	C6	0.715	0.716		K9	0.711	0.732						S7	0.752	0.754
	C7	0.695	0.696		K10	0.585	0.604						s8	0.733	0.731
External and	F1	0.666	0.666	Waste	X1	0.616	0.616								
	F2	0.625	0.625		X2	0.704	0.704								

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F3	0.684	0.684		X3	0.649	0.649
F4	0.678	0.679		X4	0.778	0.778
F5	0.639	0.638		X5	0.648	0.648
F6	0.606	0.607		X6	0.688	0.688
F7	0.602	0.601		X7	0.639	0.64
F8	0.603	0.603		X8	0.668	0.668
				X9	0.597	0.598
			Effective to Improve CWM Factors	Z1	0.615	0.627
				Z2	0.645	0.656
				Z3	0.65	0.651
				Z4	0.64	0.652
				Z5	0.705	0.704
				Z6	0.651	0.661
				Z7	0.626	0.632
				Z8	0.518	Deleted
				Z9	0.665	0.674
				Z10	0.589	0.581
				Z11	0.615	0.634
				Z12	0.504	Deleted

Table 14: Fornell-Larcker criterion

	m1	m2	x11	x12	x13	x14	x21	x22	x23	x24	x25	y1	y2	y3
m1	0.68													
m2	0.50	0.644												
x11	0.525	0.477	0.637											
x12	0.592	0.565	0.602	0.632										

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x13	0.611	0.59	0.599	0.601	0.662									
x14	0.616	0.639	0.574	0.552	0.553	0.639								
x21	0.615	0.638	0.489	0.582	0.561	0.594	0.666							
x22	0.630	0.551	0.485	0.597	0.607	0.557	0.643	0.641						
x23	0.601	0.521	0.523	0.585	0.601	0.621	0.605	0.611	0.638					
x24	0.562	0.563	0.492	0.563	0.602	0.588	0.642	0.631	0.60	0.667				
x25	0.593	0.509	0.518	0.579	0.592	0.615	0.61	0.601	0.610	0.650	0.648			
y1	0.594	0.551	0.549	0.613	0.630	0.578	0.598	0.606	0.510	0.640	0.59	0.635		
y2	0.305	0.587	0.477	0.546	0.582	0.599	0.563	0.539	0.608	0.601	0.525	0.517	0.65	
y3	0.147	0.128	0.255	0.237	0.158	0.202	0.127	0.1	0.137	0.109	0.139	0.185	0.147	0.753

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Table 15: HTMT ratio

	m1	m2	x11	x12	x13	x14	x21	x22	x23	x24	x25	y1	y2
m2	0.70												
x11	0.635	0.612											
x12	0.705	0.712	0.812										
x13	0.747	0.766	0.759	0.687									
x14	0.747	0.825	0.719	0.727	0.78								
x21	0.731	0.808	0.602	0.828	0.852	0.786							
x22	0.772	0.848	0.622	0.75	0.788	0.843	0.737						
x23	0.852	0.61	0.655	0.707	0.751	0.772	0.733	0.895					
x24	0.611	0.653	0.594	0.79	0.862	0.842	0.768	0.851	0.833				
x25	0.671	0.701	0.632	0.811	0.834	0.873	0.848	0.843	0.839	0.799			
y1	0.689	0.812	0.684	0.748	0.82	0.844	0.733	0.766	0.86	0.737	0.752		
y2	0.696	0.804	0.625	0.705	0.769	0.794	0.731	0.725	0.788	0.889	0.729	0.780	
y3	0.173	0.162	0.302	0.275	0.196	0.233	0.154	0.153	0.169	0.147	0.172	0.22	0.181

3.1.8 Assessing the Structural Model

After establishing the reliability and validity of the measurement models, it is time to assess the structural model. Researchers in the literature provided guidelines for evaluating and reporting the structural model, including collinearity, path coefficients, coefficient of determination (R2), effect size (f^2), predictive relevance (Q2), and goodness of fit (GoF) index.

3.1.9 Collinearity

Collinearity occurs when there is a high correlation between two constructs, producing interpretation issues[82]. Collinearity can be assessed using the variance inflation factor (VIF); a VIF value of 5 or higher indicates high collinearity [83]. Table (4.10) shows that most VIF values were below the cut-off point, providing evidence that the collinearity problem between independent constructs does not exist.

Table 16. Variance inflation factors

Construct	**Policy Related Factors**	**Sustainable Construction Waste Management**
Policy Related Factors		3.865
Current Practices / Generation	2.954	2.962
Improving Factors Drivers	2.954	3.072

3.20 Path Coefficients

Path coefficients refer to the estimates of the relationships between the model's constructs[84]. Those coefficients range from +1 to -1, where +1 means a strong positive relationship, 0 means a weak or non-existence relationship, and -1 means a strong negative relationship. Figure (4.4) shows the estimated model with the estimated path coefficients of the leading hypotheses along with the corresponding p-values.

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Table 17: Hypothesis testing

Path	$\boldsymbol{\beta}$	T-value	P-value	95% CI	
				LL	UL
Direct Effect					
H1: Current Practices / Generation -> Policy Related Factors	-0.046	0.619	0.537 NS	-0.217	0.071
H2: Current Practices / Generation -> Sustainable Construction Waste Management	0.252	4.878	0.000***	0.166	0.342
H3: Improving Factors Drivers -> Policy Related Factors	0.898	14.39	0.000***	0.798	1.025
H4: Improving Factors Drivers -> Sustainable Construction Waste Management	-0.077	1.043	0.3 NS	-0.211	0.066
H5: Policy Related Factors -> Sustainable Construction Waste Management	0.766	12.133	0.000***	0.626	0.871
Indirect Effect					
H6: Current Practices / Generation -> Policy Related Factors -> Sustainable Construction Waste Management	-0.035	0.584	0.561NS	-0.188	0.05
H7: Improving Factors Drivers -> Policy Related Factors -> Sustainable Construction Waste Management	0.688	8.254	0.000***	0.536	0.866

*P < 0.05; **P < 0.01; ***P < 0.001; ^{NS} Not significant

The results of the hypotheses show that; Current Practices / Generation has no statistical significant effect on Policy Related Factors since $(\beta = -0.046, t = 0.619, P > 0.05, 95\%\ CI \text{ for } \beta = [-0.217, 0.071])$So H1 is rejected. However, Current Practices / Generation has a statistically significant positive effect on Sustainable Construction Waste Management since $(\beta = 0.252, t = 4.878, P < 0.001, 95\%\ CI \text{ for } \beta = [0.166, 0.342])$So H2 is accepted. Improving Factors Drivers construct a statistically significant positive effect on Policy Related Factors since $(\beta = 0.898, t = 14.39, P < 0.001, 95\%\ CI \text{ for } \beta = [0.798, 1.025])$So H3 is accepted. Improving Factors Drivers construct no statistically significant effect on Sustainable Construction Waste Management since $(\beta = -0.077, t = 1.043, P > 0.05, 95\%\ CI \text{ for } \beta = [-0.211, 0.066])$So H4 is rejected. Policy Related Factors has a statistically significant positive effect on Sustainable Construction Waste Management since $(\beta = 0.766, t = 12.133, P < 0.001, 95\%\ CI \text{ for } \beta = [0.626, 0.871])$So H5 is accepted. The mediation analysis revealed that there is no indirect effect of Current Practices / Generation on Sustainable Construction Waste Management through Policy Related Factors since$(\beta = -0.035, t = 0.584, P > 0.05, 95\%\ CI \text{ for } \beta = [-0.188, 0.05])$. The mediation results also suggested a significant indirect positive effect of Improving Factors Drivers on Sustainable Construction Waste Management through Policy Related Factors since $(\beta = 0.688, t = 8.254, P < 0.001, 95\%\ CI \text{ for } \beta = [0.536, 0.866])$.

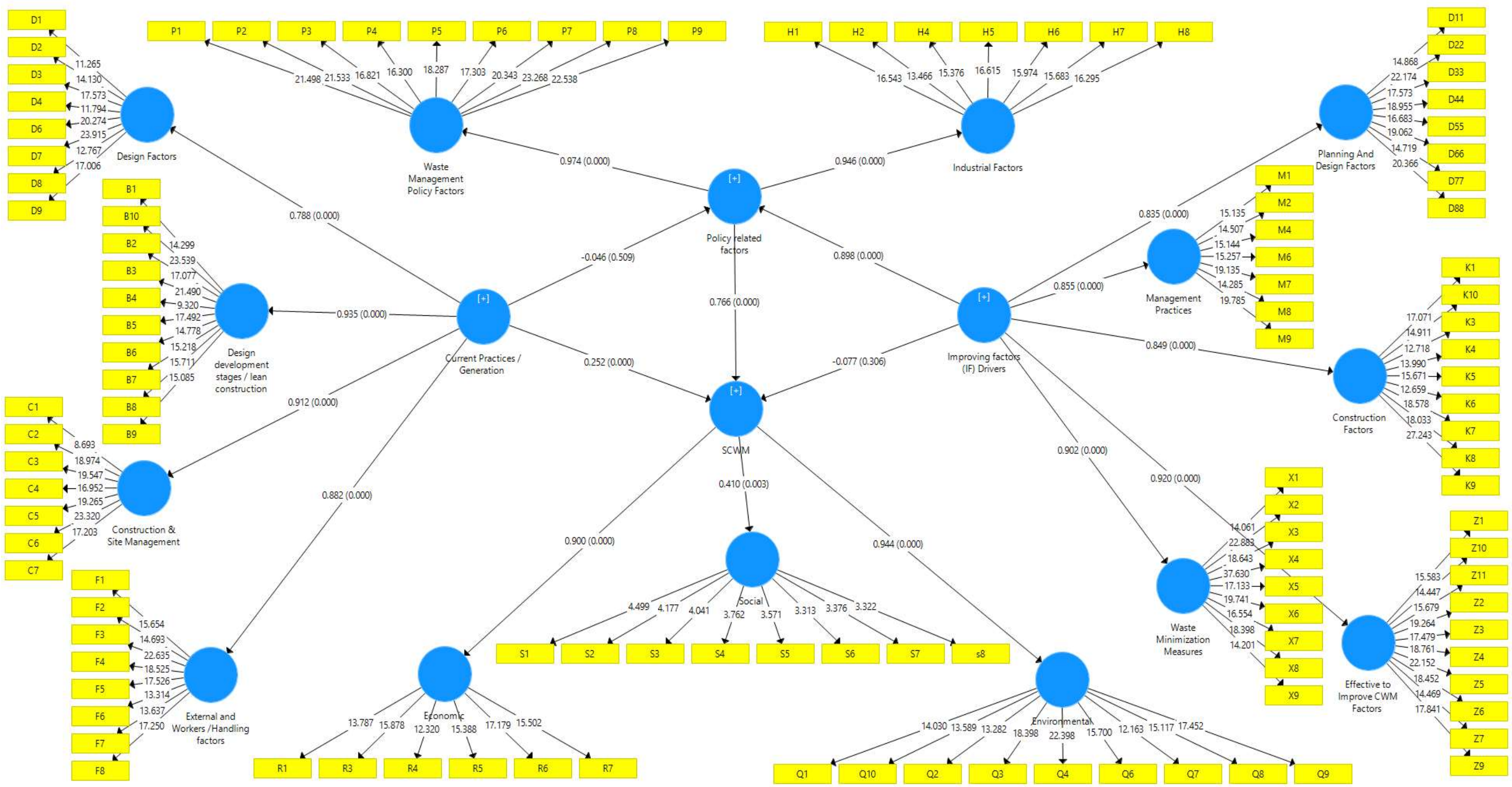

Fig 3: A structural equation modeling the main hypothesis

3.1.10 Coefficient of Determination

Coefficient of determination (R^2) refers to the effect of independent variables on the latent dependent variables, one of the structural model [84]. Hair Jr, et al. [85] suggested that R^2 with 0.19, 0.33, or 0.67 are low, moderate, or high, respectively. Furthermore, the adjusted R^2 values are useful in assessing the quality of various models or comparing the model across different contexts. The results were reported in Table (18), and the variations in the exogenous variables show high variations in the endogens variables[86].

Table 18: R Square and Associated R Square Adjusted

Construct	R Square	R Square Adjusted	Variance Explained
Policy Related Factors	0.741	0.739	High
Sustainable Construction Waste Management	0.787	0.785	High

3.1.10 Effect Size (f^2)

The f^2 effect size measures how many impacts the endogenous construct will have if an exogenous construct was removed from the model. A construct is considered to have a small effect if its f^2 value is between 0.02 and 0.14, while it is considered to have a medium effect if its f^2 value is between 0.15 and 0.34, and a large effect if its f^2 value ≥ 0.35. A construct with an f^2 value < 0.02 means it does not affect the endogenous construct [87]. Table (4.13) presents the f^2 the effect size of the constructs. The results illustrate that Current Practices / Generation does not affect Policy Related Factors and large effect on Sustainable construction waste management. Improving Factors drivers have a large impact on policy-related factors and no effect on Sustainable Construction Waste Management. Finally, Policy Related Factors have a large effect on Sustainable Construction Waste Management.

Table 19: Predictive Relevance

Construct	SSO	SSE	Q^2 (=1-SSE/SSO)
Policy Related Factors	4320	3031.281	0.298
Sustainable Construction Waste Management	6210	4985.28	0.197

3.1.11 Goodness of Fit of the Model

Henseler and Sarstedt [88] Proposed the Goodness of Fit (GoF) as a global fit indicator; it is the geometric mean of both the average R^2 the average variance extracted of the endogenous variables. Where R2 is the structural model. Simultaneously, the AVE (communality) addresses the quality of the measurement models in the index. GoF index is considered small, medium, and large if the values are 0.1, 0.25, and 0.36, respectively[89].The GoF index can be calculated as follow:

$$GOF = \sqrt{\overline{R^2} \times \overline{AVE}} = \sqrt{0.764 \times 0.4319} = 0.574.$$

The criteria of GoF for deciding whether GoF values are; not acceptable (less than 0.1), small (between 0.1 to 0.25), moderate (between 0.25 to 0.36), or high (above 0.36) to be regarded as a globally appropriate PLS model. Therefore, according to these criteria, and the value of the Gof is (0.574), it can be safely concluded that the GoF model is large enough to be considered a sufficient valid global PLS-SEM model. Based on the[90], the model GoF of 0.39 is considered large. Therefore, the research model is fitted very well. The structural model is, therefore, good.

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4. Discussion

4.1 Barriers to implementing effective C&D waste management strategies

The most significant obstacles to implementing effective building waste management solutions in Malaysia's city were discovered to be: There is a lack of attention to waste management in current regulations; there is a lack of attention to designing buildings according to waste management requirements; there is a lack of waste management awareness among contractors; there are no rules that make waste management mandatory, and there are no incentives from regulatory authorities. This finding confirmed that of [91], They discovered that the problems above prevent developing countries from implementing effective building and demolition waste management. Malaysia is no different., as [92] observed that C&D waste management legislations are deficient in Malaysia. Lack of culture in favor of waste management; Lack of support from owners and stakeholders; Lack of attention to waste management from the Community; Lack of economically viable facilities for waste management; and Lack of waste management necessities within the national building codes were found to be the 6th to 10th among the barriers hampering implementation of effective C&D waste management strategies in Malaysia. This finding is in agreement with [13]. The variables are deemed the least obstructive to the Malaysian construction industry's implementation of effective construction and demolition waste management techniques. Low costs of shipping materials to landfills rated them 11th to 15th.

The finding agrees with [93], [94] and [95]. The main barriers to the proper implementation of waste reduction strategy occur when actors in the construction industry are vulnerable to communicating and cooperating. Stakeholders properly do not have a common understanding among themselves regarding 3R CW management strategies due to the similarity of reducing reuse and recycling strategies. Construction actors will take advantage of all aspects of reduction strategy if reduction strategy is included in the C&DW management cycle for waste minimization; therefore, it is vital to pay extra attention to the reduction strategy's execution. Regarding the rapid growth of the CW generation worldwide, it is crucial to consider high priority in reducing strategy in the construction industry [96].

4.2 Impact of improving factors on SCW management

The respondents were asked to measure the effect of BIM design on sustainable construction waste during the building's design and construction using a scale of 1–5 (Very high to very low). The results revealed that Improving factors have a strong relationship with SCW management, since $(r(270) = .723, P < 0.001)$ and R Square of 0.787. Assessment and brief design step specific (CWM). Improvements related to briefing requirements were identified during the evaluation and Brief design stages as presented in the work of Liu, et al. [97].

4.3 Impact on policy-related factors on Sustainable construction waste management

The results indicate that policy-related factors have a significant moderating effect with sustainable construction waste management by constituting The mediation results also suggested a significant indirect positive effect of improving factors drivers on SCW management through policy-related factors since $(\beta = 0.688, t = 8.254, P < 0.001, 95\%\ \text{CI for}\ \beta = [0.536, 0.866])$. Finally, policy-related factors construct has a strong relationship with SCWM) management, since $(r(270) = .811, P < 0.001)$ and the R Square of 0.785. It is well-aligned with the work of Bamgbade, et al. [98], Samari (2012), government funding is the most successful in stimulating green construction, as it is more result-oriented than other techniques that can drive to progress sustainable construction waste management. Also, governments can enhance the adoption of sustainable construction waste management in several ways. The research of Bamgbade, et al. [98] stated that government could drive sustainable construction waste agendas with several policies, including fiscal supports, legislation and standards, and building labeling with energy efficiency rating in the Malaysian construction industry. This process may transform into the waste management system, which comprises reduction, minimization, reuse, recycling, recovery, and construction waste disposal. Many researchers have sported the above result [47, 99-102] - various sustainable waste management steps on government policy-related factors.

5.0 Conclusion

This paper presented the research on prevention approaches using BIM-based design for construction waste management in Malaysian projects. The following conclusions were drawn at the accomplishment of research objectives: The factors that course construction waste generation was identified through extensive literature review and descriptive statistic, Impact of Improving factors on SCW management contain correlation analysis and Impact on policy-related factors on Sustainable construction waste management constitute with PLS-SEM formwork. A questionnaire was developed to obtain the required information for the study from the relevant professionals. Cronbach alpha was calculated to determine the reliability and validity of the instrument. The calculated reliability and validity of the instrument are 0.882,0.815, and 0.889, respectively. SEM was determined to be the most appropriate statistical analysis technique for this study. Based on their findings, the authors stressed that employees must use data when solving quality-related problems. Customer satisfaction ($r = 0.29$) and operational performance ($r = 0.30$) are both statistically significant at the p-value of 0.05. Statistical analysis results indicate a significant effect between Sustainable Construction Waste management, since($r(270) = .687, P < 0.001$). Improving factors has a strong relationship with Sustainable Construction Waste management, since ($r(270) = .723, P < 0.001$). The mediation results also suggested a significant indirect positive effect of improving factors drivers on Sustainable Construction Waste management through policy-related factors since ($\beta = 0.688, t = 8.254, P < 0.001, 95\%$ CI for $\beta = [0.536,0.866]$). Finally, policy-related factors construct has a strong relationship with SCWM) management, since($r(270) = .811, P < 0.001$) With the R Square of 0.787 and 0.785. The results may also be helpful to many construction companies, particularly those in developing countries where there is a lot of construction waste with low awareness. It can assist small and medium construction companies to become extremely sustainable and technologies for practical and sustainable manner. The barriers against the implementation of effective construction and demolition waste management strategies in the study area.

The significant barriers to implementing effective construction waste management strategies in Malaysia metropolis were found to be Lack of attention to waste management in current regulations; Lack of attention to designing buildings according to requirements of waste management; Lack of awareness among contractors about waste management; Stakeholders properly do not have a common understanding among themselves regarding 3R CW management strategies due to the similarity of reducing reuse and recycling strategies.

This paper contributes to the literature to allow academic researchers to replicate similar research using additional variables from different locations and compare the results obtained because the data used in this research may have limited generalizability because it was collected in Malaysia. The results enable project leadership teams to prioritize the workforce, materials, equipment, and time of their construction projects in the planning phase to eliminate the waste generated by the projects, thereby improving efficiency and sustainability. The sustainability approaches proposed in this study can be used as a guideline for any project team to build successful management toolkits for minimizing essential productivity-enhanced SCWmanagement implementation activities. This study has established a basis for improvements in the specifications that could be critical for evaluating and removing waste. Construction waste prevention is significant, leading to avoiding design errors contributing to waste generation. The construction waste is identified chiefly through processes that involve conventional construction.

Author Contributions: For research articles with several authors,

Musa Mohammed: Conceptualization, Investigation, Data curation, Writing -original draft.

Nasir Shafiq: Supervision, Writing- review & editing.

Ali Elmansoury: Writing- review & editing

Noor Amila Abdallah Supervision, Writing- review & editing.

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