DEVELOPMENT OF MATURITY MODEL FOR THE ASSESSMENT OF CONSTRUCTION WASTE MANAGEMENT

(建設廃棄物管理に対する評価における成熟度評価モデルの構築)

BY

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A dissertation submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy in Engineering

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ABSTRACT

The rapid increase in population coupled with industrialization has driven urban development, leading to a surge in construction projects. This recent surge of construction projects has generated substantial construction waste (CW) that negatively impacts social, economic, and environmental aspects. Despite the unstoppable rise of construction projects, effective construction waste management (CWM) is crucial to minimize this waste. Building contractors play a vital role in minimizing CW, as they are directly involved in material handling and usage during construction. However, there is a limited availability of actionable tools for them to implement and improve their CWM. To address this gap, this study aimed to develop a maturity model for assessing construction waste management (CW3M) to assist building contractors in assessing their CWM performance and identifying areas to enhance their capabilities. The objectives of the study include identifying attributes that determine CWM capability, exploring the concept of maturity models for assessing CWM, developing the CW3M model, implementing and validating the model, and drawing conclusions and recommendations for its application. The model was developed using an approach that included a literature review, expert verification, factor analysis, multi-criteria decision analysis, model tool development, model implementation, and model validation.

The process began by identifying attributes through a literature review. This was followed by an expert verification process involving 32 experts, with analysis using item-total correlation and Cronbach's alpha to ensure validity and reliability. A total of 42 attributes were retained after the expert verification. A questionnaire incorporating these attributes was administered to 304 construction professionals in Cambodia and Thailand with experience as building contractors and familiarity with CWM practices. Exploratory Factor Analysis (CFA) was then conducted to group the attributes and name the factors, which was confirmed using Confirmatory Factor Analysis (CFA), resulting in a final 27 attributes across five key factors. These attributes and factors were used for pairwise comparisons with 10 experienced construction professionals through interviews, employing multi-criteria decision analysis using the Best Worst Method (BWM). From BWM, local weights were assigned to all attributes and factors, and then global weight was calculated and normalized, referred to as global standardized weight. These global standardized weights and refined maturity levels were used to develop the CW3M model. The developed model comprised 27 attributes across five key factors: governance and policies (8 attributes), materials and equipment (8 attributes), requirements and specifications (4 attributes), construction information systems (4 attributes), and waste collection facilities (3 attributes). The CW3M model was implemented by experts from 16 building contractors in Cambodia and Thailand. Following implementation, the experts provided feedback as part of the model validation process. With these results, the CW3M model was validated as appropriate, reliable, and suitable for building contractors to assess their current CWM performance and identify areas to enhance their capabilities.

The findings of this research study provide a valuable guide for building contractors to enhance their CWM. The validation of the CW3M from the perspective of building contractors will ensure its industrial relevance and practical applicability. Ultimately, the results suggest that implementing the CW3M model has the potential to support more sustainable construction practices by minimizing CW, which will contribute to sustainable construction, mitigate social, economic, and environmental adverse impacts, and promote sustainable development.

Keywords: Construction waste, Waste management, Reduce, Reuse, Performance measures, Construction project, Sustainable development

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LIST OF ABBREVIATIONS AND SYMBOLS

2R	Reduce and Reuse
3R	Reduce, Reuse, and Recycle
a_B	Best Attribute
a_W	Worst Attribute
ACPE	ASEAN Chartered Professional Engineer
AHP	Analytic Hierarchy Process
AMOS	Analysis of Moment Structures
APEC Engineer	Asia-Pacific Economic Cooperation Engineer
ASEAN	Association of Southeast Asian Nations
AUN/SEED-Net	ASEAN University Network/Southeast Asia Engineering Education Development Network
B.Eng.	Bachelor of Engineering
BIM	Building Information Modeling
BREEAM	Building Research Establishment Environmental Assessment Method
BWAS	Building Waste Assessment Score
BWM	Best Worst Method
C&D	Construction and demolition
CCTV	Closed-circuit Television
CDWM	Construction and Demolition Waste Management
CEM	Construction Engineering and Management
CEP	AUN/SEED-Net Collaborative Education Program
CFA	Confirmatory Factor Analysis
CFI	Comparative-fit Index
CIS	Construction Information Systems
CO_2	Carbon Dioxide
CW	Construction Waste
CW3M	Maturity Model for the Assessment of Construction Waste Management

CWM	Construction Waste Management
D.Eng.	Doctor of Engineering
DF	Degree of Freedom
DfD	Design for Deconstruction
EFA	Exploratory Factor Analysis
GDP	Gross Domestic Product
GIS	Geographic Information System
GP	Governance and Policies
HU	Hokkaido University
IFI	Incremental-fit Index
ISO	International Organization for Standardization
JICA	Japan International Cooperation Agency
LCA	Life Cycle Assessment
LEED	Leadership in Energy and Environmental Design
M.Eng.	Master of Engineering
MCDA	Multiple-criteria Decision Analysis
MCDM	Multi-criteria Decision Making
ME	Materials and Equipment
ML	Maximum Likelihood
MLMUPC	Ministry of Land Management, Urban Planning and Construction, Cambodia
MMs	Maturity Models
NFI	Normed-fit Index
PE	Professional Engineer
Ph.D.	Doctor of Philosophy
PPP	Public-Private Partnerships
P-value	Significance Level
RC	Reinforced Concrete
RS	Requirements and Specifications
SD	Standard Deviation
SDGs	Sustainable Development Goals
SEA	South-East Asia

Sig.	Significant
SIIT	Sirindhorn International Institute of Technology
SPSS	Statistical Package for the Social Sciences
TLI	Tucker-Lewis Index
TU	Thammasat University
UN	United Nations
USD	United States Dollar
USEPA	United States Environmental Protection Agency
WCF	Waste Collection Facilities
χ^2	Chi-square Statistics

CHAPTER 1
INTRODUCTION

1.1 Research background

Urban development has been driven by industrialization and population growth, leading to a surge in construction projects within cities globally (Lee et al., 2024; Li et al., 2024; Ma et al., 2023a). These construction projects are crucial for sustainable development (Ma et al., 2023a). However, this surge in construction projects has resulted in significant social and environmental issues, primarily due to the extensive generation of construction waste (CW) (de Andrade Salgado et al., 2022; Gursel et al., 2023; Lee et al., 2024). As urban development accelerates globally, CW has significantly contributed to solid waste, accounting for approximately 30% of all solid waste produced worldwide (Bao et al., 2023; Lu et al., 2022; Soto-Paz et al., 2023). In 2022, global solid waste generation reached an estimated 2.25 billion tons (Cárdenas-León et al., 2024; World-Bank, 2022). This escalating waste crisis poses severe risks to urban ecosystems, public health, and resource sustainability (Bao et al., 2020b; Mazzoli et al., 2024; Pallewatta et al., 2023; Sadri et al., 2022), making it an urgent need to minimize waste generation in high-impact sectors like building construction (Adhikary et al., 2022; Ibrahim, 2016). Effective CWM is essential for minimizing CW, prioritizing resource efficiency, mitigating social and environmental negative impacts, and fostering sustainable development (He et al., 2021; Hussain et al., 2024; Qi et al., 2024; Yi et al., 2024). Furthermore, effective CWM practices can reduce costs, as inadequate CWM significantly increase project costs through material wastage and associated expenses, often resulting in cost overruns of 21-30% (Babalola et al., 2019; Forghani et al., 2023; Nilupa et al., 2015).

Construction waste generation is substantial in developed and developing countries (Sharma et al., 2022; Wang et al., 2020; Zhang et al., 2022). For instance, Thailand produced approximately 4.2 million tons of CW in 2014 (Thongkamsuk et al., 2017), while Vietnam produced approximately 1.9 million tons in 2011 (Lockrey et al., 2016), and the European Union countries collectively produced approximately 374 million tons of CW in 2016 (Hoang et al., 2021). Landfills, the expected destination for CW, are rapidly reaching capacity, while the improper disposal of hazardous CW threatens ecosystems and human health (Abdulai et al., 2024; Gursel et al., 2023; Ray et al., 2024; Xu et al., 2024). There is a lack of comprehensive approaches to accurately determine material usage, primarily due to insufficient attention and priority given to effective CWM practices (Chen et al., 2024a; Kylili et al., 2017; Sinoh et al., 2023). Contractors contribute significantly to CW generation as they are responsible for onsite material handling and execution processes in the construction phase (Ding et al., 2023; Janani et al., 2022; Li et al., 2022). Many contractors face barriers due to inadequate planning, misinterpretation of design specifications, and poor logistical coordination, all of which contribute to higher CW generation in the construction phase (Janani et al., 2022; Li et al., 2022; Osmani et al., 2008). For example, in Tehran, the building construction phase alone accounts for approximately 36% of the total CW generated across project phases (i.e., design, procurement, and construction) (Nezhaddehghan et al., 2023).

Numerous research studies have aimed to identify factors contributing to CW production and propose recommendations for minimizing CW (Akinade, 2018; Osmani et al., 2008; Wang et al., 2015; Wang et al., 2019). To effectively measure and improve CWM, further steps are needed, including setting criteria and levels of improvement. Assessment techniques are essential to advance waste minimization in construction, with contractors being major stakeholders directly involved in the use of construction materials, and this initiative technique should be designed to encourage a shift towards waste minimization during building construction (Bilal et al., 2016; Xue et al., 2021). Contractors must improve their CWM, which will have the most significant impact (Bilal et al., 2016; Xue et al., 2021).

This study proposes a maturity model for assessing construction waste management (CW3M). This CW3M model is developed for building contractors to enhance CWM practices during the execution of building projects.

1.2 Research gap

Several studies have examined the factors contributing to effective CWM practices and proposed theoretical approaches to minimize CW. For instance, Wang et al. (2010) and Wu et al. (2017) conducted research on the construction phase to implement onsite sorting. Other studies identified influence factors affecting CWM from various construction stakeholders (i.e., clients, designers, contractors, subcontractors, suppliers, construction demolition companies, and CW recycling companies) (Akinade, 2018; Janani et al., 2022; Khanh et al., 2014; Osmani et al., 2008; Poon et al., 2004; Udawatta et al., 2015). Although research efforts have primarily focused on influencing factors and operational strategies, limited studies have concentrated on developing assessment models to help contractors improve their CWM in building construction. Developing and implementing sustainable models can help reduce CW, encourage material circularity, and effectively address environmental issues (Akinade et al., 2018; Kuoribo et al., 2024). Janani et al. (2022) recommended that structured models be developed and employed during construction to minimize CW.

In addition, several other studies have developed models related to construction waste management in various construction phases (i.e., design, construction, renovation, demolition), such as models for waste data collection, waste management plans and guides, waste estimation, and environmental assessment. For instance, the "Webfill system" is for collecting waste data (Chen et al., 2003), "SMARTWaste" is for auditing CW (McGrath, 2001), and the "Building waste assessment score" is for assessing waste in building design (Ekanayake et al., 2004). The "Waste index" is for material control to reduce waste in high-rise buildings (Poon et al., 2004)". Other tools like the "Spanish model (Solís-Guzmán et al., 2009)", "Stock-Flow model (Bergsdal et al., 2007)", "Material Flow Analysis model (Cochran et al., 2010)", "Multiple regression model (Parisi Kern et al., 2015)," "Demolition and Renovation Waste Estimation (Jack C.P. et al., 2013)," "DeconRCM (Banias et al., 2011)," and "Web-based Construction Waste Estimation System (Li et al., 2013)" are for estimating waste in various countries, including Spain, Norway, the USA, Brazil, Hong Kong, and Greece. Meanwhile, the "BREEAM New Construction Standards (BREEM, 2024)," "LEED for Homes (USGBC, 2005)," "LCA (Hoxha et al., 2017)," "GBEL (Lu et al., 2019)," are for promoting sustainable design and construction practices. These models have addressed various aspects of CWM across multiple construction phases. Still, there is a lack of frameworks specifically designed to support building contractors, who play a crucial role in reducing CW through effective CWM during the construction phase. Consequently, there is an urgent need for actionable tools to help building contractors implement and enhance their CWM practices to minimize CW for sustainable construction and contribute to sustainable development.

The maturity model offers a structured approach to support incremental progress for contractors in CWM practices. The maturity model addresses various practices for each process, guiding the increment progress from one stage to the next (Humphrey, 1988; Paulk et al., 1991). Some studies have adapted the maturity model to the construction industry. For instance, Htoo et al. (2023), Liao et al. (2023), and Pennypacker et al. (2002) developed maturity models for assessing project management and organizational performance. Mohamed (2011) and Asah-Kissiedu et al. (2021a) developed maturity models for construction safety management. Chen et al. (2024b), Chen et al. (2023), and Liang et al. (2016) developed maturity models to assess building information modelling (BIM). Suprun et al. (2024), Perera et al. (2023), and Wernicke et al. (2023) developed maturity models to assess digital technologies in construction management. However, threre is limited research on the development of maturity models specifically focused on CWM for contractors in the building construction phase. There is a pressing need to develop practical, actionable, assessment-based approaches that enable contractors to effectively measure and enhance their CWM efforts. With their crucial role in CWM, contractors can align their organizational practices with industry sustainability goals to reduce costs, boost productivity, and mitigate environmental impacts (Hasik et al., 2019; Hossain et al., 2018; Park et al., 2017; Xue et al., 2021).

To address this gaps, this study developed a novel maturity model to assist contractors in assessing their construction waste management performance and identify areas to enhance their capabilities (CW3M) based on the 2R strategy (reduce and reuse). While previous studies have commonly emphasized the 3R strategy (Reduce, Reuse and Recycle) (Huang et al., 2018; Kabirifar et al., 2020b; Ma et al., 2023b; Victar et al., 2024), this study focused on the 2R strategy, which is entirely within contractors' control during construction. Recognizing that the recycling component often lies beyond the contractors’ direct influence (Bao et al., 2020a; Caro et al., 2024; Peng et al., 2021), this study proposed a more feasible strategy that contractors can implement and improve CWM onsite.

1.3 Problem statement

Waste minimization through effective CWM is essential (Lu et al., 2022; Marzouk et al., 2014). Construction waste (CW) has been produced in significant amounts as a result of construction activities due to the recent acceleration of urbanization and rapid development of the construction industry (Osmani et al., 2008; Yuan et al., 2011a). Construction waste is having an impact on the economics of all nations globally (Wang et al., 2015). Construction waste significantly impact economic, social, and environmental sustainability (Ma et al., 2020; Tang et al., 2020; Yang et al., 2021). This waste fills up a lot of landfill space and significantly influences people's lives. It also contains dangerous elements that endanger the environment and people's health (Huang et al., 2011). For instance, China produces over 200 million tons of municipal waste each year, of which about 40% (or 100 million tons) is generated by construction of new buildings (Huang et al., 2011). Therefore, minimizing CW is the most sensible course of action (Lu et al., 2022; Wang et al., 2014a; Yuan et al., 2011b).

Minimizing CW is considered an ad hoc activity (Osmani et al., 2008). How to effectively minimize CW has become a pressing and challenging issue on a global scale (Hao et al., 2019) due to the urgent need to address the issue of construction waste generation. However, limited research has been conducted to evaluate CWM during the construction phase, making it challenging to determine CWM's overall performance (Ding et al., 2018; Singh et al., 2023). Contractors are essential to managing construction waste because they work closely with all construction materials on the project site (Ding et al., 2023; Li et al., 2022). The contractors’ inadequate site planning, incorrect interpretation of the design drawings and specifications, and onsite logistical and operational resulted in the production of CW (Li et al., 2022; Osmani et al., 2008).

Therefore, there is a need to develop a maturity model for assessing construction waste management (CW3M) that contractors can use. It will help contractors enhance their CWM and minimize CW throughout construction processes.

1.4 Research aim

Given the lack of research regarding the assessment tools to improve construction waste management (CWM) in the construction phase, this research aimed to develop and validate the maturity model for assessing construction waste management (CW3M) that contractors can use.

1.5 Research questions

This research study would address the following questions in light of the research aim:

- **Question 1:** What attributes are appropriate for developing a maturity model to assess construction waste management?
- **Question 2:** How important are those attributes that can be used to develop a maturity level of construction waste management?
- **Question 3:** Can this maturity model be used for construction waste management?

1.6 Research objectives

Five research objectives are outlined for developing the maturity model for assessing construction waste management that contractors can use to improve CWM and minimise CW at the company level to fill the research gaps, address the research aim, and address research questions. This study's originality is its ability to improve the effectiveness of the contractors' CWM performance for the construction phase. The following are the objectives of this research study:

- **Objective 1:** To identify the key attributes that determine construction waste management capabilities of contractors in the building construction phase
- **Objective 2:** To explore the concept of maturity models and their application for assessing the construction waste management practices of contractors in the building construction phase
- **Objective 3:** To develop the maturity model for the assessment of construction waste management (CW3M) of contractors in the building construction phase
- **Objective 4:** To test and validate the CW3M model in terms of its applicability and relevance to industrial practices among contractors in the building construction phase
- **Objective 5:** To conclude and recommend the use of the CW3M model for assessing and improving contractors' construction waste management practices in the building construction phase.

1.7 Research scope

This research was conducted on construction waste management for building contractors by covering three aspects: economic, environmental, and social. The experts for the survey, expert interviews, testing and validation were mainly from building contractors practising in Cambodia and Thailand. This study was scoped within the building construction phase, as highlighted in **Figure 1.1.**

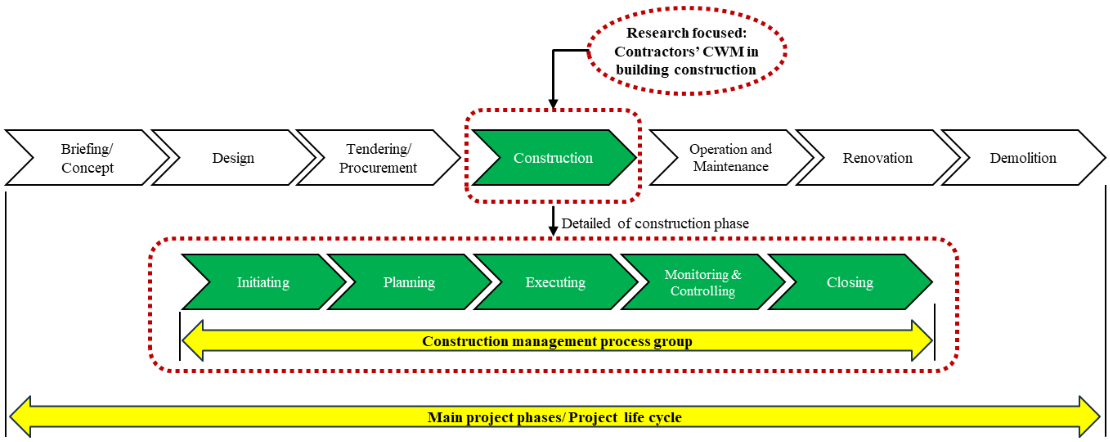


Figure 1.1 Project life cycle

(Adapted from Wang et al. (2023), PMI (2017) and Vilches et al. (2017))

1.8 Research significance

This study will contribute to the body of knowledge and practical insight on the improvement of construction waste management by evaluating the capacity of the current performance of the contractor and targeting the next level of improvement, which could help to minimize the amount of CW that will benefit for cost saving, reducing the negative impact on the environment, socially acceptable, and applicable for practical implementing by contractors. This CW3M model is a practicable and actionable assessment tool for improving CWM. This would meet the contractors' requirements to enhance their company's capacity in CWM.

This research study presents the novelty in the following terms:

- Addressing an urgent industry need: This study identified a significant gap in construction waste management (CWM) practices among building contractors and emphasizes the pressing need for actionable assessment tools. Building contractors are critical players in minimizing CW in building construction for urban development, given their direct involvement in material handling and usage during the construction phase.
- Developing a new maturity model to assist building contractors in assessing their CWM performance and identifying areas to enhance their capabilities (CW3M). The model provides a structured and incremental approach to enhance contractors' CWM capabilities through five maturity levels. It comprised 27 attributes across five key factors, and the model offers contractors a detailed, actionable roadmap for improving their CWM practices to minimize CW for sustainable construction, thereby contributing to sustainable development.
- Establishing performance assessment benchmarks for building contractors: The results of model implementation from building contractors in Cambodia and Thailand, serve as benchmarks for assessing and enhancing contractors' CWM performance. These benchmarks offer valuable insights for building contractors from countries with similar economic development who aim to evaluate and improve their CWM practices in building construction.

The findings indicate that implementing the CW3M model has the potential to support more sustainable construction practices by minimizing CW and improving resource efficiency. This can help mitigate the adverse social, economic, and environmental impacts, thereby fostering sustainable development. Furthermore, the model aligns with the United Nations' Sustainable Development Goals, particularly Goals 8, 9, and 11.

1.9 Research limitation

The CW3M model was developed specifically for contractors to assess their current CWM practices and guide future improvement. It is not intended for use by other construction stakeholders. The model development and validation process were based on input from experts of different contractors in Cambodia and Thailand. While this model aimed to benefit both developed and developing countries, as it is the first to assess CWM for contractors, future research may need further improvements to maximize its usefulness, such as implementing and validating the model in developed countries. Future research could also focus on developing other maturity models for assessment by different stakeholders, such as project owners, designers, consultants, subcontractors, and suppliers, individually or in combination. Additionally, the rapid growth in digital technology and industrialization of the construction sector may lead to new attributes and factors influencing contractors’ CWM performance, necessitating updates to the model to capture these evolving requirements. Future research should also consider developing similar maturity models for assessment across all project phases.

1.10 Chapters outline

This dissertation consists of 11 chapters as follows:

- CHAPTER 1-Introduction: This chapter presents the research background, research gap, problem statement, research aim, research questions, research objectives, research scope, research significance, research limitations, and an outline of the chapters.

- CHAPTER 2-Literature review: This chapter presents an extensive literature review. It covers the introduction of the literature review, the definition of important terms, the significance of construction waste management, CWM during the construction phase, factors contributing to CW generation, stakeholders involved in CWM, CWM practices in different geographical areas, CWM in the context of sustainable development goals, existing assessment models, attributes or factors enabling effective CWM, and the mapping of CWM using the CW3M model.
- CHAPTER 3-Research methodology: This chapter outlines the research methodology, including an introduction to the approach, research design, quantitative and qualitative methods, and the mixed methods used in this study. It describes the data collection methods, sample sizes, and data analysis techniques employed.
- CHAPTER 4-Attributes identification and verification: This chapter focuses on identifying and verifying the relevant attributes as a preliminary study. It includes the process of attribute identification, frequency analysis, expert verification, and the conclusions drawn from this preliminary work.
- CHAPTER 5-Descriptive analysis: This chapter presents a descriptive analysis, including the questionnaire survey and respondent profiles, data screening, preliminary findings, and consistency tests among sample groups.
- CHAPTER 6-Exploratory and Confirmatory Factor Analyses: This chapter covers reliability tests, Exploratory Factor Analysis, and Confirmatory Factor Analysis, providing a detailed examination of these statistical techniques.
- CHAPTER 7-Best Worst Method for weighing attributes: This chapter offers a detailed explanation of the Best Worst Method, including an introduction, demographic information of the experts involved, the results of pairwise comparisons, a discussion, and the conclusion of this chapter.
- CHAPTER 8-Maturity model for the assessment of construction waste management (CW3M): This chapter provides a detailed explanation of the development of the CW3M model, including the definition of each attribute, the demographic profiles

of the experts involved, and the processes used in the development of the CW3M maturity model.

- CHAPTER 9- CW3M model implementation and validation: This chapter explains the CW3M maturity model's implementation and validation processes.
- CHAPTER 10-Discussion: This chapter discusses the findings from the development, implementation, and validation of the CW3M maturity model.
- CHAPTER 11-Conclusion and recommendations: This chapter presents the study's overall conclusions and offers recommendations on the use and benefits of the developed CW3M model for both practical and academic applications to minimize construction waste in building construction.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter provides an overview of the literature review conducted for the research study, focusing on improving construction waste management (CWM). There is a lack of studies on developing a maturity model to assess CWM, typically for building contractors for the construction phase. However, several related research publications could support the development of a maturity model for CWM, including identified attributes or factors for CWM improvement, maturity models adapted for construction industries, and other assessment models for building projects. Attributes for developing a maturity model for assessing CWM were identified from the literature review.

This chapter begins with an overview of the key term definitions in Section 2.2. Subsequently, Section 2.3 discusses CWM and its significance, followed by Section 2.4, which outlines the role of CWM during construction. Next, Section 2.5 highlights CW generation, examining its sources and impacts. Section 2.6 identifies the CWM stakeholders, emphasizing their roles and responsibilities. Additionally, Section 2.7 explores CWM practices and challenges across various regions. Furthermore, Section 0 focuses on how CWM aligns with Sustainable Development Goals, underscoring its global relevance. Subsequently, Section 2.9 critically reviews existing CWM assessment models, identifying key gaps and opportunities. This leads to Section 2.10, which examines the attributes and factors contributing to effective CWM, synthesizing insights from prior studies. Finally, Section 2.11 concludes the chapter by mapping CWM using the proposed CW3M model, offering a CWM assessment and improvement process.

2.2 Definition

Defining the critical terms when considering the research in construction waste management (CWM) is essential. The critical terms are defined as below:

- Construction waste: Any building materials which arise from construction activities, encompassing but not limited to concrete, mortar, steel, fragmented bricks, timber, aluminium, glass, tile, plasterboard, paper, plastics, and other related materials (Akinade, 2018; Arif et al., 2012; Bi et al., 2022; Lu et al., 2022; Yuan et al., 2022).
- Construction waste management (CWM): It is the application of knowledge, skills, tools and techniques to construction activities to minimize construction waste (Brioso, 2015; Kolaventi et al., 2020; Sasitharan Nagapan et al., 2012).
- Construction waste management assessment: It is the systematic collection, review, and use of information to evaluate the quality or ability of CWM undertaken for its improvement or development (College, 2022; Marzouk et al., 2014).
- Waste management system: It is the process of monitoring the generation, collection, storage, transportation, processing, recovery, and disposal of solid waste to keep the environment clean (Hoklis, 2014).
- Better CWM: The degree of achievement in meeting objectives during the execution of CWM; these objectives primarily revolve around well-managed and minimized construction waste (CW) within the construction project (Yuan, 2013b).

2.3 Construction waste management and its significance

Over the past decade, researchers have increasingly focused on CW issues, publishing numerous studies in various journals. This attention highlights the growing concern about CW within the academic community. However, authorities and many professional stakeholders are not sufficiently engaged with these issues (Umar et al., 2016). Construction waste is recognized as a significant challenge facing the construction sector (Ding et al., 2018; Park et al., 2017). The effective CMM is crucial for the economic development of the construction industry (H et al., 2022). Previous research on CWM has primarily concentrated on various aspects, including waste reduction, reuse, recycling, and response (Chinda, 2013; Yuan, 2012). Strategies for minimizing waste impact can be categorized into five levels of environmental effects: Reduce, Reuse, Recycle, recovery, and disposal (Park et al., 2017; Singh et al., 2021; Yuan et al., 2022). Coordinating these strategies during the design, construction, renovation, and demolition processes is fundamental and represents a basic principle of WM. Waste reduction is typically prioritised among these strategies due to its vital role in preventing CW generation (Baldwin et al., 2009; Hao et al., 2019). Reduction is considered one of the most effective methods, not only minimizing waste generation and addressing environmental concerns but also reducing construction material costs, waste sorting costs, transportation costs, and disposal costs (Lu et al., 2011; Park et al., 2017; Yuan, 2012; Yuan et al., 2022). However, generating some CW is unavoidable, and reuse strategies provide practical methods to minimize the amount of CW (Park et al., 2017). The principles of reduction and reuse govern CWM (Yuan et al., 2011d).

The significance of CWM lies in its ability to minimize CW onsite, leading to cost savings and reduced environmental and social impact (Janani et al., 2022; Yuan, 2012). The CW minimization can result in various benefits, including reduced waste transportation costs and CO_2 emissions, increased environmental awareness, improved company image, cost savings, profit maximization, reduced demand for landfill space, and legislative compliance(Janani et al., 2022). Disposing of CW in landfills contributes to the depletion of land resources, and illegally dumped waste poses severe threats to soil, water, and air, endangering the environment (Hao et al., 2019).

Given the annual increase in building construction activities, CW's environmental and economic impacts cannot be ignored (Akinade, 2018). Addressing the challenges of CW requires a strategic approach to planning and construction, focusing on waste reduction and the reuse of building materials (Akinade, 2018; Singh et al., 2021). Ghaffar et al. (2020) found that using recycled products with a shorter lifetime may not necessarily be better for the environment than using raw materials. Remanufacturing products still incur environmental costs regarding energy consumption, material use, and greenhouse gas emissions. **Figure 2.1** illustrates the main priority of CWM strategies, emphasizing the 2R strategy (Reduce and Reuse).

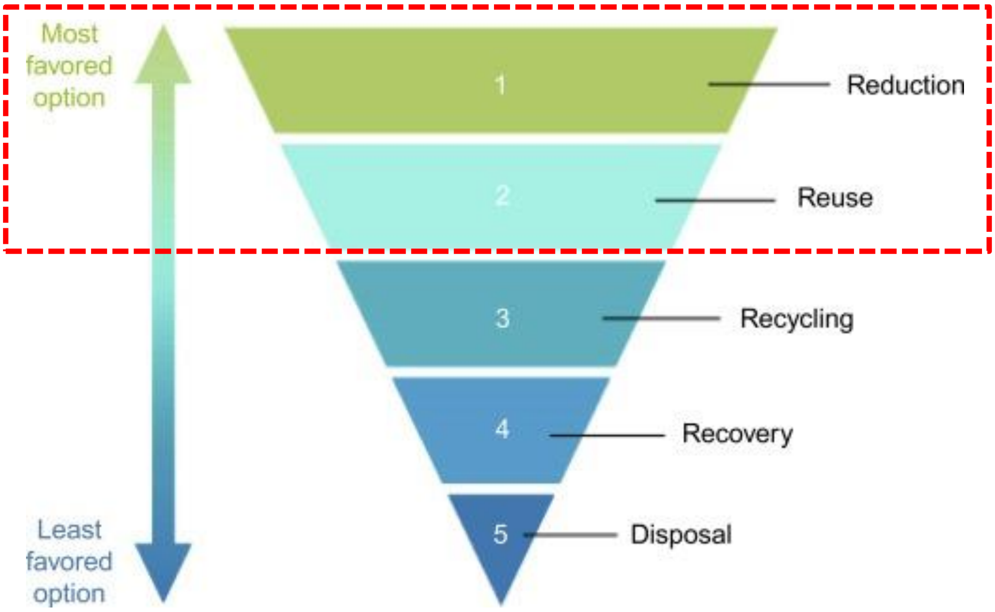


Figure 2.1 Main priority of CWM or CWM hierarchy (2R)

Source(s): (Singh et al., 2021)

Minimizing CW has the potential to yield significant economic, social, and environmental benefits, including a reduction in the demand for landfills, lower CO_2 emissions, conservation of embodied energy, preservation of the natural environment, and decreased project costs (Akinade, 2018; Poon et al., 2003; Porter et al., 2022). Researchers have emphasized that highly effective CWM contributes to the smooth execution of construction activities while mitigating adverse effects on the natural environment (Poon et al., 2013; Villoria Saez et al., 2013). This approach aligns with the two sustainability pillars in construction: reducing resource utilization and eliminating environmental pollution (Yuan et al., 2011c). Given the rapidly increasing amount of CW (Yuan et al., 2022), initiating CWM through waste assessment emerges as a potent strategy for waste reduction due to its evident environmental and socioeconomic benefits. **Figure 2.2** below illustrates the initiation of effective CWM at the site, offering economic, social, and environmental value.

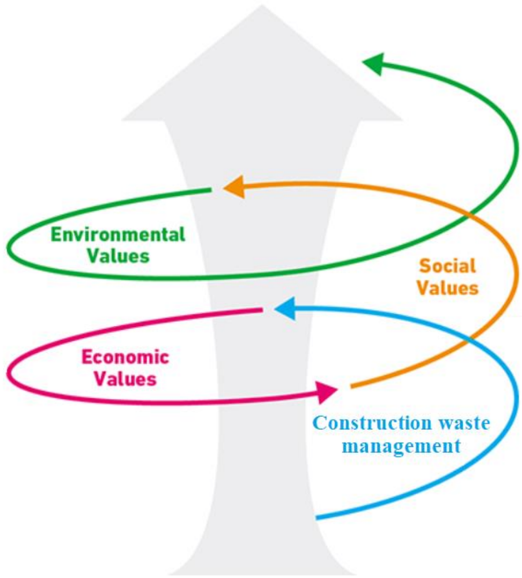


Figure 2.2 The value of construction waste management

Source(s): (Nichiro, 2022)

2.4 Construction waste minimization in the construction phase

Regrettably, limited comprehensive research exists to explore solutions for CWM during the construction phase (Nilupa et al., 2015). Numerous CWM strategies have been advocated to establish a more closed loop for materials and building components (Akinade, 2018). Some research has been conducted during the design phase (Wang et al., 2019) since it is considered a solution for waste minimization. A well-thought-out design that anticipates every detail of the entire construction project is efficient in preventing unnecessary material waste (Wang et al., 2015). However, most studies have predominantly focused on recycling CW, neglecting the importance of waste reduction and reuse strategies and measures in the construction phase (Hao et al., 2019).

Previous investigations have identified factors affecting CW in various WM stages, including waste generation, onsite reduction, and waste disposal, which inevitably influence the effectiveness of the implemented management strategies (Hao et al., 2019; Wang et al., 2019). In the construction phase, several studies have pinpointed critical influencing factors contributing to problems in CWM and subsequently recommended improvements in these factors for better CWM (Hao et al., 2019; Wang et al., 2015).

To mitigate the undesirable effects of waste disposal, there is a need for an overall change in strategy towards reduction in the total project cost (Oyedele, 2013). According to Janani et al. (2022), in the pursuit of minimizing CW during the construction phase, contractors need to plan for the most cost-effective approach, and the following recommendations have been proposed:

- Ensuring adequate supervision and controlled use of materials by experts for site development, along with employing skilled machinists.
- Storing standard substances in repositories and charging maintenance amounts.
- Receiving product details and usage instructions from product providers and skilled agents.
- Using sufficient materials during production and avoiding the purchase of excessive substances.
- Providing continuous guidance to field workers, despite potential extra expenses, plays a crucial role in effective performance.
- Maintaining various drums and repositories to segregate different types of waste.
- Selecting skilled and talented staff members to facilitate the smooth execution of work and enhance understanding of waste reduction on the site.
- Compiling a register detailing waste, including substances purchased and the original amounts used.

2.5 Construction waste and its generation

In response to urbanization and economic growth, there has been a significant surge in development projects, leading to a proportional increase in the generation of CW (Janani et al., 2022; Scherbakov et al., 2023). Construction waste emerges during various construction activities, including building construction, renovation, and demolition of buildings. Construction practices involve diverse procedures and the utilization of substantial quantities of essential materials, raising environmental concerns regarding the impact of construction activities on the environment (Janani et al., 2022). In the construction of buildings, waste primarily comprises nonbiodegradable materials such as cement, ceramic, steel, broken bricks, etc. These materials contribute to substantial waste volumes, occupying significant space on construction sites, pathways, or open areas, often ending up in public containers, scrap yards, and municipal waste facilities. Unfortunately, this waste is usually not recycled, as it is considered non-combustible and challenging to treat through methods like power retrieval and incineration (Janani et al., 2022).

Despite the growing challenges in managing CW, efforts to address these challenges have primarily focused on substance separation, enhanced profitability, reduced transportation costs, and minimizing environmental impacts. The primary emphasis is reducing decomposable materials, such as cement, ceramic, plaster, steel, and broken bricks. To conserve natural resources, there is a need to underscore the importance of reducing and reusing these materials preserving essential building components for future use in other critical tasks (Dahlbo et al., 2015). According to Dahlbo et al. (2015), the most identified waste-producing components in building construction work are (1) Formwork, (2) Packaging and protection, (3) Finish work, (4) Masonry work, (5) Scaffolding, (6) Concrete work, (7) Material handling, and (8) Hoarding.

2.5.1 Common types of materials in construction waste in building projects

There is a perspective that the primary generation of waste occurs during site execution (Osmani et al., 2008). Excessive material wastage, inadequate management at the construction site, and insufficient focus on waste minimization are observed issues in construction site practices (Janani et al., 2022). The primary causes of waste include mishandling, improper storage, rework, lack of recycling, and excessive ordering (Janani et al., 2022). According to Poon et al. (2004), the following are common causes of waste in specific construction materials and activities:

Timber Formwork: Timber is a commonly used construction material due to its affordability, lightweight, high load-bearing capacity, and pliability. However, its relatively low durability and reusability contribute to high wastage. Most timber waste arises from formwork, with a significant amount discarded after several reuses.

Building contractors often need to use a new set of timber formwork after a certain number of floor cycles, as the building design dictates.

Wet Trades: Wet trades encompass brick/block walling, plastering, floor screeds, and internal and external finishings. These activities, which involve forming internal walls, fixtures, and decorative finishes, cause waste at various stages of construction. Brick/block wastage may occur during transportation, loading, unloading, and layering due to damage during handling, over-stacking, and overordering. Plastering waste is generated through excessive mixing, leftover mixed plaster, loss during application, poor storage, and off-cuts. Tiles are lost during cutting, transportation, loading, and unloading, with breakage due to improper storage practices.

Concrete Work: Concrete work, a fundamental construction process, involves a significant portion of ready-mixed concrete. On average, 3 to 5% of the material is wasted due to excessive material ordering, broken formwork, and the need for rework resulting from poor concrete placement quality.

Lu et al. (2022) and Villoria Sáez et al. (2015) have categorized common construction waste materials in building projects, as illustrated in **Table 2.1**.

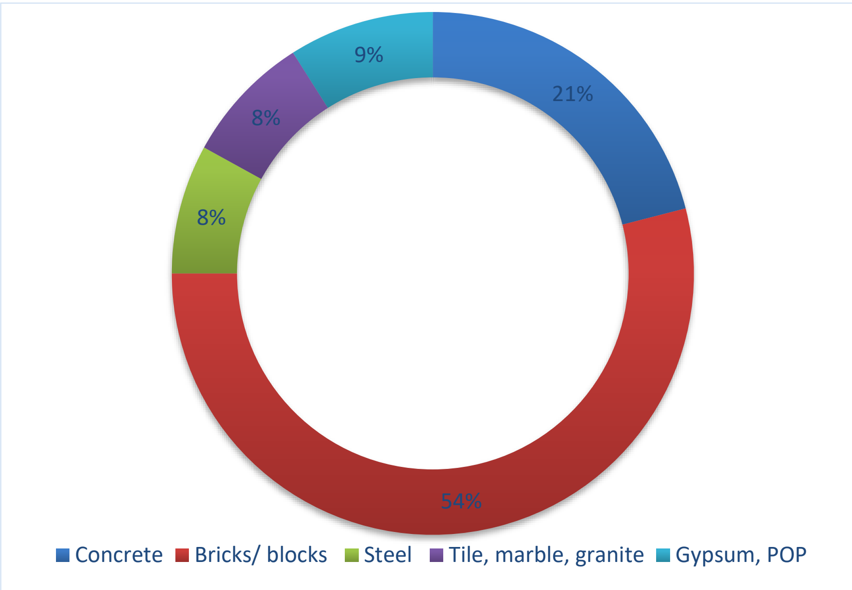
Table 2.1 CW materials and related objects in the construction project

No.	Type of materials	Description of material
1.	Rock/ stone/ rubble/ debris	Stone, concrete slabs, rocks, rubble, and debris. It tends to be large and bulky.
2.	Concrete/ brick/ aggregates	Concrete, bricks, gravel, crushed stone, sand. It tends to be medium sized.
3.	Packing/ fabric/ plastic	All types of bags (plastic, fiber, etc.).
4.	Wood/ cardboard	Furniture made of wood, wood board, boxes made of paper or cardboard.
5.	Other non-inert	Other non-inert waste for example chairs, appliances, and ladder etc.
6.	Mixed	A mixture of inert and non-inert waste that is difficult to distinguish.

Source(s): (Lu et al., 2022; Villoria Sáez et al., 2015)

2.5.2 Proportion of construction waste in building project

Construction activities exhibit a close correlation with the volume of generated waste. Timber formwork is the primary contributor to CW, constituting 30% of the total waste identified on these sites. Wet trades, encompassing finishing work like screeding, plastering, and tile laying, collectively represent the second-largest waste generator, contributing to 20% of the total waste. Concrete work and masonry work follow closely as the third and fourth major contributors, each accounting for 13%. Material handling ranks fifth, contributing to 10% of the identified waste. This analysis provides valuable insights into the specific site activities that require focused attention to reduce building waste effectively (Poon et al., 2004). CW generation on building projects highlights that bricks and blocks constitute the primary waste category onsite, contributing to 54%. Concrete waste ranks second at 21%, followed by steel at 8%. Tiles, marble, granite, and steel contribute 8%, while gypsum, pop, and paints represent 9% of the overall construction waste (Janani et al., 2022). The proportional contribution of construction waste from project sites is illustrated in **Figure 2.3**.



Noted: POP: Paster of Paris

Figure 2.3 Contribution of construction waste at site

(Adapted from Janani et al. (2022))

According to Poon et al. (2004), in a Hong Kong-based research study, the percentage wastage for various trades in public housing and private residential buildings, and the main wastage were formworks (timber) followed by tiles and concrete works. The details are presented in **Table 2.2**.

Table 2.2 Percentage wastage of residential buildings

Trade	Material	Percentage wastage	
		Public housing (%)	Private residential (%)
Concrete	Concrete	3–5	4–5
Formwork	Timber broad	(large panel formwork and precast element was adopted)	100
Reinforcement	Steel bars	3–5	1–8
Masonry	Brick and block	3	4–8
Dry wall	Fine aggregate	3	–
Wall screeding	Ready-mix cement	7	4–20
Floor screeding	Ready-mix cement	1	4–20
Wall plastering	Plaster	3	4–20
Ceiling plastering	Plaster	3	4–20
Wall tiling	Tiles	8	4–10
Floor tiling	Tiles	6	4–10
Installation of bathroom fitting	Sanitary fitting	6	1–5
Installation of kitchen joinery	Kitchen joinery	1%	1–5

Source(s): (Poon et al., 2004)

2.5.3 Causing of construction waste in building project

Various factors generate substantial waste on construction sites, significantly escalating project costs. These factors, as outlined by Janani et al. (2022), are shown below:

- Changes and Design Revisions: This factor involves alterations and revisions in the design, which can lead to increased waste generation on site.
- Reworks Contrary to Specifications: Rework due to labor mistakes or deviations from specified requirements contributes to the creation of additional waste.
- Poor Schedule in Materials Procurement: Inefficient scheduling of materials procurement can lead to delays, affecting the overall construction process and increasing waste.

- Ordering Substances Not Meeting Task Needs: The procurement of materials that do not align with project requirements results in wastage and increased project costs.
- Excessive Quantities of Materials: Consuming more quantities of materials than necessary contributes to unnecessary waste generation and cost escalation.
- Unnecessary Inventories at Site: Maintaining unnecessary inventories onsite leads to increased waste, as materials may become obsolete or damaged over time.
- Lack of Onsite Materials Control: Inadequate control over materials onsite is identified as a significant factor contributing to increased waste generation.
- Inadequate Stacking and Insufficient Storage: Improper stacking and insufficient storage facilities can damage or deteriorate materials, leading to increased waste.
- Inappropriate Storage Leading to Damage: Storage practices that do not align with the characteristics of materials can lead to damage and increased waste.
- Lack of CWM Plan: The absence of a comprehensive waste management plan contributes to uncontrolled waste generation on construction sites.
- Inadequate Supervision: Lack of adequate supervision is highlighted as a crucial factor influencing waste generation onsite.
- Change Orders: Changes in project orders contribute to increased waste and can impact the project timeline and costs.

2.5.4 Technologies in construction waste generation

The need for effective CWM has become increasingly critical in an era of shrinking natural resources, scarcity, and the escalating challenges associated with increasing CW (Bakshan et al., 2017; Yang et al., 2021). To enhance the efficiency of CWM, the construction industry has embraced various informatization technologies, including Geographic Information System (GIS), sensor technology, Internet of Things (IoT), and computer vision (Chen et al., 2021; You et al., 2019; You et al., 2020). With the rapid advancement of hardware and software, such as Building Information Modelling (BIM), embedded devices, and various sensors, the construction sector has entered the era of big data for the digitization of construction waste handling processes (Bilal et al., 2016; Xue et al., 2021). The BIM-based approach facilitates the seamless integration of the CW process into construction management practices, leading to the reduction and reuse of construction materials (Akinade, 2018). More holistic approaches that leverage digital technology have the potential to minimize CW, diminish the environmental impact, preserve resources, and create new opportunities for circular business models and global marketing (Ratnasabapathy et al., 2019). The transformation of industry logic must be incorporated into strategic decisions to maintain competitiveness in the future (Paulus-Rohmer et al., 2016). The construction industry faces significant challenges in adopting digital technologies (Mariana, 2019). Technologies are the tools that will help all construction teams contribute to project decisions and the project's success (Akinade et al., 2017; Spoann, 2019).

2.6 Stakeholders in construction waste management

2.6.1 Concerned stakeholders in construction waste management

In a broad context, a stakeholder is defined as "any identifiable group or individual who can affect the achievement of an organization's objectives or who is affected by the achievement of the organization's objectives." In a more specific sense, stakeholders are those groups or individuals crucial for an organization's ongoing viability (Lu et al., 2015). Various stakeholder types, such as primary stakeholders who are directly affected by an organization's actions and secondary stakeholders who serve as intermediaries indirectly impacted by organizational activities. Applying these types to CWM, stakeholders include: (1) Project owners or clients, (2) Designers (e.g., architects and engineers), (3) Consultants, (4) Main contractors, (5) Sub-contractors and material vendors, (6) Construction waste recyclers, (7) Regulators, (8) Environmentalists, and (9) The general public (Lu et al., 2015; Park et al., 2017). Despite this range of stakeholders, CWM research has predominantly concentrated on contractors as frontline stakeholders, with clients expected to play a pivotal role since they bear the ultimate cost of the generated CW (Lu et al., 2015; Wang et al., 2014b). Contractors play a crucial role in developing and implementing effective materials control and handling strategies. This includes initiatives to educate workers on waste minimization practices and maintaining open communication with suppliers. Additionally, site workers need to be sensitized to the environmental repercussions of waste and the intrinsic value of the materials they handle. This collaborative and informed approach across all stakeholders contributes to the reduction of wastage throughout the construction lifecycle (Poon et al., 2004).

2.6.2 Contractors in construction waste management

Several constraints generation of waste in construction, including contractors' lack of interest and attitudes toward waste minimization, along with a lack of training in CWM, are the challenges to proactive and sustainable waste reduction efforts reduction (Osmani et al., 2008; Wang et al., 2019). Regulations aimed at fostering a minimization-oriented attitude among construction stakeholders have been suggested as a means to reduce CW (Wang et al., 2019). The enhancement of attitudinal approaches is deemed necessary to minimize waste generation in construction projects (Nilupa et al., 2015).

Research on the attitudes and behaviour of construction stakeholders towards CWM has revealed noteworthy findings. For instance, managerial staff in a large Australian contractor exhibited a less positive perception of the WM climate than site workers, prioritizing cost, time, and quality objectives over potential environmental concerns (Wu et al., 2017). In Malaysia, Begum et al. (2009) explored the factors influencing contractors' attitudes and behaviours regarding WM, concluding that a positive attitude contributes to satisfactory WM behaviour. The absence of a regulatory framework in Malaysia led local contractors to base their WM behaviour primarily on direct economic considerations (Begum et al., 2009; Wu et al., 2017). In Europe, studies investigated factors influencing CWM behaviour. Calvo et al. (2014) tested the impact of governmental policies, such as economic incentives and penalties, on recycling CW aggregates in Spain. Wu et al. (2017) underscore the significance of contractors' attitudes and behaviour in CW minimization efforts.

Therefore, contractors play a crucial role in CW, and their attitudes and behaviour toward CWM significantly impact waste minimization initiatives.

2.7 Construction waste management in various geographical areas

2.7.1 Construction waste management in Southeast Asia

The trend of urbanization in ASEAN has played a significant role in the notable increase in urban development, leading to a continuous rise in the generation of CW (Wu et al., 2016). Construction waste is identified as an “emerging waste stream” in this region (Hoang et al., 2019). The construction industry is increasingly contributing to the economies of Southeast Asian (SEA) countries, accounting for approximately 5% of their total value added (Hoang et al., 2019). **Figure 2.4** illustrates the construction industry’s contribution to the total value added in SEA.

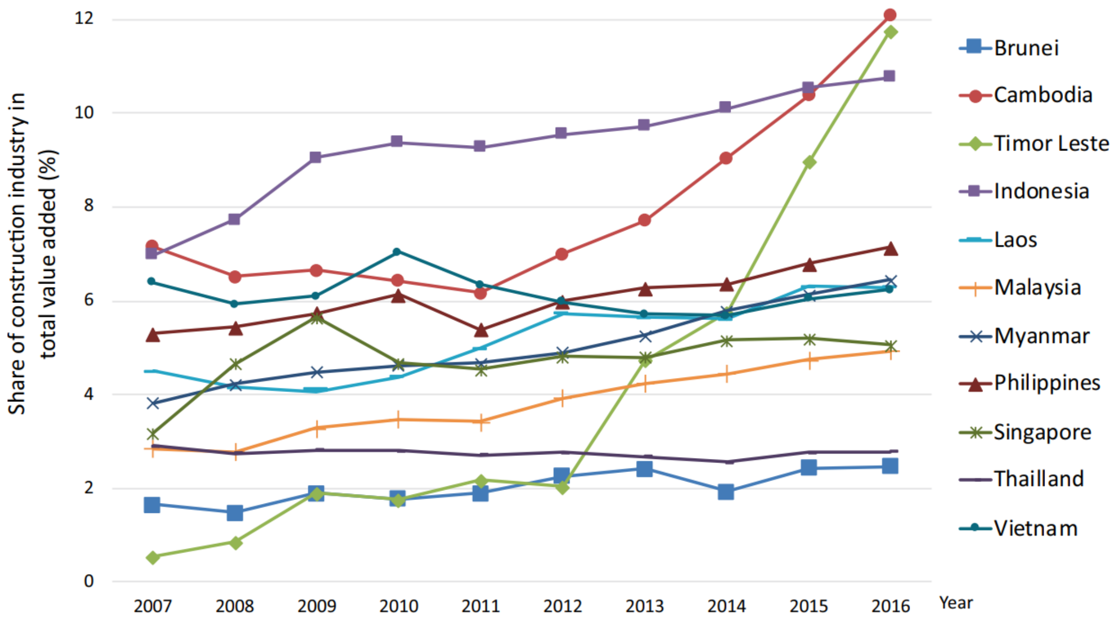


Figure 2.4 Construction industry in total value added in Southeast Asia

Source(s): (Hoang et al., 2019)

It is recognized as one of the primary sources of energy and natural resource consumption. Approximately 40% of the input materials in the global economy are reportedly utilized for construction activities (Asif et al., 2007), making the uncontrolled disposal of CW a significant capital waste (Hoang et al., 2019). In nearly all Southeast Asian (SEA) countries, the majority of CW is directly discarded at landfills and dumpsites (Hoang et al., 2019). Therefore, reducing and reusing CW are considered promising methods to minimize the initial consumption of natural resources and mitigate the impact on human health and environmental pollution (Kofoworola et al., 2009; Mah et al., 2016). The high ratio of CW generation to the construction industry's value added in SEA suggests a substantial waste burden caused by construction activities compared to their contribution to the regional economy (Hoang et al., 2019). Efforts are expected to be made to develop mechanisms involving both the public and private sectors to enhance CWM in SEA (Hoang et al., 2019). **Figure 2.5** illustrates the composition of CW in SEA.

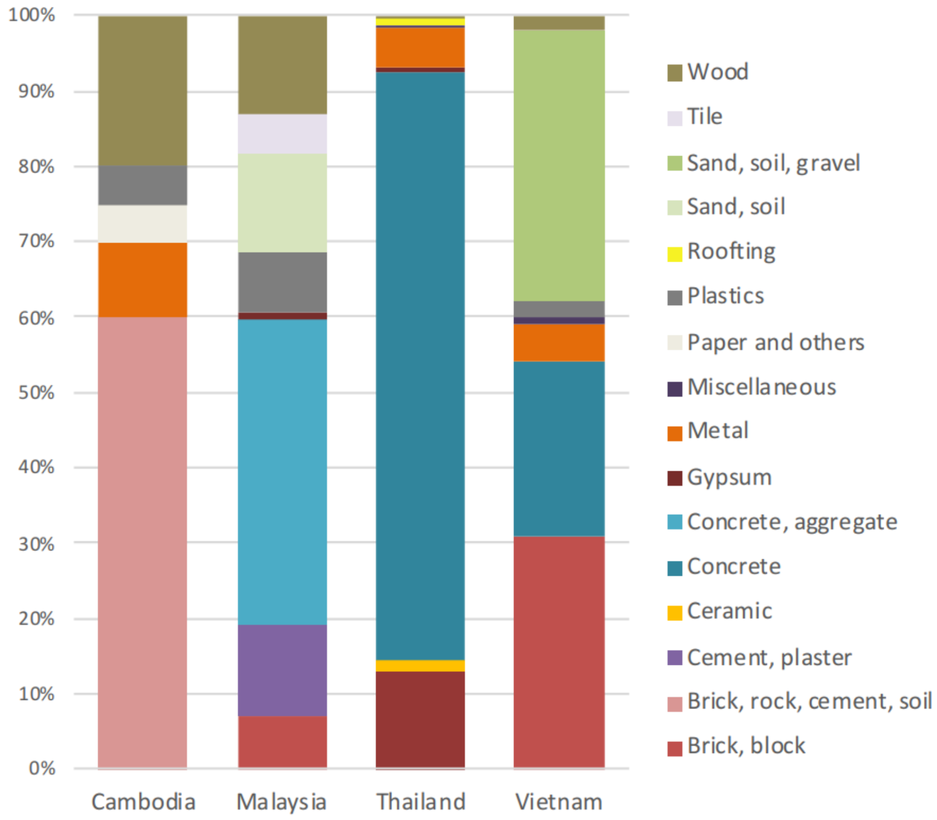


Figure 2.5 CW composition in Southeast Asia

Source(s): (Seng et al., 2011)

Figure 2.6 illustrates the quantity of CW generated in the construction industry in SEA and other countries in 2014. The inclusion of figures from countries outside SEA aims to facilitate a visual comparison of CW generation in SEA with the global context, beyond the absolute indicator of CW generation quantity, which allows for a direct comparison of CWM practices across different countries.

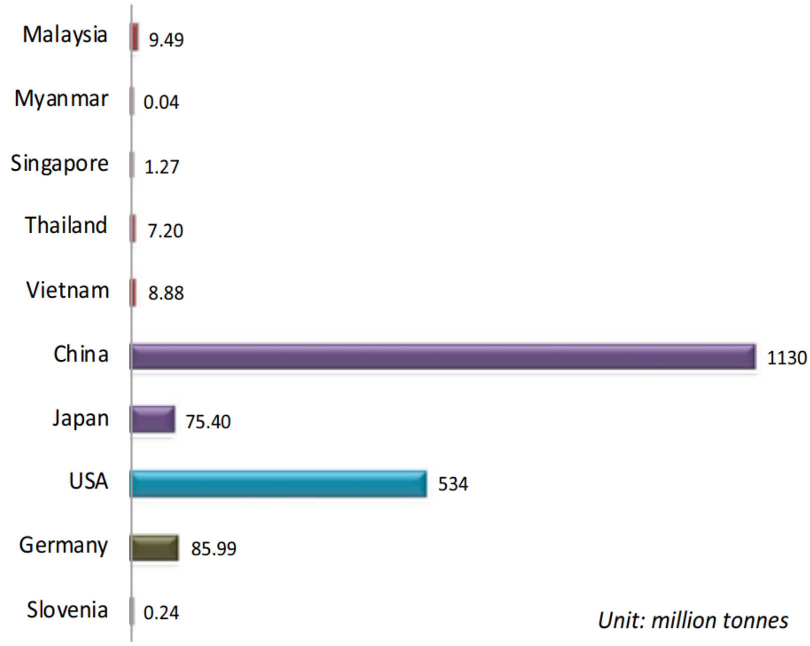


Figure 2.6 CW generation in Southeast Asia and other countries in 2014

Source(s): (Hoang et al., 2019)

2.7.2 Construction waste management in Europe

The cumulative volume of CW stands at approximately 860 million tons in Europe (EU) (Bravo et al., 2015; Lei et al., 2020). Waste prevention is a fundamental principle within the waste hierarchy, with CW prevention often assessed by reducing the generated CW quantity. Noteworthy examples include France's objective to stabilize CW generation by 2020, Sweden's goal to decrease CW yield per floor area compared to 2014, and Wales aims to reduce CW annually by 1.4% until 2050 relative to the 2006 level (Monier et al., 2017). Estimates of CW generation in EU member states rely on referencing mineral waste from construction. In 2018, EU28 generated approximately 372 million tons, while gross CW generation nearly tripled to 977 million tons. Germany, France, the UK, Italy, Netherlands, and Spain accounted for 88% of the gross CW in the EU28. Some member states, like Malta, Austria, Belgium, and Estonia, exhibited an ascending trend, while others remained relatively stable, like Luxembourg, Germany, France, Netherlands, and the UK. Some states displayed fluctuating tendencies, such as Slovenia, Spain, Latvia, Ireland, Greece, and Finland experienced a significant decline after 2010 (Zhang et al., 2022).

The UK government initiated waste minimization and sustainability initiatives, including goals to reduce waste to landfill by 2012 and achieve “Zero waste to landfill by 2020” (Oyedele et al., 2013; Phillips et al., 2011). The United States Environmental Protection Agency (USEPA) also set targets to understand CW material streams and promote research on best practices for CW reduction (Akinade, 2018). **Figure 2.7** shows the CW generation in each EU member state) (Zhang et al., 2022). In addition, **Table 2.3** shows the total CW generation and CW indicators for selected countries in 2014.

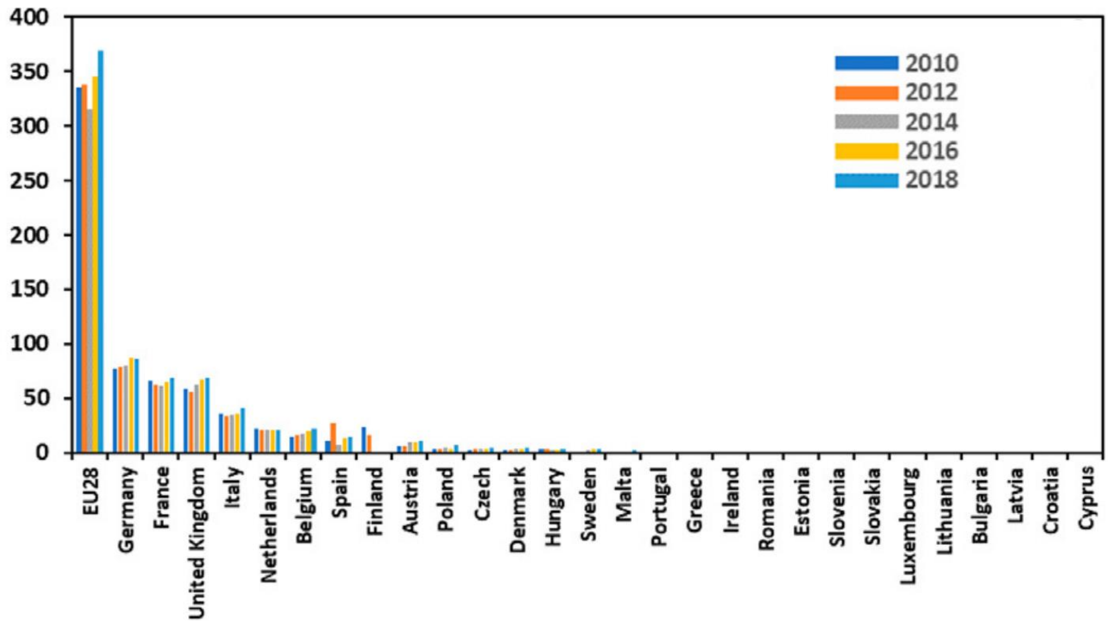


Figure 2.7 CW generation in Europe (million tons)

Source(s): (Menegaki et al., 2018)

2.7.3 Construction waste management in Japan and other countries

Countries globally are implementing various legislative measures and raising awareness to minimize CW. Leading the way in the reduction and reuse of CW are

Japan, Singapore, and several other European nations. Japan has more than 20 subdivisions for scientifically processing “construction by-products”, emphasizing waste reduction on construction sites and maximizing reuse. Singapore focuses on establishing green building standards to minimize CW generation at its source. Additionally, regions like Hong Kong have adopted new and efficient CW policies over the past decade to address and diminish CW. This underscores a global prioritization of managing CW through legislative and policy measures (Lu et al., 2013).

Table 2.3 Total CW generation and CW indicators for selected countries in 2014

Country	CDW (thousand tons)	Construction GDP (million USD)	Population density (people per sq.km of land)	CDW per million USD of construction GDP (tons)	CDW per capita (tons)
China	1,130,000	1,277,866	145.3	884.3	0.828
USA	534,000	695,788	34.8	767.5	1.676
Germany	85,986	172,045	232.1	499.8	1.062
France	65,308	153,205	121.1	426.3	0.985
UK	58,249	156,721	267.1	371.7	0.902
Italy	38,809	105,867	206.7	366.6	0.638
Netherlands	22,227	37,354	500.6	595.0	1.318
Hong Kong	20,273	12,824	6885.2	1580.8	2.804
Australia	19,496	95,934	3.1	203.2	0.831
Austria	9411	26,575	103.5	354.1	1.102
Spain	7491	88,138	92.9	85.0	0.161
Poland	5167	76,375	124.1	67.7	0.136
Denmark	3837	12,348	134.4	310.7	0.680
Czech Rep.	3015	18,695	136.3	161.3	0.286
Portugal	1073	12,400	113.5	86.6	0.103
Slovakia	558	12,444	112.7	44.8	0.103
Slovenia	238	3637	102.4	65.4	0.115

Source(s): (Lu et al., 2013)

2.8 CWM in response to sustainable development goals

We must rise higher to rescue the Sustainable Development Goals (SDGs) and stay true to our promise of a world of peace, dignity, and prosperity on a healthy planet, stated Secretary-General, United Nations (Guterres, 2022; UN, 2022). To achieve these SDGs, all concerned stakeholders, such as governments, civil society, institutions, the private sector (Panzarella et al., 2023; UN, 2022), and the construction sector, such as developers, designers, consultants, contractors, subcontractors and suppliers (Yang et al., 2021), and others, are expected to contribute to the realization of the new agenda by participating and making a substantial effort to meet SDGs in our work of daily life (UN, 2022). The construction industry is increasingly under pressure and needs to promote sustainable CWM practices (Yang et al., 2021). As one of the construction sector stakeholders, we are responsible for a healthy planet. What could we do in our construction sector? There are many things, and construction waste is one of the main issues to be considered for minimization. By minimizing construction waste, we could be able to contribute to the achievement of goal 8 (decent work and economic growth), goal 9 (industry, innovation, and infrastructure), and Goal 11 (sustainable cities and communities) (UN, 2015).

2.8.1 Sustainable development goals (SDGs)

The Sustainable Development Goals (SDGs), adopted by the United Nations in 2015, serve as a universal call to action for eradicating poverty, safeguarding the planet, and ensuring universal peace and prosperity by 2030 (UN, 2015). These 17 integrated goals emphasize the interconnectedness of actions in various domains and the need for balanced social, economic, and environmental sustainability (UN, 2015). Three specific SDGs are particularly relevant to CWM, and their brief explanations are as follows:

- *Goal 8: Decent work and economic growth*

Over the past 25 years, there has been a significant reduction in the number of workers living in extreme poverty, and the middle class in developing countries has expanded considerably. Despite this progress, challenges such as slower economic growth, widening inequalities, and insufficient job creation persist. The SDGs aim to foster sustained economic growth, productivity, and technological innovation. Key elements include promoting entrepreneurship, job creation, and eradicating workforces, slavery, and human trafficking. The goal is to achieve full and productive employment and decent work by 2030 (UN, 2015).

- *Goal 9: Industry, innovation, and infrastructure*

Investments in infrastructure and innovation play vital roles in driving economic growth and development. With over half the global population residing in cities, the importance of mass transport, renewable energy, and the growth of new industries and information technologies has increased. Technological progress is essential for addressing economic and environmental challenges, creating jobs, and promoting energy efficiency. Sustainable development is facilitated by promoting sustainable industries, scientific research, and innovation (UN, 2015).

- *Goal 11: Sustainable cities and communities*

With more than half the world's population living in cities and an estimated two-thirds expected to be urban residents by 2050, sustainable development hinges on transformative practices in building and managing urban spaces (UN, 2015). Governments globally strive to engage in SDGs by encouraging all sectors to participate in waste minimization (UN, 2015). This necessitates active involvement from construction stakeholders, compelling contractors to develop and implement waste management plans and engage in on-site reduction and re-use of construction waste. For instance, government projects may adopt initiatives like the pay-for-waste management scheme, where contractors are obligated to create and execute waste management plans, along with on-site sorting of construction waste, before certain payments under contracts are disbursed (Poon et al., 2004).

2.8.2 Sustainable construction waste management

Sustainable development, as defined by the World Commission on Environment and Development, is the development that meets the public's fundamental needs while fulfilling their aspirations for a better life without compromising the well-being of future generations (Yuan, 2013b). Since the 1980s, sustainable development has evolved into a crucial value, becoming widely accepted across various disciplines, including sustainability management in engineering SMEs, sustainable infrastructure management (Fernández-Sánchez et al., 2010), and sustainable forest policy assessment (Vierikko et al., 2010). Implementing the principle of sustainable development means achieving a balance among economic, environmental, and social dimensions, commonly called the triple bottom line (Elkington, 1994).

Effective CWM should prioritize balanced development across economic, environmental, and social dimensions. The "effectiveness of CWM" is defined as the extent to which objectives are realized during the implementation of CWM, focusing on simultaneous improvements in economic, environmental, and social performance within construction projects. **Figure 2.8** illustrates the Conceptual Model for Sustainable CWM.

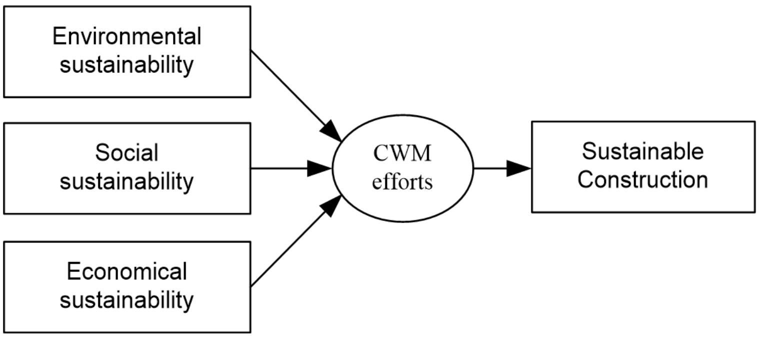


Figure 2.8 Conceptual Model for Sustainable CWM

Source(s): (Panzarella et al., 2023)

For years, WM has been linked to sustainable construction. Well-executed CWM is recognized for facilitating the smooth implementation of construction activities while minimizing environmental impacts and construction costs. This aligns with the dual sustainability pillars of resource consumption reduction and environmental pollution mitigation. New strategic instruments are deemed necessary, emphasizing waste prevention in reducing waste volumes and mitigating environmental hazards (Ismam et al., 2014). According to Ismam et al. (2014), the aspects of CWM contribute to sustainable construction, as shown in **Table 2.4**.

Table 2.4 Aspects of CWM toward sustainable construction

No.	Dimensions	View(s) Towards Sustainable Construction
1.	Environment	Deals with construction approaches to minimize the adverse impact on the environment.
2.	Economic	Employment creation, competitiveness enhancement, lower maintenance cost, high quality of working environment leading to greater productivity.
3.	Social	Enhancement of people's quality of life.

Source(s): (Ismam et al., 2014)

However, there is a current lack of awareness of resource efficiency in many countries (Janani et al., 2022). Construction waste minimization is considered a vital subcomponent for driving sustainable development, aiming to reduce waste volumes and mitigate waste-related environmental risks. Sustainable WM is crucial in preserving natural resources, curbing unwanted GHG emissions, and safeguarding public health and the environment. The success of sustainable construction hinges significantly on WM and pollution prevention (Umar et al., 2016). The outcomes of CWM are widely recognized to be influenced by factors of environmental sustainability, social sustainability, and economic sustainability (Umar et al., 2016).

The development of CWM plans has been a longstanding concern due to inadequate management and control procedures impacting the environment and the general public. The construction and building industry has seen advancements through various sustainability assessment standards and initiatives globally, such as the Green Building Index (GBI) in Malaysia, Leadership in Energy and Environmental Design (LEED) in the US, Building Research Establishment Environmental Assessment Methodology (BREEAM) in the UK, and Green Star in Australia. Despite low levels of environmental awareness and unsustainable WM practices, good WM practices exist on construction sites. Building contractors implement sustainable methods like waste reduction, reuse of materials, and using Industrialized Building Systems (IBS) to minimize onsite waste generation (Huang et al., 2011).

2.9 Existing assessment models

The subsequent sections offer concise explanations of the assessment models that were previously established.

2.9.1 Building environmental rating models

To mitigate its impact, environmental assessment methods should integrate CW as a key component in their rating systems. Consequently, building performance assessment tools must incorporate WM considerations, specifically during construction. The Building Research Establishment Environmental Assessment Method (BREEAM), established in 1990, evaluates a building's overall environmental performance and includes an onsite WM plan in its WM category, as specified by the Department for Communities and Local Government (2006). The Leadership in Energy and Environmental Design (LEED) framework, focusing on occupant safety and health, addresses CW under materials and resources in its LEED-New Construction (NC) category. It measures the generation of CW and its reuse and recycling practices (Kolaventi et al., 2018b).

Japan's Comprehensive Assessment System for Built Environment Efficiency (CASBEE), a green building management system, has dual objectives, i.e., quality and environmental loads. However, CASBEE falls short in estimating WM performance, primarily focusing on selecting construction materials with low environmental loads (Arif et al., 2012; Kolaventi et al., 2018b). The Green Building Corporation (GBC) briefly mentions using recycled materials in construction. Still, it does not explicitly include this aspect in the construction phase, categorizing it under materials and resources (Kolaventi et al., 2018b). While these tools primarily focus on the early design and planning phases, where they have significant influence, they overlook the assessment and CWM during construction. This oversight is crucial, considering the substantial indirect costs involved, which can impact project performance within the framework of these methods (Kolaventi et al., 2018b).

2.9.2 Assessment models in the construction industry

Various organizations and researchers have established several assessment models. **Table 2.5** shows the ISO standards concerning sustainable aspects of building and their indicators (Fernández-Sánchez et al., 2010). In addition, **Figure 2.9** shows the international standard models used in the construction industry.

Table 2.5 ISO standards concerning sustainable aspects in building

No.	Standard	Title	Published year	Remarks
1.	ISO 21929-1	"Sustainability in building construction sustainability indicators. Part 1: a framework for the development of indicators for buildings"	March 2006	
2.	ISO 21930	"Sustainability in building construction environmental declaration of building products"	Oct 2007	
3.	ISO 21931-1	"Sustainability in building construction framework for assessment methods for environmental performance of construction works. Part 1: buildings"	June 2006	
4.	ISO 21932	"Sustainability in building construction terminology"	2005	
5.	ISO 15392	"Sustainability in building construction-general principles"	May 2008	
6.	CEN EN 15643-1	"Sustainability of construction works integrated assessment of building performance. Part 1: general framework"	-	Drafted
7.	CEN EN 15643-2	"Sustainability of construction works-integrated assessment of building performance. Part 2: a framework for the assessment of environmental performance"	-	Drafted
8.	CEN EN 15643-3	"Sustainability of construction works-integrated assessment of building performance. Part 3: a framework for the assessment of social performance"	-	Drafted
9.	CEN EN 15643-4	"Sustainability of construction works-integrated assessment of building performance. Part 4: a framework for the assessment of economic performance"	-	Drafted
10.	RAMPICE, 2005	"Risk Analysis and Management for Projects. United Kingdom, ICE (Institution of Civil Engineers), Applicable to projects as a strategic framework with a strong economic component".	2005	Risk management

No.	Standard	Title	Published year	Remarks
11.	PRAMSimon et al., 1997	"Project Risk Analysis and Management. United Kingdom, APM (Association of Project Managers). Applicable to organizations and projects, gives all the existing techniques for managing risks, but the project team should select the combination of tools and most appropriate techniques for the project".	1997	Risk manage ment
12.	PMBoK ANSI/PMI 99-001-2004PMI, 2004	"Project Management Body of Knowledge. EEUU, PMI (Project Management Institute) Standard".	2004	Risk manage ment
13.	PMBoK construction PMI, 2003	"Extension to a guide to the project management body of knowledge, PMBoK Guide, PMI Standard. Extension of the PMBoK standard applied to construction projects".	2003	Risk manage ment
14.	AS/NZS 4360:2004 Australia Standards, 2004	"Risk management, Australia Standards. Generic guide for managing risk to be applied in a wide range of activities, decisions or operations, particularly for groups or organizations".	2004	Risk manage ment
15.	BS 6079-3:2000 British Standard, 2000	"Project Management. Guide to the Management of Business-Related Project risk. Reino Unido, British Standards (BS)".	2000	Risk manage ment
16.	BS 6079-4 British Standard, 2006	"Project Management. Guide to the Project Management in Construction Industry. Reino Unido, British Standards (BS). Application of the British generic standard to the construction projects".	2006	Risk manage ment
17.	ISO/IEC Guide 73	"Risk Management-Vocabulary-Guidelines for Use in Standards. Vocabulary relating to risk management".	2002	Risk manage ment
18.	ISO 31000	"Risk Management Guidelines on principles and implementation of Risk Management".		Drafted
19.	UNE 150008:2008	"Environmental risk analysis and assessment. Assessment methodology and analysis of environmental risks in industrial activities".	2008	

No.	Standard	Title	Published year	Remarks
20.	CPI for Thai construction industry	"Development of a construction performance index in the construction industry: system dynamics modelling approach".	2019	(Soewin et al., 2020)

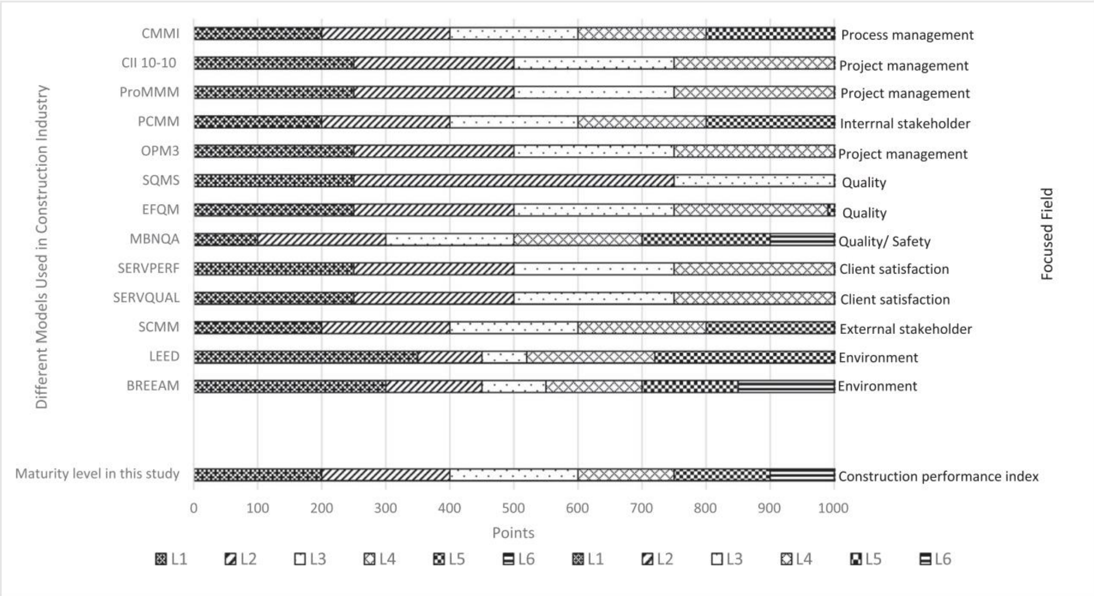


Figure 2.9 International standard models used in the construction industry

Source(s): (Soewin et al., 2020)

2.9.3 List of assessment models in construction waste management

Several construction waste management models were studied earlier for the assessment of construction waste management. The following shows each assessment model and **Table 2.6** shows the performance assessment aspects of prior CWM studies (Wu et al., 2019).

Table 2.6 Performance assessment aspects of prior CWM studies

	Paper	Region	Keywords	Environmental	Economic	Social
1	(Chung and Lo, 2003)	Hong Kong	Sustainability	√	√	√
2	(Klang et al., 2003)	Norway and Sweden	Sustainability	√	√	√
3	(Begum et al., 2006)	Malaysia	economic feasibility		√	
4	(Duran et al., 2006)	Ireland	economic viability		√	
5	(Bohne et al., 2008)	Norway	eco-efficiency	√	√	
6	(Gomes et al., 2008)	Brazil	N/A	√	√	
7	(Rocha and Sattler, 2009)	Brazil	N/A		√	
8	(Lu et al., 2009)	Hong Kong	Cost efficiency		√	
9	(Roussat et al., 2009)	N/A	sustainability	√		
10	(Shen et al., 2009)	Hong Kong	Benefits		√	
11	(Merino et al., 2010)	Spain	Sustainability	√		
12	(Ortiz et al., 2010)	Spain	Environmental performance	√		
13	(Tam et al., 2010)	Australia, Hong Kong, Japan	Benefits/Difficulties/Recommendation	√	√	
14	(Zhao et al., 2010)	China/Chongqing	Economic feasibility		√	
15	(Yuan et al., 2011)	China/Shanghai	Energy analysis (efficiency)	√	√	
16	(Zhao et al., 2011)	China/Chongqing	economic feasibility		√	
17	(Manowong, 2012)	Thailand	Sustainability	√	√	√
18	(Mercante et al., 2012)	Spain	environmental performance	√		
19	(Ye et al., 2012)	China/Shenzhen	environmental performance	√		
20	(Yuan, 2012)	China/Shenzhen	Social performance			√
21	(Simion et al., 2013)	Italy	Sustainability/Ecological footprint	√		
22	(Srour et al., 2013)	Lebanon	Economic feasibility		√	
23	(Yuan, 2013)	N/A	Effectivenss	√	√	√
24	(Marzouk and Azab, 2014)	Egypt	Environmental and economic impact assessment	√	√	
25	(Tam et al., 2014)	China/Shenzhen	Land occupy	√	√	
26	(Butera et al., 2015)	Denmark	Life cycle assessment	√		
27	(Dahlbo et al., 2015)	Finland	Environmental performance and economic performance	√	√	
28	(Dejkovski, 2016)	Australia	Environmental performance	√		
29	(Ding et al., 2016a,b)	China/Shenzhen	Environmental impacts	√		
30	(Ding et al., 2016a,b)	China/Shenzhen	Environmental performance	√	√	
31	(Kucukvar et al., 2016)	USA	Life cycle assessment	√	√	
32	(Penteado and Rosado, 2016)	Brazil	Life cycle assessment	√		
33	(Zambrana-Vasquez et al., 2016)	Spain	Environmental performance	√		
34	(Chau et al., 2017)	Hong Kong	Environmental performance	√		
35	(Marrero et al., 2017)	Spain	Ecological Footprint and economic impact	√		
36	(Wang et al., 2018)	China/Shenzhen	BIM; LCA	√		

Source(s): (Wu et al., 2019)

1. *Life cycle assessment (LCA)*

Life cycle assessment (LCA) served as the method for evaluating the environmental impacts of the system. LCA is a technique used to integrate the environmental effects of a studied product or service throughout the entire value chain (Dahlbo et al., 2015; H et al., 2022). An LCA approach has been adopted to assess the performance of CWM. Varied waste recovery rates were implemented based on compositions and material flow to analyze their impact on the environmental performance of CWM systems. The LCA approach was utilized to capture the environmental benefits resulting from the use of recovered materials (Hossain et al., 2017).

2. *Building waste assessment score (BWAS)*

The Building Waste Assessment Score (BWAS) is a design-oriented tool introduced (Ekanayake et al., 2004). Critical sources of site waste were identified under the categories of "design" with operation and material handling as pre-determined attributes. The BWAS model was developed using a multi-attribute value technique, incorporating respondents' ratings on a 6-point Likert scale to generate weights for building sub-systems. Based on the building design appraisal system developed by the Building and Construction Authority in Singapore, the model was modified to create the BWAS model. Designers are recommended to utilize this model to formulate designs with reduced potential for causing sites (Ekanayake et al., 2004). The BWAS score for a design is derived from the building systems, and the total BWAS score is the summation of waste scores for various systems within the building, as expressed in the formula:

BWAS = "Waste score of structural system + Waste score of structural slab system + Waste score for wall system + Waste score for wall finishes system + Waste score for floor finishes system + Waste score for ceiling finishes system + Waste score for roofing system" (Ekanayake et al., 2004).

3. ***Comprehensive assessment system for building environmental efficiency (CASBEE)***

CASBEE-2009, introduced in Japan by the Japan Sustainable Building Consortium (JSBC) in 2001, is a voluntary building assessment system primarily focused on design. It evaluates building environmental quality, performance (Q), and building environmental loadings (L). CASBEE assesses various aspects, including statistical values for predicted energy consumption, water use, land utilization, material usage, environmental emissions, and measurable factors related to indoor environmental conditions (Arif et al., 2012).

2.9.4 Maturity models

Maturity models (MMs) present a methodology concerning the elements related to business processes' definition, measurement, management, and control (Van Looy et al., 2011). The concepts underlying MMs are rooted in quality management and continuous process improvement. The Quality Management Maturity Grid (QMMG) by Crosby (1979, 1986) serves as the initiating point for MMs. QMMG outlines the behaviour exhibited by a company across five maturity levels concerning various aspects of quality management. This implies that a company can attain excellence in quality management by progressing through the evolutionary stages of uncertainty, awakening, enlightenment, wisdom, and certainty. QMMG, in turn, influenced the development of the Capability Maturity Model (CMM) by the Software Engineering Institute (SEI) at Carnegie Mellon University, initially for software development, serving as a reference model for assessing, evaluating, and enhancing software process maturity (Srai et al., 2013). This evolution led to the creation of its successor, the Capability Maturity Model Integrated (CMMI) (Asah-Kissiedu et al., 2021b). **Figure 2.10** illustrates the characteristics of maturity levels.

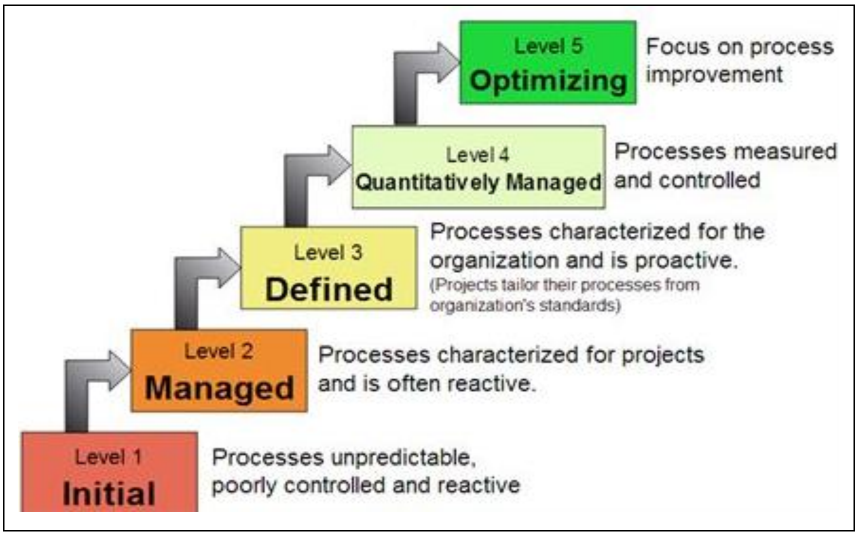


Figure 2.10 Characteristics of maturity levels

Source(s): (Al-Matari et al., 2021)

2.9.5 Adaptation of maturity models for the construction industry

Over the past two decades, the domain of performance measurement (PM) has transitioned from measurement to effective management (Bititci et al., 2014). Bititci et al. (2014) underscored the importance of PM in overseeing organizational outcomes. In the 1970s, the concept initially emerged in the literature on information systems, specifically for managing the performance of the information systems function. Nolan (1974) is credited as one of the founders of this concept, introducing a four-stage maturity model (Initiation, Expansion, Formalization, and Maturity) that assessed the maturity of an information system's function in areas like Budget, Applications, Personnel, and Management Techniques. Nolan's seminal work influenced the development of the capability maturity model (CMM) by the Software Engineering Institute. The CMM is a process maturity framework focused on the information systems function, encompassing processes such as People Capability Development, Software Acquisition, System Engineering, and Integrated Product Development (Humphrey, 1988; Moultrie et al., 2007). The CMM model addresses various practices for each process, guiding the increment of process maturity from one stage to the next (Paulk et al. 1993). The Software Engineering Institute defines CMM as “a description of the stages through which software organizations evolve as they define, implement, measure, control, and improve their software processes” (Paulk et al. 1993). The maturity model concept has found widespread adoption in various management research fields, including process management and PM (Bititci et al., 2014).

Recognizing the potential of Maturity Models (MMs), the construction industry has endeavoured to adopt them from their successful applications in the manufacturing and software sectors. Notable efforts, such as contextualizing MMs like CMM/CMMI to construction processes, have been made to influence the industry positively (Dib et al., 2012). Several studies, including the SPICE project, have explored the application of the Capability Maturity Model for Software (SW-CMM) principles in establishing a stepwise process improvement framework within the construction industry. This framework, comprising five maturity levels and assessing key organizational processes against five process enablers, aims to evaluate process capability and facilitate improvements. However, it has been noted that this model falls short of recognizing the multi-organizational nature inherent in construction work (Sarshar et al., 2000). In response, Vaidyanathan et al. (2007) introduced the Construction Supply Chain Maturity Model (CSCMM) to address inefficiencies in the construction supply chain, aiming to enhance performance and operational excellence (Vaidyanathan et al., 2007). This model operates on the premise that process maturity is achieved incrementally by managing CSC business processes along three dimensions: functional, project, and firm. It delineates a four-step progression: ad hoc, defined, managed, and controlled (Asah-Kissiedu et al., 2021b; Vaidyanathan et al., 2007). The following **Table 2.7** shows the summary list of maturity models developed earlier for use in construction industry, however, none was developed for construction waste management (Asah-Kissiedu, 2019). Despite several studies on the adaptation of maturity models, none have been conducted specifically in the context of CWM maturity models.

Table 2.7 Maturity models in construction industry

No.	Maturity model	Authors	Area	Le-vel	Maturity level description
1.	System dynamics modelling of construction safety culture	Mohamed and Chinda (2011)	Safety culture	5	Uncommitted winners, drifters, improvers, award and world class
2.	Integrated safety, health and environmental management capability maturity model (SHEM-CMM)	Millicent A.K (2019)(Asah-Kissiedu, 2019)	Safety management	5	Poor, fair, mostly good, very good, and best
3.	Structured process improvement framework for construction Environments, Facilities Management (SPICE FM)	Construct IT, (2001)	Facilities Management	5	Initial, planned and tracked, well defined, quantitatively controlled and continuously improving
4.	Benchmarking and readiness assessment for concurrent engineering in construction (BEACON)	Khalfan et al. (2002)	Concurrent Engineering	4	Adhoc, repeatable, characterized and managed
5.	Organizational project management maturity model (OPM3)	PMI, Rayner and Reiss (2002)	Project Management	4	Standardize, measure, control continuous and improvement
6.	Standardized process improvement for construction enterprises (SPICE 3)	Lockamy III and McCormack, (2004)	Not specified	5	Initial/chaotic, planned & tracked, well defined, quantitatively controlled, and continuously improving

No.	Maturity model	Authors	Area	Le-vel	Maturity level description
7.	Construction supply chain management model (CSCMM)	Vaidyanathan and Howell (2007)	Supply change management	4	Ad hoc, defined, managed and controlled
8.	Interactive capability maturity (I-CMM)	NIBS (2007)	Building information modelling	10	Not specified
9.	Change Management Maturity Model (CM3)	Sung et al. (2009)	Change management	5	Adhoc, informal, systematic, integrated and continuous improvement
10.	Risk management model (RM3)	Zou et al. (2010)	Risk management	4	Initial and Ad hoc, repeatable, managed an optimize
11.	A Safety Culture Maturity Model for the Construction Industry	McGeorge et al. (2011)	Safety culture	5	Emerging, managing, involving, cooperating and continually improve
12.	Supply Chain Relationship Maturity Model (PMOMIM-MCPs)	Jia et al. (2011)	Project management	4	Standardize, measure, control and continuously improve
13.	Program management organization maturity integrated model for MCPs (PMOMIM-MCPs)	Jia et al. (2011)	Project management	4	Standardize, measure, control and continuously improve
14.	Built environment management maturity model (BEM3)	Willis and Rankin. (2012)	Built environment	3	Immature, transitional mature and mature
15.	Construction industry macro maturity model (CIM3)	Willis and Rankin (2012)	Not specified	3	Immature, transitional mature and mature
16.	Conceptual maturity model for sustainable construction (MMSC)	Goh (2013)	Sustainable construction	5	Initial, repeatable, defined, managed and optimizing

No.	Maturity model	Authors	Area	Le-vel	Maturity level description
17.	Maturity model for a sustainable construction industry	Dahabra (2014)	Sustainable construction	5	Unsustainable, poor sustainable, satisfactory, sustainable, mature sustainable
18.	Integrated information maturity Model (IIMM)	Kang et al. (2014)	Capital projects	3	Business efficiency, Business effectiveness and Business transformation
19.	Lean maturity framework (LMF)	Nesensohnn (2014)	Lean	5	Uncertain, awakening, systematic, integrated and challenging
20.	Public commissioning maturity model for construction clients (PCMM)	Herman’s et al. (2014)	Not specified	-	Ad hoc, Repeatable, Standard, Managed Optimized
21.	Collaborative innovation capability maturity model (CICMM)	Knoke (2015)	Innovation management	5	Initial, managed, defined, quantitively managed and optimizing
22.	Construction E-Business Capability Maturity Model (CeB-CMM)	Rodrogo (2016)	E-Business	5	Initial level, Repeatable level, Defined level, Managed level and optimizing
23.	Project management maturity Model (ProMMM)	Backlun (2016)	Project management	4	Naive, Novice, Normalized and Natural
24.	Engineering change management maturity model (ECMMM)	Storbjerg et al. (2016)	Change management	5	Initial, repeated, define, managed and optimized
25.	A maturity model for the involvement of stakeholders in the city resilience building process	Gimenez, R. et al. (2016)	Resilient cities	5	Unrecognized, initial, formalized, supportive, and proactive

No.	Maturity model	Authors	Area	Le-vel	Maturity level description
26.	Management maturity model (MMM)	Langston and Ghanbaripour. (2016)	Project management	5	Core objectives, standalone projects, multiple aligned projects, and project/program collection
27.	DfOSH capability maturity model (DfOSH-CMM)	Manu et al. (2018)	Occupational safety and health design	5	Disordered level, simple level, standard level, improved level and lean level
28.	Environmental management maturity model of construction programs (EMMMCP)	Bai et al. (2018)	Environmental management	5	Disordered level, simple level, standard level, improved level and lean level
29.	Construction disability management maturity model (CDM3)	Quaigrain (2019)	Project management (Human resource)	5	Ad hoc and chaotic, Planned & managed, Standardized practices, quantitatively measured, continuously refining practices

Based on the list of maturity models above, 19 out of 29 were developed with 5 maturity levels, which is the most common and aligns with the original capability model by Paulk (1993). For example, the conceptual maturity model for sustainable construction (MMSC) adapted maturity level on a scale from 1 to 5, where Level 1 represents the lowest maturity and Level 5 represents the highest maturity (Goh et al., 2013):

- Level 1: Initial: Processes are ad hoc and inconsistent, with no defined standards or best practices.
- Level 2: Repeatable: Basic project management processes are in place, but they may be inconsistently applied and lack standardization.
- Level 3: Defined: The organisation has well-defined and standardised project management processes.

- Level 4: Managed: Project management processes are monitored, controlled, and measured for effectiveness.
- Level 5: Optimized: Continuous improvement is embedded in project management practices, and lessons learned are actively applied.

Furthermore, the SHEM-CMM maturity model employs an adapted scale ranging from 1 to 5, where Level 1 signifies poor maturity, and Level 5 denotes the highest level of maturity (Asah-Kissiedu et al., 2021b):

- ***Level 1 (Poor):*** This level is characterised by the absence of structured processes and procedures. Performance consistently remains at a poor standard.
- ***Level 2 (Fair):*** Although organizational processes and procedures may exist, they are typically ad-hoc and lack structure. Procedures and processes are not clearly defined, resulting in fair performance.
- ***Level 3 (Mostly Good):*** Organizational processes and procedures become formal and defined at this level. Processes and procedures are reactive, and overall performance is mostly good.
- ***Level 4 (Very Good):*** Organizational procedures and processes are planned, well-defined, proactive, and generally align with best practices. Performance is consistently very good.
- ***Level 5 (Best):*** Organizational processes and procedures are standardized, fully integrated throughout the organization, and subject to continuous monitoring and review for improvement. Performance at this level is exemplary and comparable to the best in the industry.

In this study, experts adapted and refined the five maturity levels and score range of 1-5. The five levels are: Level 1 (initial), level 2 (developing), level 3 (reactive), level 4 (proactive), and level 5 (optimizing).

2.10 Attributes/ factors contributing to effective construction waste management

The construction industry has been identified as a significant contributor to the generation of CW. Numerous studies have been conducted to explore potential methods for minimizing CW production throughout various construction stages, including planning, design, procurement, construction, renovation, and demolition, to address this concern. These studies approach the issue from multiple perspectives, such as environmental, social, economic, and technical considerations. For instance, Newaz et al. (2022) identified various factors influencing CWM streams. These factors include the economic value of diverted materials, onsite sorting potential, the knowledge, experience, and training of site operatives, accurate predictions of WM costs during tenders, and the identification of improved CW collection and disposal approaches. Lu et al. (2021) analyzed the framework of a “zero-waste construction site,” specifying its meaning, system boundary, assessment period, and operation strategies. This analysis demonstrated that achieving the goal of zero waste is challenging but feasible at individual construction sites. Lu et al. (2010) examined crucial success factors for WM in construction projects, revealing critical success factors such as WM regulations, the WM system, awareness of CWM, the utilization of low-waste building technologies, minimized design changes, and staff training in WM.

Other effective CWM factors for building construction have been reviewed and categorized into the following subsections.

2.10.1 Management and leadership

Effective management and leadership play pivotal roles in enhancing the efficiency of CWM (Begum et al., 2009; Cha et al., 2009). According to Ajayi et al. (2017b), contractors’ strong commitment to WM is crucial for reducing CW. Additionally, Bao et al. (2021) added that efficient site management can minimize waste generation during construction execution. Therefore, to improve CWM, contractors need to prioritize enhancing their management and leadership in this regard. This may involve implementing an organizational breakdown structure for CWM and ensuring its effective implementation (Cha et al., 2009; Tam, 2008), providing thorough supervision of WM activities with clear instructions (Bakshan et al., 2017; Udawatta et al., 2015), and maintaining precise control over on-site materials, including inspections at every stage, such as materials upon arrival (Janani et al., 2022; Osmani et al., 2008).

2.10.2 Manpower

Construction projects heavily depend on human resources, making the workforce vital in ensuring effective CWM. Cha et al. (2009); Newaz et al. (2022) have recognized manpower as a key factor contributing to the success of CWM. To minimize CW at project sites, both studies emphasize the importance of providing training and education to staff and workers in CWM management. Umar et al. (2016) similarly observed that inadequate on-site WM can lead to low productivity, which can be attributed to a lack of manpower development. De Magalhães et al. (2017) highlighted the significant impact of unskilled manpower on material waste and rework. These findings underscore the critical role of manpower development in CWM, as it can contribute to waste reduction and increased productivity in construction projects.

2.10.3 Policies and strategies

Efficient CWM is crucial for contractors aiming to ensure sustainability and minimize environmental impacts. Numerous studies have highlighted various factors contributing to the effectiveness of CWM. Among these, well-defined policies and strategies are considered indispensable (Ghaffar et al., 2020; Wang et al., 2014a). Bakshan et al. (2017) emphasized the importance of financial incentives in promoting waste minimization practices and motivating construction workers to adhere to WM policies and strategies. Newaz et al. (2022) suggested that contractors develop a formal plan for their WM practices, with a WM policy as a crucial component. This policy should articulate the contractor’s commitment to CWM, its objectives, and the strategies intended for effective implementation. Such a plan enables contractors to monitor and assess their CWM practices, pinpoint areas for improvement, and gauge their success in achieving their objectives.

Therefore, clearly defined policies and strategies, financial incentives, and a formal plan are imperative to implement CWM practices effectively.

2.10.4 Materials

Efficient CWM relies significantly on minimizing material waste. Numerous studies underscore the importance of streamlined material delivery and management to reduce CW. Notably, Cha et al. (2009); Poon et al. (2004); Udawatta et al. (2015) have emphasized the pivotal role of material use in effective CWM. Additionally, Ajayi et al. (2017a) have highlighted that adopting an efficient delivery schedule, employing the Just in Time (JIT) delivery system, and ensuring effective material delivery, including optimal job site access and protection during loading, transportation, and unloading, can contribute to CW minimization. Furthermore, Ghaffar et al. (2020) propose that building materials retain their value by incorporating valuable materials and products, as this can also reduce CW. Similarly, Daoud et al. (2021) underscore the importance of using good quality, durable, and standardized materials to reduce CW.

Therefore, minimizing CW in building construction necessitates a combination of attributes, including efficient material delivery, using valuable building materials, and using good quality, durable, and standardized materials. These measures can enhance the effectiveness of CWM and contribute to adopting efficient CWM practices (Ajayi et al., 2018; Daoud et al., 2021).

2.10.5 Equipment and tools

The efficiency and effectiveness of CWM hinge significantly on the appropriate application of equipment and tools. Previous research consistently identifies equipment and tools as crucial factors contributing to the effectiveness of CWM (Cha et al., 2009; Kabirifar et al., 2020b; Kolaventi et al., 2018a). Wu et al. (2017) highlight their role in minimizing CW generation by emphasising the necessity of sufficient equipment with advanced construction technologies. Adopting high technologies is recommended to optimize construction processes and reduce waste. One such technology is Building

Information Modeling (BIM), which has proven to facilitate construction work and reduce waste (Ajayi et al., 2015; Bao et al., 2020b; Ghaffar et al., 2020). Using BIM in construction projects improves collaboration, visualisation, and project management. Consequently, BIM minimises material waste, reduces project timelines, and enhances project outcomes. The effectiveness of CWM depends on the appropriate application of equipment and tools. Adopting other advanced construction technologies can further facilitate construction work and reduce waste. Therefore, contractors must prioritize the availability and utilization of appropriate equipment and technologies to optimize construction processes and minimize waste generation (Kabirifar et al., 2020a; Tam, 2008).

2.10.6 Construction method and processes

According to Ajayi et al. (2018); Cha et al. (2009); Kolaventi et al. (2020), all have acknowledged that construction methods and processes are fundamental factors in CW generation. To mitigate CW, it is imperative to provide sufficient site space and layout for materials movement, as emphasized by (Bao et al., 2020b; Wang et al., 2010; Yuan, 2013b). Another recommendation for CW minimization is the establishment of separate bins for different waste types and sorting of individual waste by type at the site with noticeable categories are suggested (Ganiyu et al., 2020; Kolaventi et al., 2020; Newaz et al., 2022). Furthermore, the installation of bins on every floor to facilitate waste segregation and disposal is advocated by (Newaz et al., 2022). Adopting prefabricated structural elements and preassembled components, such as bathroom and kitchen pods, can also minimise CW (Daoud et al., 2021; Ghaffar et al., 2020). Additionally, maximizing the reuse of construction materials at the site is essential (Ghaffar et al., 2020). To reduce CW from application processes, effective and efficient construction techniques (Janani et al., 2022; Osmani et al., 2008; Udawatta et al., 2015).

Therefore, the implementation of an effective WM plan is crucial for the success of effective CWM, as highlighted by Lu et al. (2021). These strategies can aid in minimizing CW during the construction process and promoting effective CWM.

2.10.7 Documentation

As highlighted by numerous studies, efficient document control stands out as a critical factor in ensuring the smooth progression of construction projects. Ajayi et al. (2018); Kolaventi et al. (2020) underscored the significance of document control in achieving effective CWM. Similarly, Udawatta et al. (2015); Zhao et al. (2022) argued that proper construction documentation is indispensable for successful CWM. Reducing variation orders and design changes during construction is also crucial for minimizing Construction Waste (CW), according to (Ajayi et al., 2015; Doust et al., 2020). There is a need to consider such factors during the construction process to prevent unnecessary CW generation. Additionally, obtaining professional quality management and certifications (such as ISO, GREEN, etc.) has been identified to reduce CW (Andersson et al., 2022; Ghaffar et al., 2020). Such certifications provide contractors with the necessary procedures to implement effective WM strategies and minimize their environmental impact.

Lastly, the significance of maintaining a lesson-learned repository or recording of CWM cannot be overstated (Janani et al., 2022; Li et al., 2022). This documentation is essential for future learning and gradual improvement in CWM practices, enabling contractors to continuously refine their CW strategies and minimize waste generation in the long run. The extracted details regarding the factors controlled by contractors contributing to effective CWM in building construction are presented in **Table 2.8**.

Table 2.8 Identified attributes influencing building contractors' CWM.

No.	Factors/ Attributes	References
I.	***Management and leadership***	
1.	Contractors' awareness of CW impacts on sustainable construction (environmental, economic, and social)	(Fernández-Sánchez et al., 2010; Wang et al., 2014a; Zulu et al., 2022)
2.	Contractor's effective and efficient site management (planning, execution, monitoring, and control)	(Bao et al., 2021; Osmani et al., 2008)
3.	Contractors' precise on-site material control (including inspection of all processes, e.g., inspect the materials when they arrive, etc.)	(Janani et al., 2022; Osmani et al., 2008)
4.	Senior management behaviour and attitude on CWM	(Begum et al., 2009; Wang et al., 2014a)
5.	Contractor's adequate supervision of WM activities with clear instructions	(Bakshan et al., 2017; Udawatta et al., 2015)

No.	Factors/ Attributes	References
6.	Effective coordination and communication among project stakeholders (Contractor vs. designer, consultant, client, subcontractor, supplier, etc.)	(Kabirifar et al., 2020b; Osmani et al., 2008)
7.	Contractor's work experience on CWM and waste minimization culture within the company	(Bakshan et al., 2017; Li et al., 2022)
8.	Contractor's action to reduce CW generation	(De Magalhães et al., 2017)
9.	Contractor's action to reuse CW	(Wu et al., 2017)
10.	Contractor detailed study and an understanding of specifications and drawing and on-time accurate quantification of material/ bill of quantity	(Kabirifar et al., 2020a; Poon et al., 2004)
11.	Organization breakdown structure for CWM	(Cha et al., 2009; Tam, 2008)
12.	Prevent site accidents	(Doust et al., 2020)
13.	Monitor and audit the waste management system periodically.	(Ghaffar et al., 2020; Tam, 2008)
14.	Looking for and having support from the client (the project owner)	(Kolaventi et al., 2018a)
II.	***Manpower***	
15.	Training and education of the engineers and workers on WM and its effectiveness	(Ding et al., 2018; Udawatta et al., 2015)
16.	Workers are assigned solely for waste minimization.	(Cha et al., 2009; Kolaventi et al., 2020)
17.	Skilled workers and workmanship	(Kabirifar et al., 2020a)
18.	Engagement of all stakeholders in CWM	(Udawatta et al., 2015)
III.	***Policies and strategies***	
19.	Establish a strict policy on CWM within the company (including the CWM system, criteria for the quality and safety of reusable materials, etc.)	(Andersson et al., 2022; De Magalhães et al., 2017; Ghaffar et al., 2020; Kolaventi et al., 2020; Lu et al., 2010)
20.	REDUCE target for every project and maximize material reduction at the construction site	(Daoud et al., 2021; Ghaffar et al., 2020; Menegaki et al., 2018; Yuan et al., 2022)
21.	REUSE target for every project and maximize material reuse at the construction site	(Ajayi et al., 2017b; Menegaki et al., 2018; Wang et al., 2014a)
22.	Establish an appropriate waste management plan in an earlier stage of each construction (Including methods to deal with reusable materials)	(Cha et al., 2009; Kolaventi et al., 2020) (Newaz et al., 2022; Poon et al., 2004)
23.	Contractual documents may include WM targets and responsibilities of sub-contractors about decreasing waste and increasing reusable waste (i.e., setting criteria)	(Cha et al., 2009; Ghaffar et al., 2020; Osmani et al., 2008; Zhao et al., 2022)
24.	Financial rewards and incentives for the effectiveness of decreasing and reusing waste	(Jaillon et al., 2009; Kabirifar et al., 2020a; Menegaki et al., 2018)
25.	Contractors' current waste assessment score and future target	(Kolaventi et al., 2020; Li et al., 2022)
IV.	***Materials***	
26.	Having central areas for cutting and storage	(Poon et al., 2004; Tam, 2008)
27.	Adequate protection of material transportation and handling (loading and unloading)	(Ajayi et al., 2017a; Daoud et al., 2021; Osmani et al., 2008)
28.	Adequate protection of different categories of materials during storage and stacking	(Kabirifar et al., 2020b; Poon et al., 2004; Tam, 2008)
29.	Preventing ordering errors and ordering appropriate material sizes and quantities to avoid excess	(Doust et al., 2020; Janani et al., 2022; Osmani et al., 2008)
30.	Use of quality, durable, and standardized materials	(Ajayi et al., 2018; Daoud et al., 2021)
31.	Adopt Just in Time (JIT) delivery system	(Daoud et al., 2021)

No.	Factors/ Attributes	References
32.	Strong security at the project site (i.e., prevent the loss of materials)	(Fernández-Sánchez et al., 2010)
V.	***Equipment/ tool***	
33.	Use and familiar with the application of BIM	(Ajayi et al., 2015; Ganiyu et al., 2020)
34.	Use and familiar with other related information technologies	(Kabirifar et al., 2020a; Tam, 2008)
35.	Availability and quality of Equipment (tools, machines, and vehicles)	(Wang et al., 2010; Wu et al., 2017)
36.	Use and familiar with the equipment	(Jaillon et al., 2009; Poon et al., 2004)
37.	Use metal scaffolding and formwork (e.g., rent them from professional suppliers)	(Ding et al., 2018; Tam, 2008; Wang et al., 2014a)
VI.	***Construction method and processes***	
38.	Adequate site space and the site layout are cleared for materials movement	(Bao et al., 2020b; Wang et al., 2010; Yuan, 2013b)
39.	Set up separated bins by waste type and sort out individual waste by type from mixed waste at the site with notice categories	(Cha et al., 2009; Kolaventi et al., 2020; Newaz et al., 2022; Wang et al., 2010)
40.	Efficient use of materials and minimizing the uneconomical cutting shapes and length (including rebar schedule and materials lists to be reused)	(Doust et al., 2020; Osmani et al., 2008; Yuan, 2013a)
41.	Effective implementation of a waste management plan	(Lu et al., 2021; Newaz et al., 2022)
42.	Store waste in easily accessible areas	(Yuan, 2013a)
43.	Bins are installed on every floor	(Newaz et al., 2022)
44.	Adopt prefabricated structural elements	(Daoud et al., 2021)
45.	Adopt preassembled components such as bathroom & kitchen pods	(Daoud et al., 2021)
46.	Minimize waste from application processes (i.e., overpreparation of mortar)	(Janani et al., 2022; Osmani et al., 2008; Udawatta et al., 2015)
47.	Minimize rework at the construction site	(Ding et al., 2018; Yuan et al., 2022)
VII.	***Documentation***	
48.	Variation orders minimization	(Daoud et al., 2021)
49.	Document control of CWM with effectiveness (amounts, kinds, etc.)	(Zhao et al., 2022)
50.	Design changes during construction minimization	(Ajayi et al., 2015; Doust et al., 2020)
51.	Shop drawing detailing errors preventing	(Ajayi et al., 2018; Doust et al., 2020)
52.	Professional quality management and certification (e.g., ISO, GREEN, etc.)	(Andersson et al., 2022; Ghaffar et al., 2020)
53.	Lesson learned repository on CWM	(Janani et al., 2022; Li et al., 2022)

2.11 Mapping of construction waste management using the CW3M model

The existing research is inadequate for practical use in the construction industry for construction waste improvement, in which essential knowledge and skills are constantly and rapidly evolving, as it assumes a slow pace of knowledge development.

Improvement of construction waste management in such environments, therefore, finds themselves inadequate in terms of well-understood cleared criteria, the current stage of construction waste management capability, and the targeted level of improvement of construction waste management.

To address these research gaps, this study is being conducted to develop the maturity model for assessing construction waste management that contractors can use. This research aims to determine effective approaches to minimize waste generation in the construction phase. Mixed methods will be adopted by combining qualitative and quantitative research approaches. Data surveys and interviews from respective contractors will be used for model development and validation. The findings will reveal critical solutions for contractors' CWM. To drive the direction of research clearly, the CWM process is developed for ease of understanding, depicted in **Figure 2.11**.

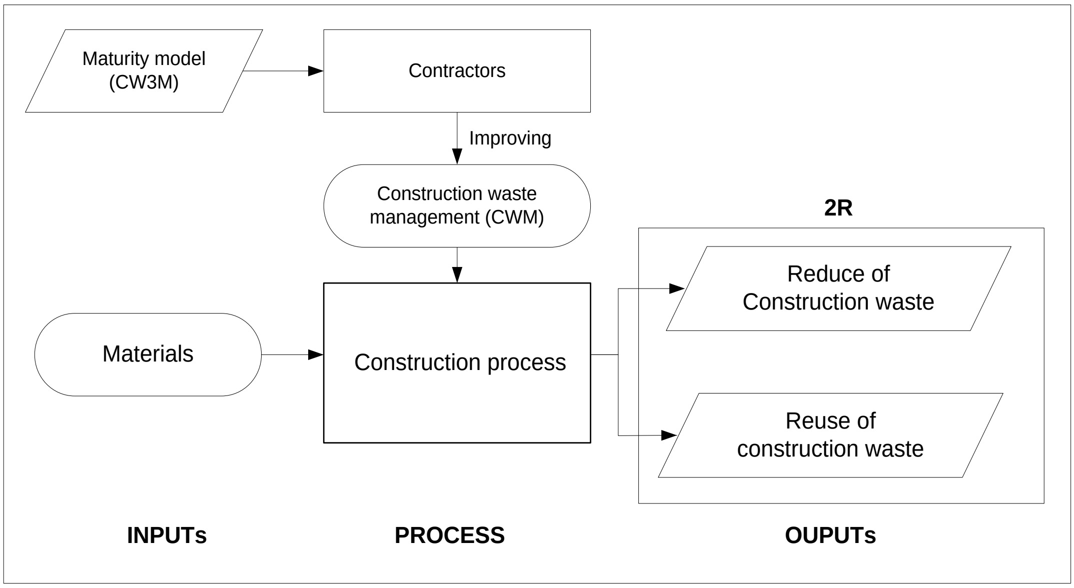


Figure 2.11 Mapping of CWM process

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the research outline. It outlines the applied approaches, including a literature review, expert verification, factor analysis, multi-criteria decision analysis using the Best-Worst Method, model tool development, model implementation, and model validation. Expert verification was used to validate the list of attributes. Exploratory Factor Analysis (EFA) identified the main categories or key factors and their associated attributes that influence CWM. Confirmatory Factor Analysis (CFA) confirmed the attributes and factors identified through EFA. The Best Worst Method was used to weigh the attributes. After obtaining the standardized global weight of all attributes, the CW3M model was developed and then tested and validated by experts from different contractors.

3.2 Research design

The research design is essential as it serves as a blueprint guiding the attainment of predefined research objectives. It aids researchers in acquiring solutions to research questions while effectively controlling variance by establishing a logical linkage between the data to be gathered and the initial research questions (Panuwatwanich, 2008). Generally, the research design involves a sequence of logical decision-making choices that researchers must judiciously make, taking into account the study's purpose, setting, degree of researcher interference, timeframe, and the unit of analysis (Cavana et al., 2001; Panuwatwanich, 2008). Moreover, decisions are made concerning the sample type and data collection methods, how attributes are measured, and the analysis of concepts and attributes (Cavana et al., 2001; Panuwatwanich, 2008). The subsequent sections described the research activities designed to fulfil the objectives of the current study.

3.2.1 Outline of research

The study begins with a comprehensive literature review to identify the attributes influencing the effectiveness of CWM, then frequency analysis, and then verified with experts by using a preliminary questionnaire and interviews with key experts in the field. Instruments in the form of questionnaires are then developed to collect data for EFA and CFA. A pilot test was conducted to ensure the effectiveness and clarity of the questionnaires. Following the pilot test, data collection takes place immediately. The questionnaires were distributed to project management teams and engineers who have experience working with contractors operating in Cambodia and Thailand. Once sufficient responses are obtained, the data is inputted for analysis using EFA and CFA.

Based on the results from EFA and CFA, a pairwise comparisons questionnaire for BWM will be developed and pilot-tested. This pairwise questionnaire will then be used for data collection from experts. The data is gathered from experts and then analyzed for each attribute's local and global weight. The global weights were normalized as global standardized weights, which were then used to develop the CW3M model. Once the CW3M model is developed, it is subjected to testing and validation with the help of key experts in the field. Finally, based on the findings, a conclusion and recommendations are drawn. The research outline is shown in **Figure 3.1**.

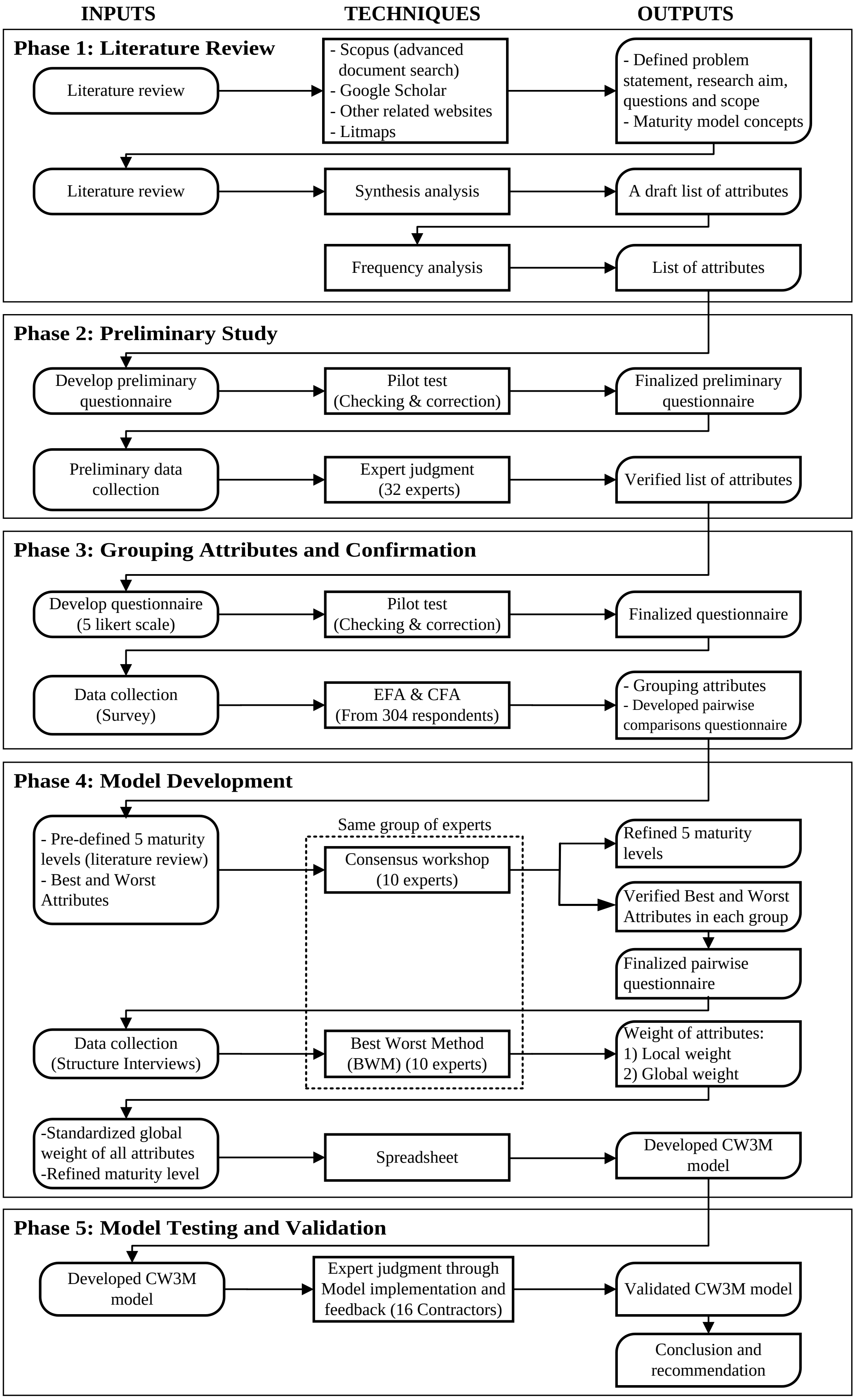


Figure 3.1 The research outline

3.2.2 Aligning research objective and methodology

Table 3.1 shows asligning research objectives and methodology, and **Figure 3.2** shows the stages of data collection.

Table 3.1 Aligning research objectives and methodology

Items	Objectives	Methodolo-gies	Outputs	Answered research questions
1.	To identify attributes that determine construction waste management capability in construction	• Literature review • Experts' judgment	List of identified attributes	It will answer research question No. 1: What attributes are appropriate for the development of a maturity model to assess construction waste management?
2.	To explore the maturity model concept for the application to assess the construction waste management	Literature review	List of maturity models in construction management	It will answer research question No. 2: How important are those attributes that can be used to develop a maturity level of construction waste management?
3.	To develop the maturity model for the assessment of construction waste management (CW3M)	- Survey and Experts' judgement **- EFA, CFA and BWM**	Maturity model for the assessment of construction waste management (CW3M)	It will answer research question No. 2: How important are those attributes that can be used to develop a maturity level of construction waste management?
4.	To validate the model and test the industrial relevance of the CW3M model from the perspective of building contractors	Expert judgment through Model implementation and feedback (Contractors)	Validated CW3M model	It will answer research question No. 3: Can this maturity model be used for construction waste management?
5.	To conclude and make recommendations relating to the use of the CW3M model	Experts' judgement	Recommendations relating to the use of the CWM3 model	It will answer research question No. 3: Can this maturity model be used for construction waste management?

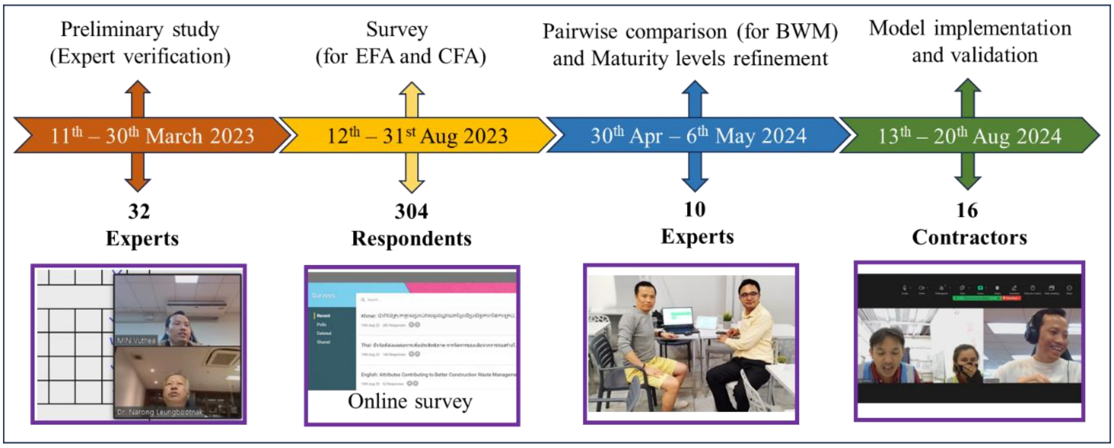


Figure 3.2 Stages of data collection

3.3 Quantitative method

Questionnaires are a common tool used in quantitative methods to obtain instrument-based data that can be examined using statistical techniques to make inferences. This method's sample sizes are frequently sizable and representative, enabling the extrapolation of quantitative findings to a larger population. Although regarded as an essential research method, some argue that quantitative approaches are strict and lack context, which could undermine the validity of study findings (Bryman, 2016; Denscombe, 2017). However, the quantitative method is still helpful when used effectively, considering the study's objectives and the questions that need to be answered. As stated by Akinade et al. (2018); Asah-Kissiedu et al. (2021b); Creswell (2009), survey research and experimental research are two common quantitative approaches. By analysing a sample from that group, surveys provide a quantitative description of attitudes, opinions, and population trends (Creswell, 2014; Creswell et al., 2017). They consist of longitudinal and cross-sectional studies that use questionnaires or interviews to gather data, with their primary objective being to extrapolate results from a sample to the entire population (Babbie, 2020). While cross-sectional surveys concurrently capture data or during a relatively short interval, offering a snapshot of the researched features at a single time, longitudinal surveys include gathering data over more extended periods. The mode of data collection and participant sample significantly impact the validity of survey results (Bryman, 2016).

3.4 Qualitative method

The qualitative method focuses on investigating and understanding the meaning that people or groups attach to a phenomenon (Creswell, 2014; Creswell et al., 2017). It involves taking on fieldwork to acquire access to individuals, environments, or organizations, utilizing subjective measurements to study behaviours in natural settings, and then analyzing the results to determine their significance (Creswell, 2009). This method focuses on clarifying the meaning of a phenomenon. Hence, words are more important than numbers (Bryman, 2016). Research issues concerning how and why are particularly appropriate for qualitative studies (Fellows et al., 2021). As a result, the interpretive framework informs the inductive procedures of the qualitative research technique about theory and literature (Asah-Kissiedu et al., 2021b; Sutrisna, 2009).

3.5 Mixed methods

According to Creswell et al. (2017), this method combines qualitative and quantitative techniques into a single research methodology. Mixed, multi, or triangulation approaches are defined by Creswell (2014) as the concurrent use of several inquiry tactics, including qualitative and quantitative ones. When the study problem permits the gathering and analysis qualitative and quantitative data, a mixed-method strategy is usually used to provide a more thorough and in-depth understanding of a phenomenon (Asah-Kissiedu, 2019). A mixed-method approach, combined with quantitative and qualitative techniques, is used in this study.

3.6 Data collection methods in this study

The methodical gathering of information is known as data collection. The present study included various data collection approaches, including a review of the existing research, expert verification process, questionnaire survey, expert interviews, model testing and validation by experts. These methods are covered in detail in the following sections.

3.6.1 Review of literature

A thorough examination of CWM literature served as the basis for identifying potential capability attributes in CWM. Extensive searches were conducted using Google Scholar, Scopus, and others. Litmaps (https://app.litmaps.co), a prominent science discovery platform, was employed for this study. Litmaps offers a visual citation navigation interface, serving as an ultimate tool for exploring scientific literature, mapping the research landscape, and identifying articles closely linked to specific topics. Utilizing Litmaps, the study incorporated various quick-start options, such as importing articles from reference managers, conducting keyword searches and initiating searches with a seed article (Arief et al., 2023; Kaur et al., 2022; Normann et al., 2023). The research keyword "Construction Waste Management" was employed for exploration for this study. **Figure 3.3** shows the typical example of Seed Articles from Litmaps.

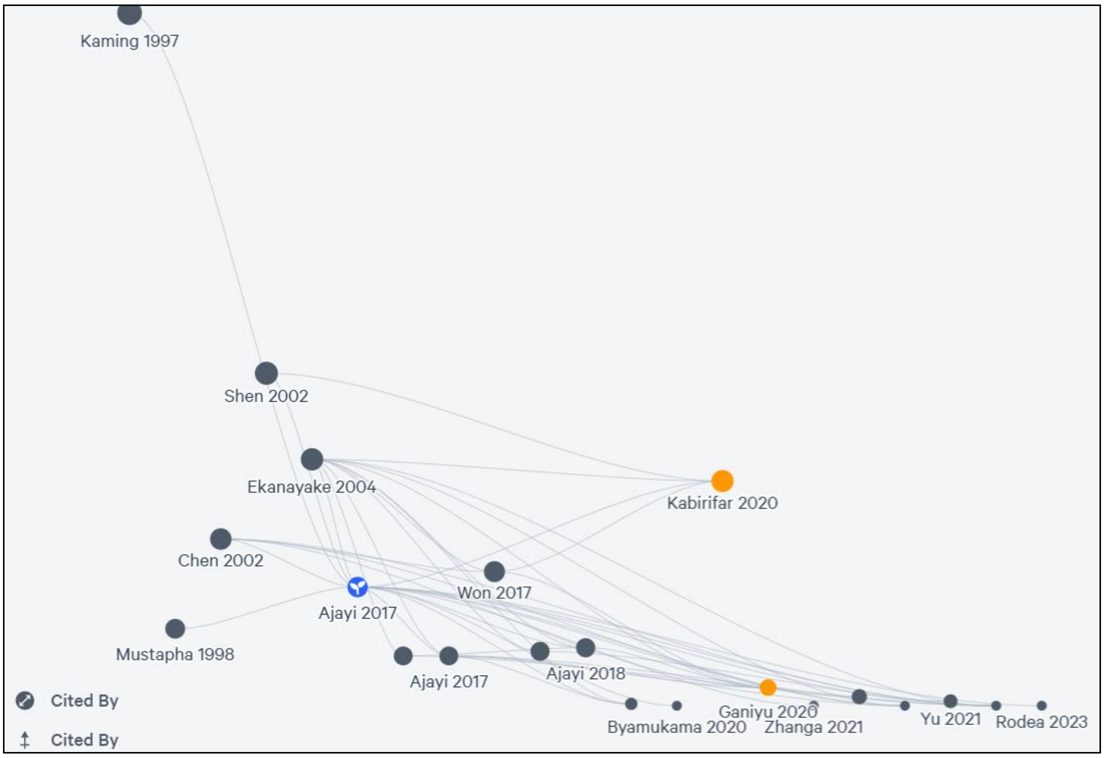


Figure 3.3 Typical example of Seed Articles from Litmaps

Zhao et al. (2022) and (Jin et al., 2019) used Scopus "advanced document search" to identify the related article papers related to CWM. This study applied the Scopus search "Advanced document search" to determine the journal articles related to CWM, which concerned contractors in the 2R strategy. A list of 56 journal articles was generated from the initial search. The screening process thoroughly examined the titles, abstracts, and keywords (Bao et al., 2023). The coding for the search was as follows:
TITLE-ABS-KEY (contractor) AND TITLE-ABS-KEY (construction OR building) AND TITLE-ABS-KEY (waste) AND TITLE-ABS-KEY (manag*) AND TITLE-ABS-KEY (attribute OR factor OR indicator) AND TITLE-ABS-KEY (reduc* OR reus* OR minimi*) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re"))

3.6.2 Expert verification process

A validation process was conducted with experts working in the construction industry to verify the identified attributes for CWM. By using experts' opinions and in-depth expertise, this verification attempted to improve or enhance certain features. A group of experts was gathered to guarantee the effectiveness of this verification process. The experts were chosen based on what was provided by Asah-Kissiedu et al. (2021b); Hallowell et al. (2009) to select the experts. These requirements included an advanced degree in Construction Engineering and Management (CEM) or similar subjects, with a minimum qualification of a bachelor's degree (BSc.) and a minimum of five years of professional experience in the construction industry. The questionnaire distribution and interviewing methods aligned with the guidance for thorough data collection (Creswell et al., 2017). An item-total correlation analysis was used to analyze the data. The relationship between a particular attribute and the composite score obtained from all the qualities that make up the measure of the construct is evaluated using this type of correlation. The total construct score and the scores of each characteristic should show a significant association when all attributes collectively represent the same construct (Omani-Samani et al., 2018; Wang et al., 2017). SPSS is used to apply for the item-total correlation value. According to Park et al. (2020); Pett et al. (2003), an attribute that measures something different from the overall construct is indicated by a corrected item-total correlation value of less than 0.30. It is advised that you remove it in these circumstances.

3.6.3 Exploratory and Confirmatory Factor Analysis

To get data for Exploratory and Confirmatory Factor Analysis involving the survey method. The survey method is an approach to gathering data that involves asking people questions over the phone, online, in-person or online interviews, or using paper-based, standardized questionnaires (Ponto, 2015). Both qualitative and quantitative research can use this methodology. The two main forms of the survey method are questionnaires and document reviews. It is common to consider questionnaires part of the more extensive survey process. A questionnaire consists of a predetermined list of questions that participants must complete and send back to the researcher (De Leeuw, 2012; Ponto, 2015).

This study employed both purposive and snowball sampling techniques (Biernacki et al., 1981; Campbell et al., 2020). According to Dattalo (2008), purposive sampling involves using the researcher's knowledge of the population regarding research goals. Respondents are selected based on the researcher's judgment that they will provide access to the desired information. Purposive sampling can also be used to select participants based on their willingness to be studied or their knowledge of a particular topic. Purposive sampling involved identifying construction professionals in Cambodia and Thailand, with respondents further requested to distribute questionnaires within their networks. The research instrument comprised two sections. The first was to capture demographic details such as academic and professional qualifications, organization type, and work experience. The second was about attributes contributing to better CWM performance. This current study conducted the survey online using a questionnaire developed through the licensed platform "https://shout.com". The questionnaire design ensured that each question was mandatory for respondents to answer, thus enabling progression to subsequent sections and the questionnaire submission. Before data collection, a pilot test was carried out to refine the instrument.

Respondents were chosen based on their engagement in building construction, with the expectation that they had worked as contractors for at least a year (Ikuabe et al., 2022).

3.6.4 Best Worst Method

A Multi-Criteria Decision Analysis (MCDA) based on the Best Worst Method (BWM) was employed in this study. The primary purpose of utilising the BWM is to determine the weights of each attribute influencing CWM. Introduced in 2015, the BWM addresses multi-criteria decision-making (MCDM) problems by identifying the best and worst criteria, conducting pairwise comparisons, and formulating a maximin problem to derive weights. This method aims to reduce the complexity of pairwise comparisons and enhance consistency in decision-making (Rezaei, 2015). In MCDM problems, alternatives are assessed based on various criteria to select the best alternative(s). The BWM involves identifying the best and worst criteria, conducting pairwise comparisons between each of these criteria and others, and solving a maximin problem to determine weights. The method introduces a consistency ratio for reliability checks (Rezaei, 2015).

Rezaei (2015) conducted numerical examples and real-world decision-making problems to compare BWM and the Analytic Hierarchy Process (AHP). Statistical results indicate that BWM outperforms AHP regarding consistency ratio, minimum violation, total deviation, and conformity. BWM requires less comparison data and produces more consistent and reliable results than the existing AHP technique (Rezaei, 2015). BWM utilizes two vectors of pairwise comparisons to determine the weights of criteria. Pairwise comparisons are made after identifying the best and worst criteria, leading to more efficient and consistent decision-making (Rezaei, 2015). Since its introduction, BWM has garnered attention for its efficiency in reducing the amount of pairwise comparisons. A survey of BWM publications from 2015 to 2019 reveals its widespread adoption in various fields (Mi et al., 2019). The method addresses challenges posed by AHP, such as numerous pairwise comparisons and consistency issues. BWM’s linear growth in complexity compared to AHP’s exponential growth demonstrates its superior performance in decreasing the number of pairwise comparisons (Mi et al., 2019). The BWM was proposed in response to AHP's challenges, offering a new structure for pairwise comparisons. By predetermining the best and worst criteria, BWM significantly reduces the number of necessary pairwise comparisons, overcoming AHP's complexity and inconsistency issues (Mi et al., 2019; Rezaei, 2015). **Figure 3.4** illustrates times of pairwise comparisons of BWM and AHP in general. In addition, **Table 3.2** illustrates the number of pairwise comparisons of five factors with 27 attributes in this current study. The lesser the number of pairwise comparisons per participant, the more manageable the cognitive load and the more reliable the results (Rezaei, 2015). In this study, with 27 attributes under five factors, the number of pairwise comparisons under the BWM was 44, compared to 81 by the AHP. Therefore, BWM was considered for this study.

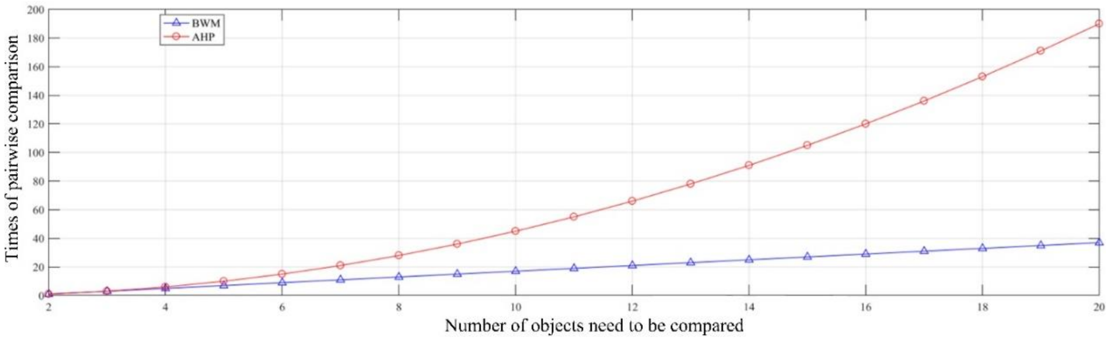


Figure 3.4. The times of pairwise comparisons of BWM and AHP

Source(s): (Mi et al., 2019; Rezaei, 2015)

Table 3.2 Comparing the number of pairwise comparisons using AHP Vs. AHP

Factors		**AHP**	**BWM**
	n	**n(n-1)/2**	**2n-3**
1 "Governance and policies (GP)"	8	28	13
2 "Materials and equipment (ME)"	8	28	13
3 "Requirements and specifications (RS)"	4	6	5
4 "Construction information systems (CIS)"	4	6	5
5 "Waste collection facilities (WCF)"	3	3	3
Sub-total number of pairwise comparisons of attributes	*27*	*71*	*39*
Number of pairwise comparisons of factors	*5*	*10*	5
Total		**81**	**44**

Table 3.3 Lists other weighting methods employed to determine the weights of attributes in previous studies (Zardari et al., 2015).

Table 3.3 List of weighing methods used in other studies

No.	Author, year	Techniques	Weighting method	Country
1.	Machiwal et al. (2011)	AHP	Pairwise comparison, eigenvector method	India
2.	Calizaya et al. (2010)	AHP	Pairwise comparison	Bolivia
3.	Kodikara et al. (2010)	PROMETHEE	PROMETHEE	Australia
4.	Özcan et al. (2011)	TOPSIS, ELECTRE, grey theory	SIMOS procedure	Turkey
5.	Tervonen et al. (2009)	ELECTRE Tri, SMAA Tri	SIMOS procedure	Portugal, Finland
6.	Shanian et al. (2008)	ELECTRE Tri	Revised SIMOS procedure	Material selection
7.	Chen and Zhang (2010)	TOPSIS	Pairwise comparison	China
8.	Supriyasilp et al. (2009)	AHP	Pairwise comparison	Thailand
9.	Guo and Yu (2011)	TOPSIS, AHP	Pairwise comparison	China
10.	Myllyviita et al. (2012)	MADM	ReCiPe LCI assessment method, SMART	Finland
11.	Yeh and Chang (2009)	Fuzzy group MCDM	Pairwise comparison	Australia, Taiwan
12.	Balasubramaniam et al. (2007)	ELECTRE III, weighted summation	SWING	UK
13.	Hämäläinen and Alaja (2008)	MCDM	SWING	Finland
14.	Morais and Almeida (2012)	PROMETHEE II	Ranking	Brazil
15.	Chang and Yeh (2001)	MADM	SAW, SP, TOPSIS	Taiwan, Australia
16.	Arnette et al. (2010)	VAHP	Pairwise comparison	USA

No.	Author, year	Techniques	Weighting method	Country
17.	Gallego-Ayala and Juízo (2011)	AHP, A'WOT analysis	Pairwise comparison	Mozambique
18.	Chen et al. (2011)	FMCDM, FAHP	Pairwise comparison	Taiwan
19.	Sorvari and Sep-pälä (2010)	DST based on MAVT	Ratio method, pairwise comparison	Finland
20.	Wang et al. (2002)	DSSDSS based on MAUT	SMART	Singapore
21.	Gómez-Limón et al. (2003)	MAUF, EUT	Additive utility function	Spain
22.	Chowdhury and Rahman (2008)	MCDA	Weighted sum method	
23.	Rezaei (2015)	BWM	Pairwise comparison (Original establishment of BWM)	Netherland

3.6.5 Testing and Validation of the maturity model

After the CW3M model is developed, construction professionals in Cambodia and Thailand will be requested to assess its practical utility. An evaluation questionnaire, as suggested by Asah-Kissiedu (2019), will be employed to validate the model and gather insights on its effectiveness in practical applications. This method is appropriate for evaluating and validating models (Adeniyi, 2017; Babatunde et al., 2016; Cheung, 2009; Yeung, 2007). The questionnaire will consist of two sections, with the first gathering background details of the respondents.

In the second section, participants will be asked to use the model and requested to evaluate the model using six criteria, namely the pertinence of attributes, inclusiveness of attributes, suitability, sufficiency of capability maturity levels, clarity, ease of utilization, and the degree of usefulness and practicality (Adeniyi, 2017; Asah-Kissiedu, 2019; Cheung, 2009). The extent of satisfaction was assessed based on a five-point Likert scale, in which experts were asked to select the relative score for each feedback aspect below to indicate your level of satisfaction, with 1 representing “Poor”, 2 “Average”, 3 “Good”, 4 “Very Good”, and 5 “Excellent” (Cheung, 2009; Osei-Kyei et al., 2018).

3.7 Sample sizes

3.7.1 The sample size for expert verification

Razak Al-Ani et al. (2016) employed 11 experts in their verification process, and Hartono et al. (2014) used 30 experts to verify the empirically validated project risk maturity model in the construction industry. In the current study, 32 experts were employed in the expert verification process, slightly exceeding 30, which is generally considered adequate for attribute verification as the higher the better for the sample size.

3.7.2 Sample size for factor analysis

As of January 2024, the Board of Engineers of Cambodia (BEC) documented approximately 7,465 registered engineers (BEC, 2024), and the number of registered architects was approximately 1,546 as of November 2022, according to the Ministry of Land Management, Urban Planning and Construction (MLMUPC, 2023). This resulted in a combined total of registered engineers and architects in Cambodia 9,011. Simultaneously, Thailand's Council of Engineers (CoE) reported approximately 201,000 registered engineers as of January 2024 (CoE, 2024). Additionally, the number of registered architects in Thailand was approximately 3,000, according to The Association of Siamese Architects, as of January 2024 (ASA, 2024). The total number of registered professionals, encompassing engineers and architects in Thailand, reached approximately 204,000. Consequently, Cambodia's and Thailand's registered engineers reached approximately 213,011.

According to Yamane (1973), the sample size is calculated as follows:

$$n = \frac{N}{1+N(e)^2}$$

Whereas,

- n: Sample size
- N: Population size
- e: Margin of error or level of precision

In this study, the population size, N=213,011; margin of error, e= 5.8% or 0.058(Lakens, 2022; Puisa et al., 2023), then the sample size can be calculated as below.

$$n = \frac{213{,}011}{1+213{,}011(0.058)^2} = 297.$$

Williams et al. (2010) acknowledge the importance of sample size in factor analysis. Still, there is a lack of consensus and varying opinions, leading to several guiding rules of thumb. Hogarty et al. (2005) noted that these disparate recommendations on sample size have not been beneficial for researchers. Various general guidelines exist, such as Tabachnick's rule of thumb (Tabachnick et al., 2007), suggesting a minimum of 300 cases for factor analysis. Hair et al. (2019) proposed that sample sizes should be 100 or greater. Williams et al. (2010) recommended sample sizes for Exploratory Factor Analysis (EFA) as follows: 100 as poor, 200 as fair, 300 as good, 500 as very good, and 1000 or more as excellent.

Hogarty et al. (2005); Williams et al. (2010) suggested the importance of guiding the sample-to-variable ratio, denoted as N:p ratio, where N represents the number of participants, and p represents the number of attributes. Disparate recommendations for sample-to-attribute ratios include 3:1, 6:1, 10:1, 15:1, or 20:1 (Williams et al., 2010). Despite these guidelines, studies by Hogarty et al. (2005) and MacCallum et al. (1999) testing these recommendations found no minimum N or N:p ratio level for achieving good factor recovery across examined conditions.

In this study, the calculated sample size is 297, falling slightly below the recommended range of 300 or above, which is considered good. However, the respondents' responses to our questionnaire were 304, which is deemed a suitable sample size for factor analysis, according to Williams et al. (2010).

3.7.3 The sample size for weighing attributes in BWM

According to Gupta et al. (2020), co-authored by Jafar Rezaei (an establisher of the BWM), eight experts were selected to interview in the pairwise comparison process, aiming to establish attribute weights related to “Barriers and overcoming strategies to supply chain sustainability innovation.” The study emphasized a minimum of five responses for each attribute, deeming response counts of 5, 6, 7, and 8 as acceptable for their research topic. Pamučar et al. (2021) also interviewed four experts for attribute weight establishment in BWM for a "new original integrated multicriteria decision-making model for healthcare waste management." Almahdi et al. (2019) also applied BWM, with four experts participating in the pairwise comparison process. Based on the above input, the number of experts for the pairwise comparison process for BWM could be used within the range of four to eight. However, a larger number of experts would yield more accurate results.

The optimum number of participants for a focus group may vary. Krueger (2014) suggests there should be between six and eight participants, as smaller groups show greater potential. However, Krueger (2014) added that the number generally indicated as being manageable is between six and ten participants, large enough to gain various perspectives and small enough not to become disorderly or fragmented. However, Tezel et al. (2021) applied focus group interviews to gather opinions from experts in three distinct groups to develop models for Supply Chain Management in Construction. These groups included (1) a contractor group comprising five experts, (2) an academia group with four experts, and (3) a client group with six experts. The number of experts in each focus group interview ranged from four to six.

Regarding the selection of experts, Almahdi et al. (2019) chose experts with a minimum of five years of experience in the related field, Gupta et al. (2020) selected experts with at least 10 years of experience, holding at least a bachelor's degree, and occupying management-level positions for attributes weight establishment in BWM.

Based on the references mentioned above, in our study, we plan to involve 10 experts for the focus group interviews for pairwise comparison to establish attribute weights in BWM (Best Worst Method). It was divided into two focus group interviews: a Cambodia group with five experts and another with a Thailand group with five experts. To achieve better results, this study selected experts with a minimum of 10 years of experience in building construction management, consistently involved in CWM. The experts hold at least bachelor's degrees and be in management positions.

3.7.4 Sample size for testing and validation of maturity model

According to Asah-Kissiedu et al. (2021b), they purposefully selected a panel of six experts to review and refine the developed maturity model. These experts held management positions in their respective fields, and the chosen panel size was considered appropriate. In addition, Cheung (2009) employed nine experts in management positions and researchers to validate a maturity model. Moreover, Adeniyi (2017) involved 10 experts in management positions to validate a maturity model. All these three studies involved sending the developed maturity models and questionnaires to experts for evaluation and validation. Their maturity models were related to construction management (Adeniyi, 2017; Asah-Kissiedu et al., 2021b; Cheung, 2009).

In this study, after developing the maturity model (CW3M), experts from 16 different contractors in Cambodia and Thailand were requested to use the model to test the model's practical utility. An interview with each expert through a guidance questionnaire was conducted to gain feedback from them and gather insights on the model's effectiveness in practical applications. All experts work in management positions, as executives or as owners of contractors, with 8 experts from Cambodia and 8 experts from Thailand. This approach aims to ensure a comprehensive evaluation by professionals actively involved in the construction industry. To achieve better results, this study selected experts from contractors with a minimum of 10 years of experience in building construction management, consistently involved in CWM. The experts hold at least bachelor's degrees and management positions (Asah-Kissiedu, 2019; Cheung, 2009; Gupta et al., 2020). This approach aims to ensure a comprehensive evaluation by professionals involved in building construction management.

3.8 Data analysis

The quantitative analysis of the questionnaire survey data was conducted using multivariate statistical methods, which were selected to handle complicated datasets with several independent and dependent variables (Tabachnick et al., 2007). The analyses pursued three main goals: (1) using descriptive statistical analysis to understand the data better; (2) assessing the validity and reliability of the measurement scale and identifying factors that underlie model constructs; and (3) evaluating and improving the model (Panuwatwanich, 2008). The first descriptive data analysis was carried out using the SPSS software (version 25) to get to know the data and ensure it satisfied the requirements for multivariate data analyses. To obtain a general understanding of respondents' perceptions of each construct across the entire survey population and similar groups, this involved looking at respondent profiles, screening the data (evaluating normality, means, standard deviations, and standard error of the mean), and performing preliminary analyses of mean values (Field, 2013). The statistical techniques employed in the testing to compare the means between the groups were the student's t-test (T-test), analysis of variance (ANOVA) or F-test. To compare the means of two groups, use the independent T-test; to compare the means of three or more groups, use the One-way ANOVA (F-test) (Cohen, 2013; Mishra et al., 2019; Zhou et al., 2017). Nevertheless, Welch's t-test and Welch's F-test were substituted due to variations in variances (Delacre et al., 2017; Erceg-Hurn et al., 2008; Karch, 2021; Vaccari et al., 2019). The measuring scale that was utilized in the questionnaire to capture the model construct was evaluated for validity and reliability after the descriptive analysis. Scale reliability, or the consistency of responses among scale items, was measured using Cronbach's alpha. Furthermore, to determine the degree to which a particular item contributed to the scale, "item-total correlations" were employed (Hair et al., 2019; Panuwatwanich, 2008). Apart from the reliability analysis, factor analysis was utilized to evaluate the validity of the measurement scale. Two consecutive procedures were employed for this purpose: (1) Exploratory Factor Analysis (EFA) and (2) Confirmatory Factor Analysis (CFA). EFA aimed to identify the quantity of components (Hair et al., 2019). Following CFA's validation of these findings, the Best Word Method (BWM) for attribute weighing in the development of CW3M was further applied (Rezaei, 2015).

This study followed the process outlined by Ikuabe et al. (2022), in which it involved conducting a survey questionnaire followed by descriptive analysis, examination of differences in means, exploratory factor analysis (EFA), and confirmatory factor analysis (CFA) for attribute grouping. Notably, this approach aligns with the methodology previously employed by Panuwatwanich (2008).

3.8.1 Descriptive data analysis

Descriptive analysis was utilized to present the profiles of survey respondents, perform data screening (including checks for missing data, normality tests, outlier tests, and assessment of standard deviation), and present preliminary findings, aiming to identify statistical differences in sample means (Hair et al., 2019).

Subsequently, a consistency test among the groups was conducted, employing Student's t-test (T-test) and analysis of variance (ANOVA) or F-test for hypothesis testing on mean comparisons between groups. While T-test and F-test are commonly used for comparing means, they assume equal variances among groups, and sample sizes should be sufficient to ensure robust results (Cohen, 2013; Mishra et al., 2019; Zhou et al., 2017). Traditional T-test and F-test may not provide strong results in cases of heterogeneity of variances, which is non-parametric data. Welch's Test was applied instead of the classical T-test or F-test to address this. Welch's Test is a robust statistical method that accounts for different group variances, ensuring more reliable results (Delacre et al., 2019; Karch, 2021; Liu, 2015). The testing decision flow chart for comparing among groups is summarized as shown in **Figure 3.5**.

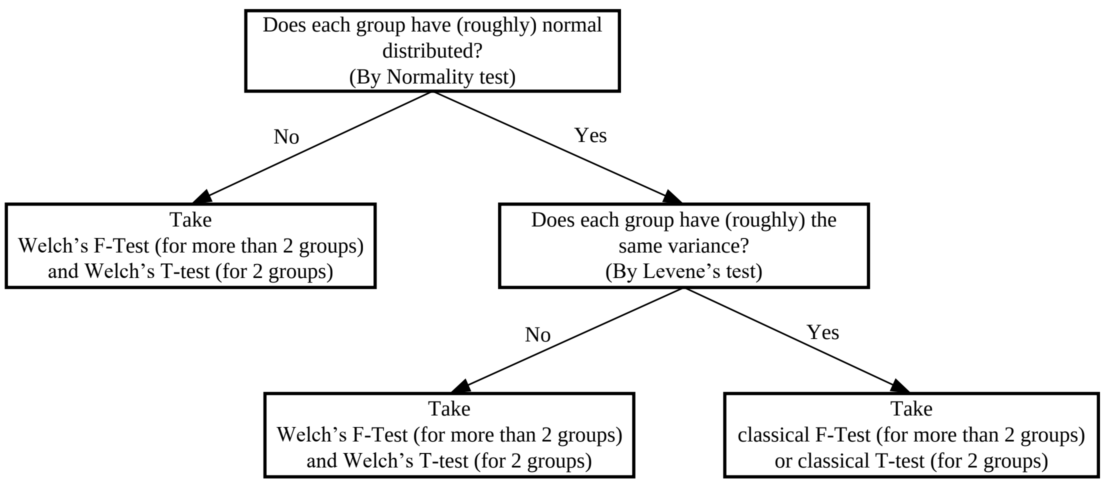


Figure 3.5 Testing decision flow chart for comparing groups

3.8.2 Reliability test

When using a reliability test to assess internal consistency, a result of greater than 0.7 for Chronbach's alpha is deemed sufficient (Cronbach, 1951). Additionally, the items-total correlation was examined to verify the items' relationship. Items are considered inappropriate and are eliminated when the items-total correlation value is less than 0.3.

3.8.3 Exploratory factor analysis

In this investigation, exploratory factor analysis (EFA) was conducted using the approach described by Hair et al. (2019); Kim et al. (1978). EFA's main objective is to minimize information loss while condensing data from a larger set of original attributes into a smaller set (factors). EFA provides an objective basis for summated scale creation by offering an empirical estimation of the structure of the investigated attributes (Hair et al., 2019; Thompson, 2004; Williams et al., 2010). EFA is a technique that validates expectations based on existing theory by identifying factors and factor loadings of measurable attributes (Thompson, 2004; Williams et al., 2010; Win, 2019).

EFA has been used in many construction-related research. For example, Chan et al. (2019) classified these criteria from the viewpoints of affordable housing specialists worldwide by utilizing EFA to develop critical success criteria (CSC) for performance measurement in sustainable, affordable housing projects. Soewin et al. (2018) used EFA to discover elements influencing construction performance in Thailand to facilitate efficient performance development planning. Using EFA, Ajayi et al. (2017b) examined essential site management techniques for CW minimization, highlighting the significance of contractual provisions for waste reduction. Udawatta et al. (2015) used EFA to identify practical strategies for reducing waste production in building projects and developed 26 essential WM solutions. Chinda (2016) studied the critical variables influencing the choice of construction safety equipment in the Thai construction sector. The study confirmed six important variables: equipment design, safety-related policies, supplier agreements, assistance, personal characteristics, and cost-value considerations.

EFA analysis can be performed using a variety of software packages, including the Bio-Medical Data Package (BMDP), Statistical Analysis System (SAS), and Statistical Package for the Social Sciences (SPSS) (Field, 2013; Win, 2019). In this study, SPSS Version 27 was selected.

3.8.4 Confirmatory factor analysis

Confirmatory Factor Analysis (CFA), an advanced analytical technique judged more rigorous than exploratory methods like item-total correlation and EFA, was utilized in the study to assess construct validity and unidimensionality thoroughly (Bandalos et al., 2018; Gerbing et al., 1988). A factor structure that has already been constructed and the loadings that go along with it can be tested using CFA (Hair et al., 2019; Kline, 2023). It allows testing a known dimensional structure in other populations, validating an existing structure, and improving an existing theoretical perspective (DiStefano et al., 2005). CFA was used to strengthen the preliminary factor structure derived from EFA based on extracted factors and loadings to refine further and reinforce the identified factor structures. This procedure assessed construct validity and unidimensionality by looking at model parameters and assessing how well the construct's factor structure suited the data (Hair et al., 2019). According to Hair et al. (2019), the CFA model illustrated correlations showing how the measured qualities reflected a latent factor by treating the factor structure as a model. Like EFA, the CFA model specification required knowledge and specification of the number of factors and the relationships between attributes and factors before analysis (Hair et al., 2019). Using a multi-dimensional approach, the model assessment took into account several indices, including the Bentler comparative fit index (CFI), goodness-of-fit index (GFI), Satorra-Bentler scaled chi-square (S–Bχ^2), root mean square error of approximation (RMSEA), and goodness-of-fit index (GFI) (Ikuabe et al., 2022). The model fit indices threshold requirements for a good-fit model are shown in **Table 3.4**.

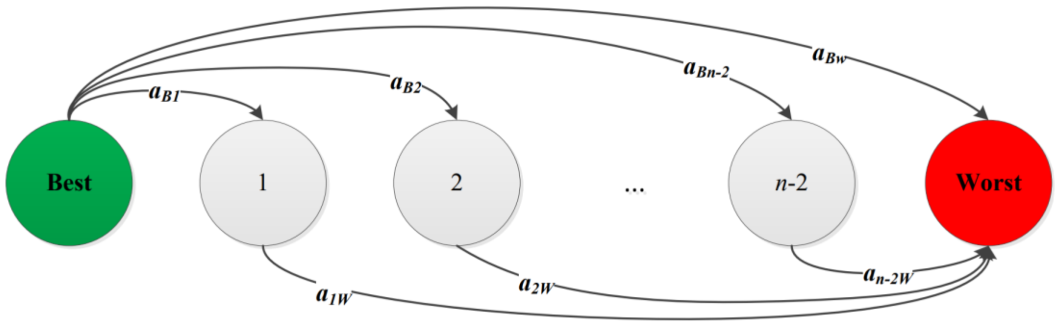
Table 3.4 Model fit indices threshold

Fit indices	Threshold and references (recommended)
Chi-square(χ^2)	-
Df	-
p-value	-
x2/Df	< 3 (Hair et al., 2019; Kline, 2023)
GFI	> 0.8 (Cheng, 2011; Doll et al., 1994)
TLI	> 0.9 (Hoyle, 1995; Kline, 2023; Xia et al., 2019)
CFI	> 0.9 (Hoyle, 1995; Kline, 2023; Xia et al., 2019)
IFI	> 0.9 (Hoyle, 1995; Kline, 2023)
NFI	> 0.8 (Bentler et al., 1980; Simon et al., 2010)
RMSEA	< 0.08 (Browne et al., 1992; Hair et al., 2019; Steiger, 1990; Xia et al., 2019)
SRMR	< 0.08 (Bagozzi et al., 2012; Hu et al., 1999)

3.8.5 Best worst method

In this study, the Best Worst Method (BWM) was employed to conduct pairwise comparisons to identify the relative importance of the attributes. According to Rezaei (2015), the steps to obtain the local weights of criteria (attributes) using the BWM are as follows:

- **Step 1:** Determine a set of criteria, i.e., n criteria (attribute). In this study, the criteria consisted of 27 attributes under five factors derived from the Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA).
- **Step 2:** Determine the "best" and the "worst" criteria from the set of criteria defined in Step 1. In this study, the best and worst criteria under each respective factor, as well as the best and worst factors among the five factors, were determined by each expert during the interview.
- **Step 3:** Determine the preference of the "best" criterion over all the other criteria using a number between 1 and 9. In this study, the best criteria under each respective factor, as well as the best factors among the five factors, were determined by each expert during the interview.
- **Step 4:** Determine the preference of all the other criteria over the "worst" criterion using a number between 1 and 9. In this study, the worst criteria under each respective factor, as well as the worst factors among the five factors, were determined by each expert during the interview.
- **Step 5:** Find the local weights of each criterion. In this study, the local weights of each criterion and the local weights of each factor were obtained using the BWM Solvers (Rezaei, 2022). The BWM reference comparison is shown in **Figure 3.6**.



Note: a_B: best attribute; a_W: worst attribute; n: number of attributes

Figure 3.6 BWM reference comparison

Source(s): (Rezaei, 2015)

To determine the global weights of the attributes, the local weights of the attributes under each factor were multiplied by the corresponding local weight of the factor (Chen et al., 2013; Haseli et al., 2020; Rezaei, 2015; Saaty, 2004). Global weight is the final weight of all attributes (Rezaei, 2015; Saaty, 2004). The sum of all weights should equal 1. The global weights were then normalized to ensure the sum of all weights equals 1; these are standardized global weights (Chitsaz et al., 2017).

The pairwise comparisons were conducted with input from 10 construction professionals with at least 10 years of building construction management experience and CWM involvement. The experts were drawn from two countries, with five from Cambodia and five from Thailand. All held at least a bachelor's degree and occupied management positions. This approach aligns with recommendations from prior studies using the BWM for attribute weight establishment, which suggest utilizing 4 to 8 experts, with a larger number yielding more accurate results. For example, Pamučar et al. (2021) interviewed four experts for attribute weight establishment in BWM for a "new original integrated multi-criteria decision-making model for healthcare WM," while Gupta et al. (2020) employed eight experts for the pairwise comparison process to establish attribute weights related to "Barriers and overcoming strategies to supply chain sustainability innovation." Moreover, Gupta et al. (2020) selected experts with at least 10 years of experience, holding at least a bachelor's degree, and occupying management-level positions for attributes weight establishment in BWM.

CHAPTER 4

ATTRIBUTES IDENTIFICATION AND VERIFICATION

4.1 Introduction

A preliminary study was conducted to verify the list of final attributes and develop a maturity model to assess construction waste management. The list of attributes was extracted from the literature view and then done with frequency analysis to get a list of attributes. This list of attributes was then used to develop the expert verification questionnaire for the expert verification process.

4.2 Identification of attributes

The attributes for analysis were derived from a comprehensive literature review, followed by a frequency analysis. A literature review serves as a systematic strategy for collecting and synthesizing prior works that are more or less organized, fostering an in-depth understanding of a specific research topic and laying a robust foundation for theory and knowledge development (Zhao et al., 2022). Only attributes identified in journal papers that ranked at least in the second quartile (Q2) were considered for analysis in this study. However, it is noteworthy that most of the journal papers reviewed fell within the first quartile (Q1) (Zhao et al., 2022). A rigorous screening process, including examination of titles, abstracts, and keywords, was undertaken from Google scholar, Scopus, Litmaps and others (Arief et al., 2023; Darko et al., 2017; Kaur et al., 2022; Normann et al., 2023), 63 journal articles which contained the list of attributes contributing to better CWM were identified and subsequently, attributes extraction was carried out based on 43 selected journal articles. The earliest publication was in 1996 by Bossink et al. (1996), while the most recent was in 2023 by Bao et al. (2023). The detailed list of attributes from the output of frequency analysis is shown in **Table 4.1**.

4.3 Frequency analysis

The primary objective of this stage was to identify attributes contributing to better CWM in building construction, intending to minimize waste generation through prevention and reuse. A total of 43 articles were reviewed, yielding 92 potential attributes that underwent subsequent analysis using frequency analysis to identify the most common attributes. Attributes with a frequency of at least 86% were deemed acceptable(Soewin et al., 2020), while those with a frequency below 14% were excluded, except two attributes retained with a frequency of 13.3%. The remaining 53 attributes were categorized into seven groups: Management and Leadership, Manpower, Policies and Strategies, Materials, Equipment and Tools, Construction Methods and Processes, and Documentation. **Table 4.1** below provides a comprehensive overview of the analysis of various attributes contributing to better CWM.

4.3.1 Management and leadership

Management and Leadership emerged as the most extensively studied category, with 33 studies focusing on contractors' awareness of CWM impacts on sustainable construction. The studies underscored the significance of effective site management, precise on-site material control, and senior management’s behaviour and attitude toward CWM. Adequate supervision of waste management (WM) activities, clear instructions, effective coordination and communication among project stakeholders, work experience in CWM, and a waste minimization culture within the company were also identified as critical for effective CWM.

4.3.2 Manpower

Within the Manpower category, the most studied attribute (33 studies) was the training and education of engineers and workers on WM and its effectiveness, followed by the assignment of workers solely for waste minimization (17 studies). Other essential attributes included skilled workers, workmanship, and the engagement of all stakeholders in CWM.

4.3.3 Policies and Strategies

The Policies and Strategies category emphasized the importance of establishing a strict CWM policy within the company, setting REDUCE and REUSE targets for each project, and developing an appropriate WM plan in the early stages of each construction project. Suggestions also included incorporating WM targets and responsibilities in contractual documents, providing financial rewards and incentives for waste reduction and reuse, and assessing contractors' current CWM abilities and future targets.

4.3.4 Materials

In the Materials category, critical attributes for effective CWM included having central areas for cutting and storage, ensuring adequate protection during material transportation and handling, and protecting different categories of materials during storage and stacking. Additional recommendations focused on preventing errors, ordering appropriate material sizes and quantities to avoid excess, and using quality, durable, and standardized materials.

4.3.5 Equipment/Tools

Within the Equipment/Tool category, the study highlighted the importance of using and being familiar with Building Information Modeling (BIM) and other related information technologies. Other critical attributes included the availability and quality of equipment, familiarity with equipment use, and the use of metal scaffolding and formwork for effective CWM.

4.3.6 Construction method and processes

In the Construction method and processes category, key attributes included ensuring adequate site space, maintaining a clear site layout for materials movement, setting up separate bins by waste type, and efficiently using materials to minimize uneconomical cutting shapes and lengths. Effective implementation of a WM plan, storing waste in easily accessible areas, and adopting prefabricated structural elements and preassembled components were also identified as necessary.

4.3.7 Documentation

Lastly, in the Documentation category, attributes critical to effective CWM included minimizing variation orders, controlling CWM documentation effectively, minimizing design changes during construction, preventing shop drawing detailing errors, and maintaining a lesson-learned repository on CWM. Professional quality management and certification, such as ISO and GREEN certifications, were also important.

The comprehensive results highlighted the significance of various attributes in better CWM, spanning Management and Leadership, Manpower, Policies and Strategies, Materials, Equipment/Tools, Construction methods and processes, and Documentation. This study's stage findings offer valuable insights into the process of attribute verification as a part of the development of CW3M for contractors seeking to enhance their CWM practices in building construction.

Table 4.1 Result of frequency analysis of the contractor's controlling attributes contribute to effective CWM in building construction

No.	Categories	Factors/ Attributes	1 (Ganiyu et al., 2020)	2 (Poon et al., 2004)	3 (Lu et al., 2010)	4 (Kabirifar et al., 2020)	5 (Tam, 2008)	6 (Ghaffar et al., 2020)	7 (Kabirifar et al., 2020a)	8 (Daoud et al., 2021)	9 (Wu et al., 2017)	10 (Osmani et al., 2008)	11 (Ajayi et al., 2015)	12 (Li et al., 2022)	13 (Janani et al., 2022)	14 (Jaillon et al., 2009)	15 (de Magalhães et al., 2017)	16 (Bossink et al., 1996)	17 (Ajayi et al., 2018)	18 (Fernández S. et al., 2010)	19 (Andersson et al., 2022)	20 (Ding et al., 2018)	21 (Udawatta et al., 2015)	22 (H. Yuan, 2013)	23 (Saheed O Ajayi et al., 2017)	24 (Lu et al., 2021)	25 (Cha et al., 2009)	26 (Kolaventi et al., 2018)	27 (Newaz et al., 2022)	28 (Bao et al., 2020b)	29 (Wang et al., 2010)	30 (Yeheyis et al., 2012)	31 (Bakshan et al., 2017)	32 (Wang et al., 2014)	33 (Begum et al., 2009)	34 (Bao et al., 2021)	35 (Zhao et al., 2022)	36 (Doust et al., 2020)	37 (Menegaki et al., 2018)	38 Kolaventi et al. (2020)	39 (Umar et al., 2016)	40 (Yuan et al., 2022)	41 (Yuan, 2013)	42 (Ajayi et al., 2017)	43 (Zulu et al., 2022)	Number of studies	Number of studies in (%)
1	Management and leadership	Contractor's awareness of CW impacts on sustainable construction	√	√	√	√	√	√	√	√	√		√	√			√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√		√	√					√	**33**	**73.3**
2		Contractor's effective and efficient site management	√		√	√	√	√	√		√	√	√	√	√	√	√	√	√	√	√		√			√		√	√	√	√		√	√		√			√			√	√			**29**	**64.4**
3		Contractors' precise on-site material control (e.g., inspecting the materials when they arrive, etc.)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√		√	√			√		√	√	√	√	√	√		√			√					√			**29**	**64.4**
4		Senior management behavior and attitude on CWM	√	√	√	√	√		√	√	√		√	√	√	√	√		√	√	√	√	√						√	√	√		√	√	√	√	√		√							**27**	**60.0**
5		Contractor's adequate supervision on WM activities with clear instructions	√		√	√	√				√	√	√	√	√	√	√	√	√	√		√	√			√			√	√	√		√	√		√			√				√			**25**	**55.6**
6		Effective coordination and communication among project stakeholders	√	√	√	√		√	√	√	√	√	√			√	√		√		√		√			√	√			√	√		√		√				√				√			**23**	**51.1**
7		Contractor's work experience on CWM and waste-minimizing culture within the company	√	√		√				√	√	√	√	√	√	√	√	√		√		√	√	√						√			√	√	√											**20**	**44.4**
8		Contractor's action to reduce CW generation		√		√	√		√	√	√		√	√	√	√	√			√	√	√	√										√	√	√		√									**19**	**42.2**
9		Contractor's action to reuse CW		√		√	√		√	√	√		√	√	√	√	√			√	√	√	√										√	√	√		√									**19**	**42.2**
10		Contractor detailed study and well understanding of specifications and drawing	√	√	√	√			√	√		√	√		√		√	√	√							√			√	√							√	√								**17**	**37.8**
10		Contractor's on-time accurate quantification of material/ bill of quantity	√	√	√	√			√	√		√	√		√		√	√	√							√			√	√							√	√								**17**	**37.8**
11		Organization breakdown structure for CWM	√				√		√			√		√	√				√	√	√						√	√	√	√																**13**	**28.9**
12		Prevent site accidents	√		√		√	√				√						√		√			√	√														√								**10**	**22.2**
13		Monitor and audit waste management system periodically					√	√	√		√	√								√	√					√										√										**10**	**22.2**
14		Looking to get a support from the client (the project owner)	√								√					√			√								√	√									√									**7**	**15.6**
15	Manpower	Effective training and education for the engineers and workers on WM	√	√	√	√	√	√	√	√	√	√	√	√	√			√		√	√	√	√	√			√	√	√	√			√	√	√		√		√	√	√	√	√		√	**33**	**73.3**
16		Workers are assigned solely for waste minimization							√		√		√	√	√	√						√		√		√	√	√			√		√		√		√			√	√					**17**	**37.8**
17		Skilled workers and workmanship		√				√	√		√			√	√	√	√	√			√	√		√		√							√					√			√					**16**	**35.6**
18		Engagement of all stakeholders in CWM	√	√	√		√	√	√	√			√	√							√	√	√								√		√		√		√									**16**	**35.6**
19	Policy and strategy	Establish a strict policy on CWM within the company (including the CWM system)	√		√	√	√	√		√	√	√	√	√	√	√	√		√		√	√	√		√	√	√	√	√			√	√	√		√	√		√	√	√	√	√	√	√	**34**	**75.6**
20		REDUCE target for every project and maximize material reduction at the construction site	√	√	√	√	√	√		√	√	√	√	√	√	√	√		√			√		√	√	√	√	√				√		√	√		√		√			√		√	√	**29**	**64.4**
21		REUSE target for every project and maximize material reuse at the construction site	√	√	√	√	√	√		√	√	√	√	√	√	√	√		√			√		√	√	√		√				√		√	√		√		√					√	√	**27**	**60.0**
22		Establish an appropriate waste management plan in the earlier stage of each construction		√	√	√		√	√		√	√	√	√	√		√	√	√			√				√	√		√			√	√			√		√	√	√	√	√			√	**26**	**57.8**
23		Contractual documents may include the responsibilities of sub-contractors on WM targets	√		√	√	√	√		√	√	√	√		√			√	√				√		√	√	√	√	√			√		√		√	√			√				√		**24**	**53.3**
24		Financial rewards and incentives for effective decrease and reuse of waste			√	√			√		√	√	√	√	√	√					√	√	√				√			√			√						√			√	√		√	**19**	**42.2**
25		Contractor's current waste assessments score and future target					√	√	√		√	√	√							√	√					√										√				√		√				**12**	**26.7**

Table 4.1 Result of frequency analysis of the contractor's controlling attributes contribute to effective CWM in building construction

No.	Categories	Factors/ Attributes	1 (Ganiyu et al., 2020)	2 (Poon et al., 2004)	3 (Lu et al., 2010)	4 (Kabirifar et al., 2020)	5 (Tam, 2008)	6 (Ghaffar et al., 2020)	7 (Kabirifar et al., 2020a)	8 (Daoud et al., 2021)	9 (Wu et al., 2017)	10 (Osmani et al., 2008)	11 (Ajayi et al., 2015)	12 (Li et al., 2022)	13 (Janani et al., 2022)	14 (Jaillon et al., 2009)	15 (de Magalhães et al., 2017)	16 (Bossink et al., 1996)	17 (Ajayi et al., 2018)	18 (Fernández S. et al., 2010)	19 (Andersson et al., 2022)	20 (Ding et al., 2018)	21 (Udawatta et al., 2015)	22 (H. Yuan, 2013)	23 (Saheed O Ajayi et al., 2017)	24 (Lu et al., 2021)	25 (Cha et al., 2009)	26 (Kolaventi et al., 2018)	27 (Newaz et al., 2022)	28 (Bao et al., 2020b)	29 (Wang et al., 2010)	30 (Yeheyis et al., 2012)	31 (Bakshan et al., 2017)	32 (Wang et al., 2014)	33 (Begum et al., 2009)	34 (Bao et al., 2021)	35 (Zhao et al., 2022)	36 (Doust et al., 2020)	37 (Menegaki et al., 2018)	38 Kolaventi et al. (2020)	39 (Umar et al., 2016)	40 (Yuan et al., 2022)	41 (Yuan, 2013)	42 (Ajayi et al., 2017)	43 (Zulu et al., 2022)	Number of studies	Number of studies in (%)
26	Materials	Having central areas for cutting and storage		√		√	√	√	√	√	√	√			√	√	√	√	√						√	√				√	√	√			√	√		√					√	√		**23**	**51.1**
27		Adequate protection of material transportation and handling (loading and unloading)	√	√	√	√	√	√	√	√		√	√		√	√		√						√	√		√	√			√	√				√		√					√			**22**	**48.9**
28		Adequate protection of different categories of materials during storage and stacking	√	√	√	√	√		√	√		√	√		√		√	√							√			√			√	√						√		√						**18**	**40.0**
29		Preventing from ordering errors and purchase appropriate material sizes and quantities to avoid excess	√	√	√	√	√	√	√	√		√			√			√					√		√		√									√		√						√		**17**	**37.8**
30		Use of quality and durable, and standardized materials		√	√	√		√		√			√			√		√		√			√		√	√						√							√							**14**	**31.1**
31		Adopt Just in Time delivery (JIT) system	√	√					√	√	√			√				√							√				√	√	√	√				√										**13**	**28.9**
32		Strong security at the project site (i.e., prevent theft and loss of materials)		√	√	√	√			√		√				√		√		√					√		√					√						√								**14**	**31.1**
33	Equipment or	Use and familiar with the application of BIM	√	√	√	√	√	√	√	√	√		√	√		√			√		√		√	√	√					√		√				√					√				√	**22**	**48.9**
34		Use and familiar with other related information technologies	√	√	√	√	√	√	√	√	√		√	√		√			√		√		√	√	√					√						√					√				√	**21**	**46.7**
35		Availability of quality of equipment (i.e., tools, machines, and vehicles)		√	√	√					√			√				√			√			√						√	√										√					**11**	**24.4**
36		Familiar with the equipment usage		√		√		√	√	√	√			√		√					√			√																	√					**11**	**24.4**
37		Use of scaffolding and formwork that can be reused many times (e.g., metal, plastic etc.)			√	√	√				√			√							√	√		√										√								√				**10**	**22.2**
38	Construction method and process	Adequate site space and the site layout are cleared for materials movement	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√				√	√		√	√	√	√	√	√			√	√		√		√			√	√		**31**	**68.9**
39		Set up separated bins according to the waste type and sort out waste at the site	√	√	√	√	√	√	√	√	√			√	√					√	√	√		√		√	√	√	√		√	√				√			√	√	√		√	√		**27**	**60.0**
40		Efficient use of materials and minimizing the uneconomical cutting shapes and length	√		√	√	√	√		√			√			√	√	√	√	√			√	√	√	√		√	√		√	√	√		√			√				√	√			**25**	**55.6**
41		Effective implementation of a waste management plan		√			√	√	√		√	√		√	√		√	√		√	√	√						√	√		√	√	√				√	√	√		√	√				**23**	**51.1**
42		Store waste in easily accessible areas	√	√	√	√	√	√		√		√				√	√			√					√	√	√	√	√	√	√				√	√		√		√				√		**23**	**51.1**
43		Bins are installed on every floor	√		√	√	√	√	√	√	√			√	√					√	√	√		√	√			√	√		√	√							√	√	√					**22**	**48.9**
44		Adopt prefabricated structural elements	√	√	√		√	√	√	√		√		√		√			√			√	√	√	√		√							√			√			√	√	√				**21**	**46.7**
45		Adopt preassembled components such as bathroom & kitchen pods	√	√	√		√	√	√	√		√		√		√			√			√	√	√	√		√							√			√			√	√	√				**21**	**46.7**
46		Minimizing waste from application processes (i.e., overpreparation of mortar)	√	√	√		√	√									√	√	√	√	√			√		√		√	√													√				**15**	**33.3**
47		Minimizing rework at the construction site	√					√	√						√		√					√			√		√			√					√		√					√				**12**	**26.7**
48	Documentation	Minimizing variation orders (VO)	√	√					√	√		√	√				√	√	√			√		√	√									√				√						√		**15**	**33.3**
49		Document control of CWM with effectiveness (amounts, kinds, etc.)	√		√	√						√			√	√			√	√			√			√	√	√	√										√	√						**15**	**33.3**
50		Minimizing design changes during construction	√	√								√	√				√	√	√					√										√				√						√		**11**	**24.4**
51		Shop drawing detailing errors preventing	√	√								√					√	√	√																			√								**7**	**15.6**
52		Professional quality management and certification (e.g., ISO, GREEN, etc.)						√									√			√	√																		√						√	**6**	**13.3**
53		Lesson learned repository on CWM	√												√			√		√										√				√												**6**	**13.3**
54		**TOTAL**	**37**	**35**	**34**	**34**	**34**	**33**	**33**	**32**	**32**	**31**	**29**	**29**	**29**	**28**	**27**	**26**	**25**	**25**	**24**	**24**	**23**	**23**	**22**	**22**	**21**	**21**	**20**	**20**	**19**	**19**	**18**	**18**	**17**	**17**	**17**	**17**	**17**	**15**	**14**	**14**	**12**	**11**	**10**		

In summary, a comprehensive review of 43 articles was conducted to ascertain the attributes pertinent to contractors contributing to effective CWM) in building construction. All attributes were identified through a subsequent analysis and synthesized into seven distinct categories: i. Management and Leadership (14 attributes), ii. Manpower (4 attributes), iii. Policies and Strategies (7 attributes), iv. Materials (7 attributes), v. Equipment and tools (5 attributes), vi. Construction method and processes (10 attributes), and vii. Documentation (6 attributes). This stage contributes to the literature on CWM in building construction by delineating critical attributes that contractors need to consider to achieve better CWM. In future studies, these attributes will undergo further analysis and serve as key components in developing a maturity model. This model aims to assist contractors in assessing their CWM practices in building construction, providing a framework for evaluating performance and identifying areas for improvement. Ultimately, the development and utilization of such a model are anticipated to enhance CWM practices within the construction industry.

4.4 Expert verification of attributes

Expert verification was considered a crucial step before the development of the maturity model, as it was necessary to finalize the right attributes list for further development of the maturity model. To this end, a questionnaire was formulated, utilizing the attributes list derived from the frequency analysis results. The questionnaire was initially developed in English and subsequently translated into Khmer (Cambodian) and Thai languages.

4.4.1 Respondents sampling

The verification exercise aimed: (a) to ensure that the identified capability attributes were appropriate and comprehensive enough to be included in developing the CW3M model and (b) to identify any additional capability attributes that may have been overlooked. A group of experts was carefully selected based on specific criteria, as guided by Asah-Kissiedu et al. (2021b). These criteria included at least five years of professional experience in the construction industry, work experience should be involved in CWM, an advanced degree in Construction Management or a related field (at least a bachelor's degree), an affiliation with a professional body, and academic research experience in construction management in Cambodia and Thailand. The selected experts possessed relevant experience and expertise in CWM, particularly in Cambodia and Thailand. A total of 55 experts were selected and engaged in the verification process through interviews and questionnaires. The respondents were given 19 days to respond, and 32 responses were received, which was considered sufficient based on the study of Asah-Kissiedu et al. (2021b), with 9 responses (experts). The results of the verification exercise are presented in the Table **Table 4.2**, confirming the relevance and comprehensiveness of the capability attributes for effective CWM.

4.4.2 Preliminary questionnaire development

After performing a frequency analysis, a preliminary questionnaire consisting of 56 attributes was developed. The questionnaire was designed to elicit responses from experts in the field, using a 5-point Likert scale to indicate their level of agreement. The scale ranged from 1, representing "strongly disagree," to 5, representing "strongly agree".

A pilot test was conducted to ensure the questionnaire's effectiveness, and it involved five Ph.D researchers specializing in construction management and related fields. During this process, specific questions were refined for better clarity and understanding. The final preliminary questionnaire made during the pilot test are shown in APPENDIX 1.

4.4.3 Preliminary data collection

A preliminary data collection was conducted between 11th and 30th March 2023 to elicit insights from experts in Cambodia and Thailand. Of the 55 experts approached to participate in the questionnaire, 32 experts provided their responses. This data collection process was carried out through two distinct methods. The first method involved utilizing a questionnaire as a guide for conducting online interviews with eight experts via platforms such as Zoom and Google Meet. The second method entailed an online questionnaire survey with 24 experts.

4.4.4 Preliminary data analysis

The preliminary data analysis was done with the data screening, then analysis using the mean value of 3.5, and then the item-total correlation was conducted using SPSS version 25.

4.4.4.1 Demographic of experts

The results of the experts' demographic are shown in **Figure 4.1** to **Figure 4.9** below.

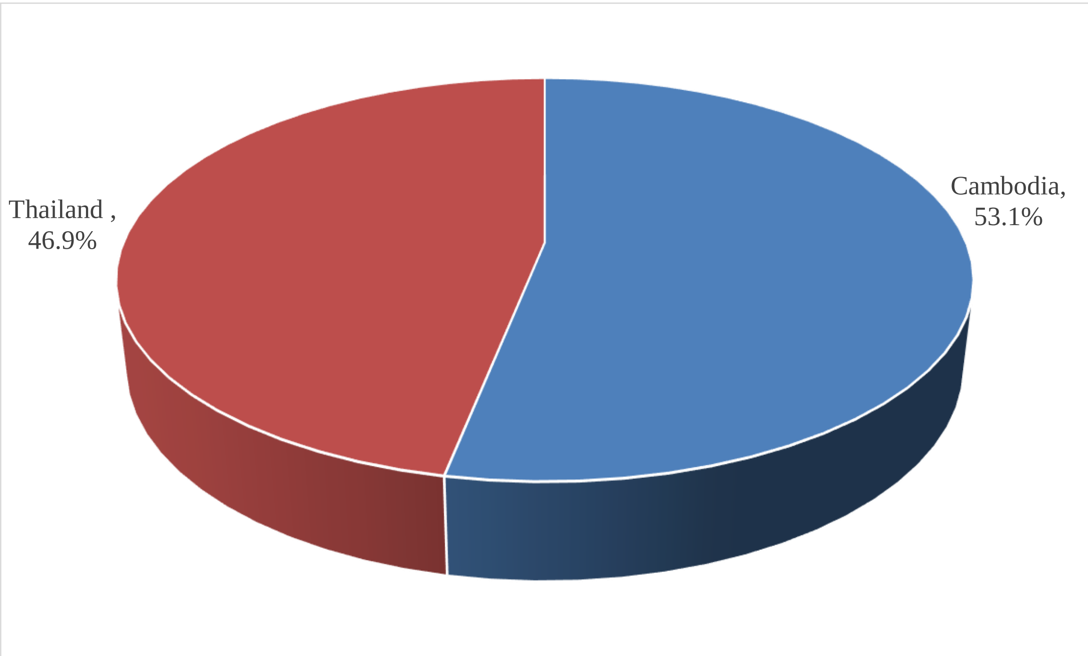


Figure 4.1 Countries

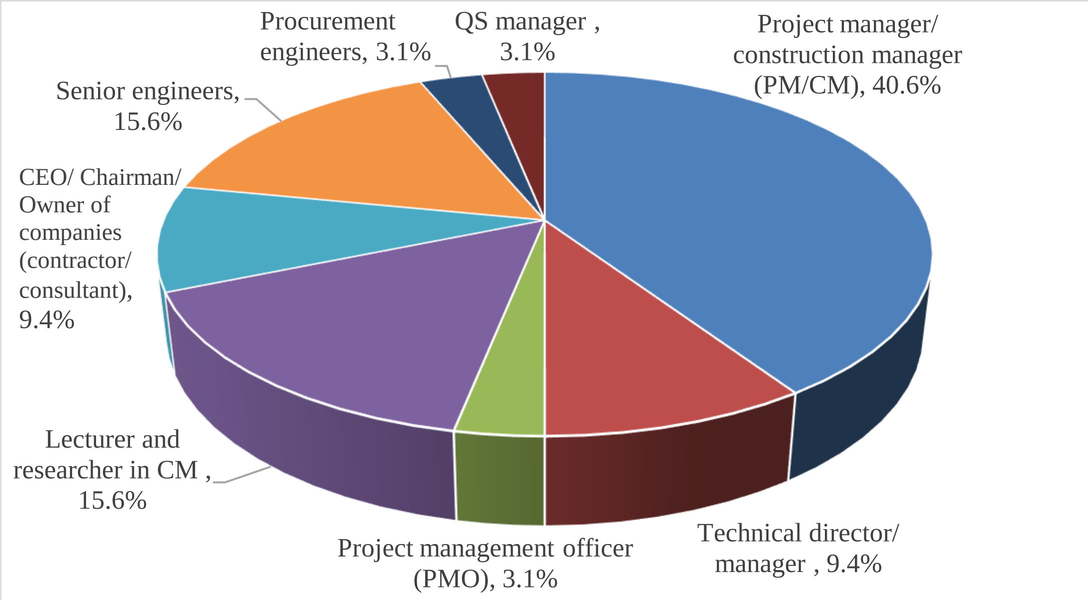


Figure 4.2 Positions

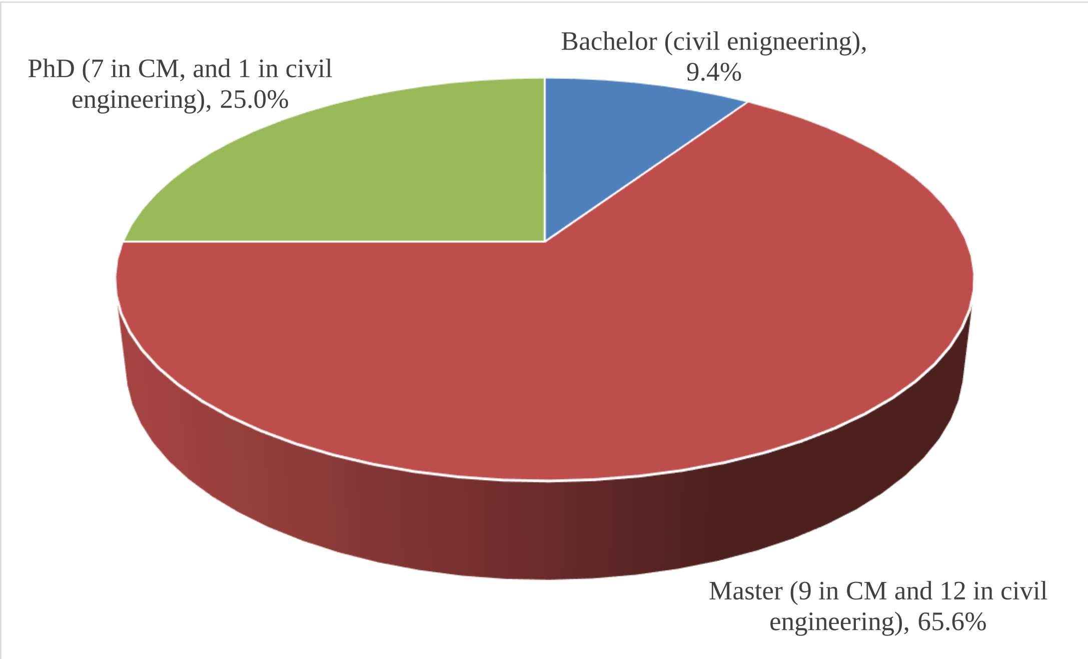


Figure 4.3 Level of education

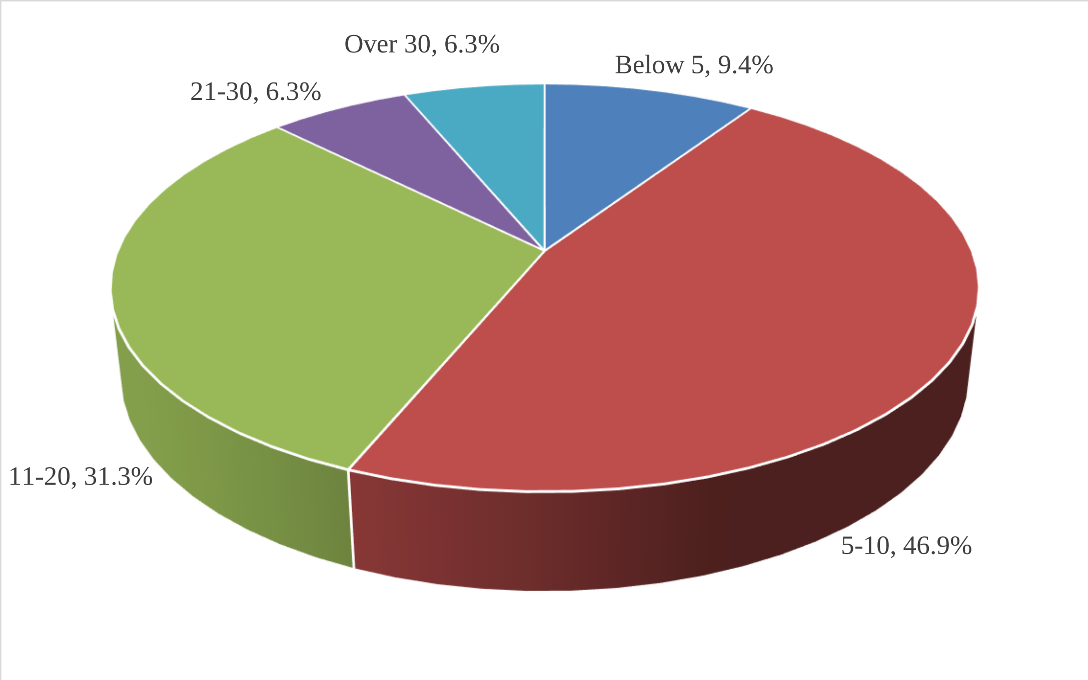


Figure 4.4 Years of experience in the construction industry

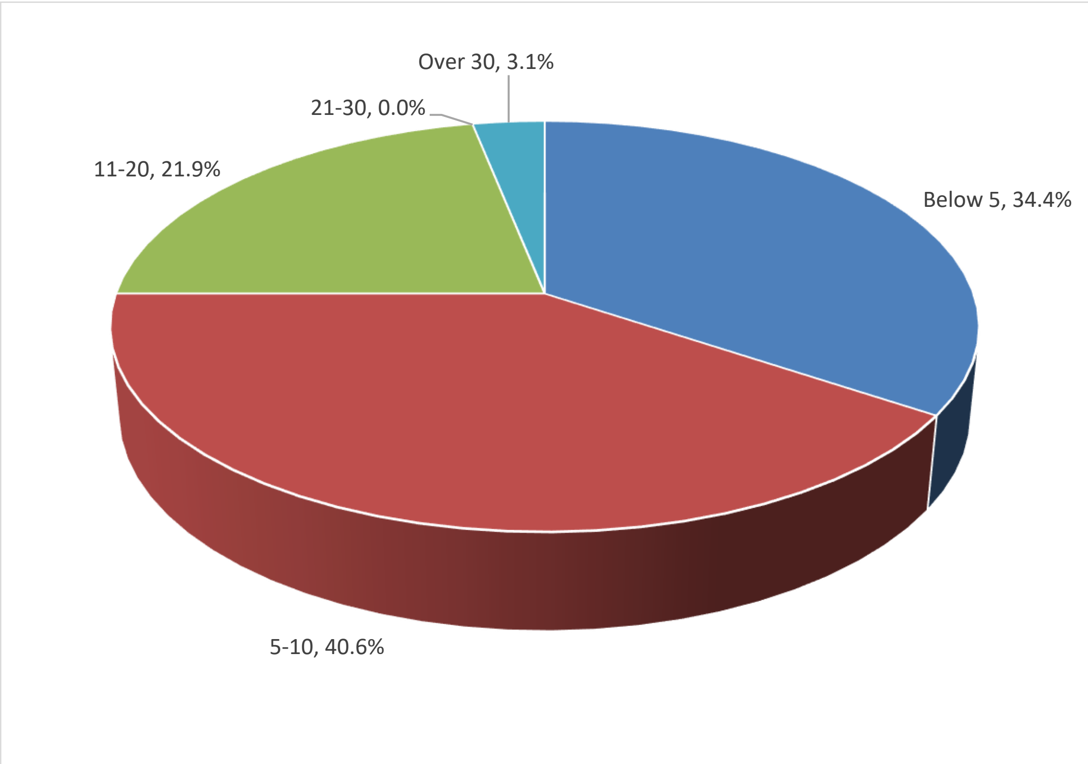


Figure 4.5 Years of experience working as contractor(s)

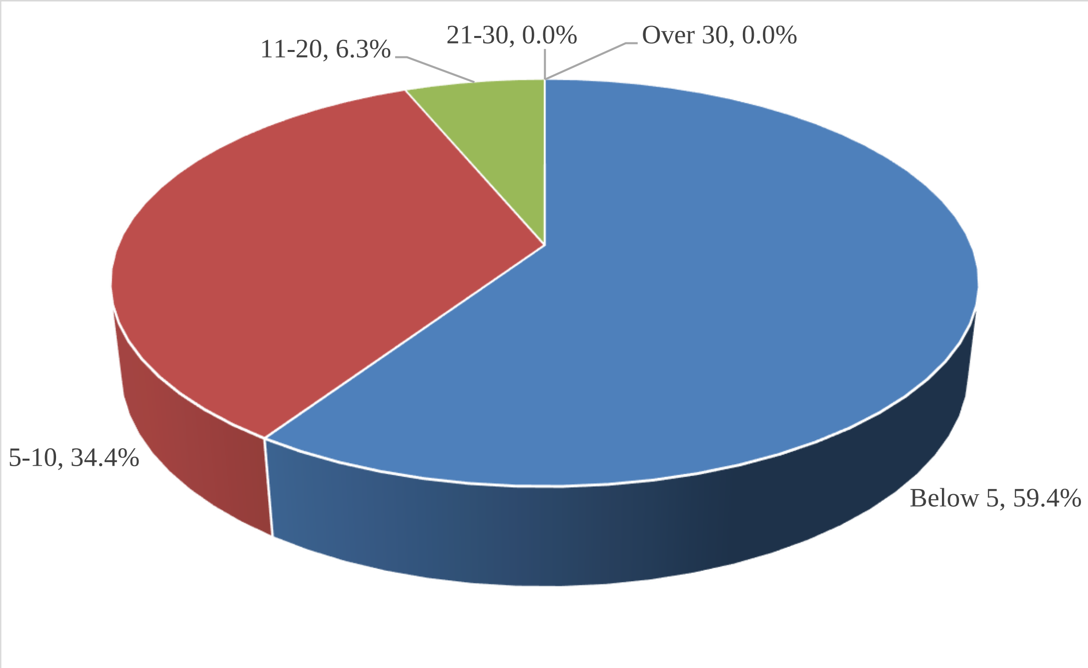


Figure 4.6 Years of experience related to CWM

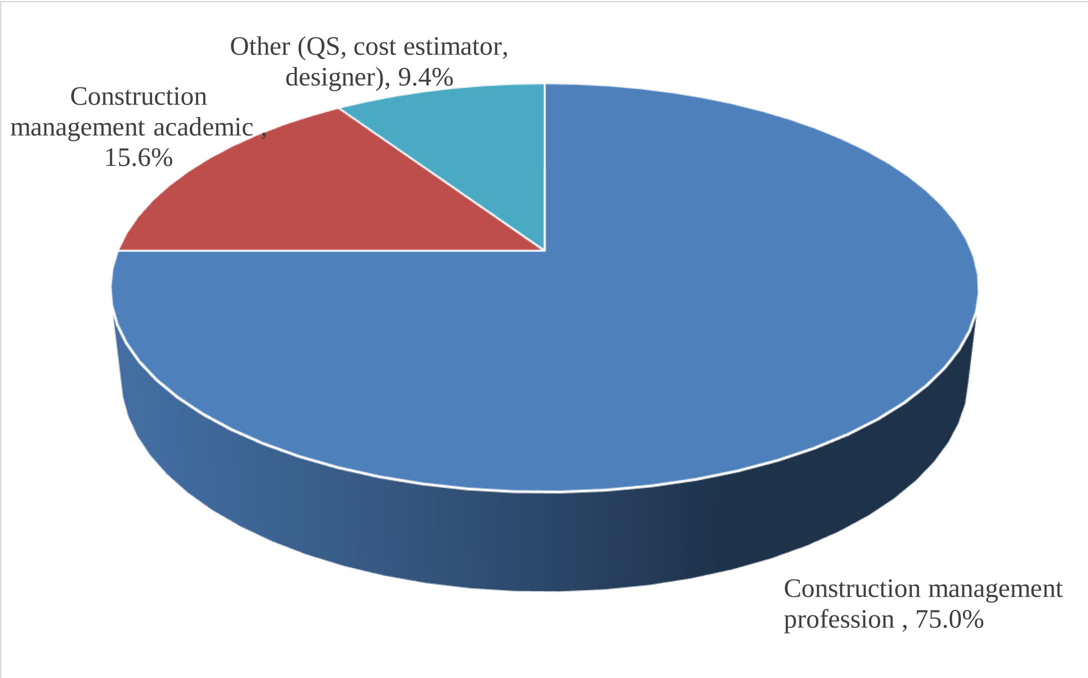


Figure 4.7 Area(s) of expertise

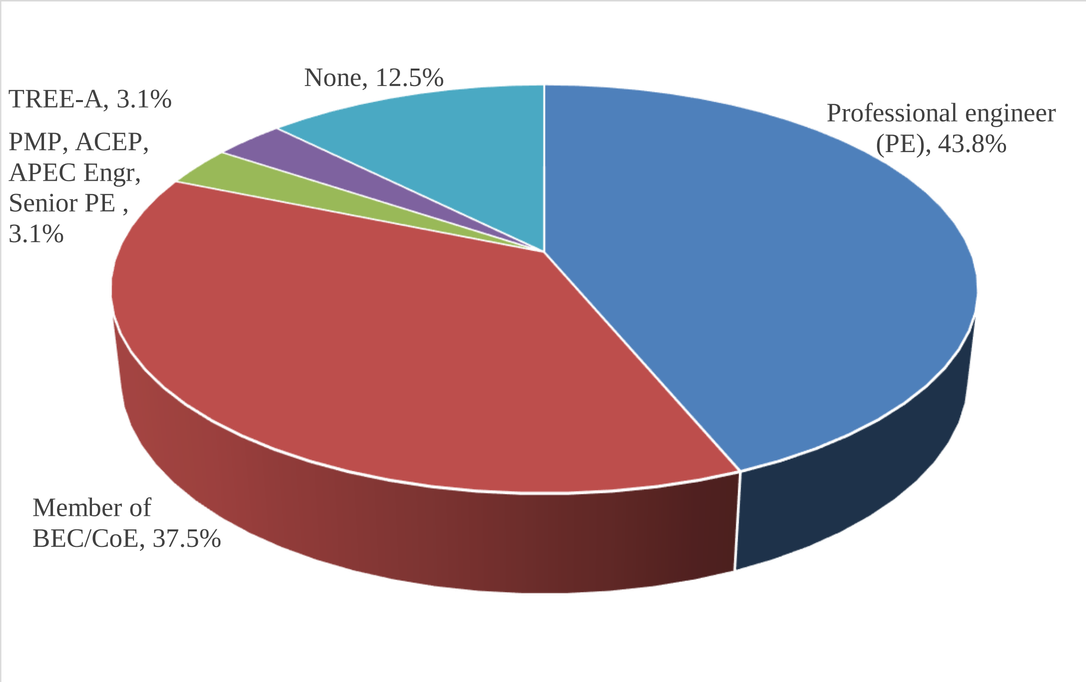


Figure 4.8 Professional qualifications/affiliations

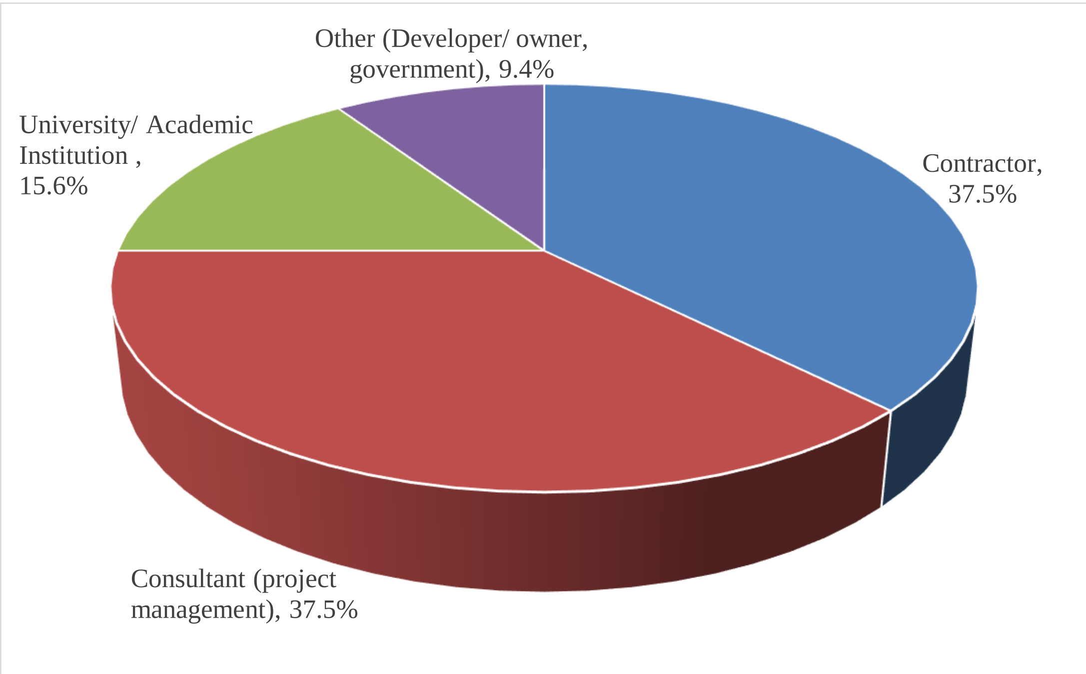


Figure 4.9 Current organization

4.4.4.2 Internal consistency test

Internal consistency refers to the extent of uniformity in responses across items (attributes) within a single measurement scale. A common measure for assessing internal consistency, Cronbach's alpha coefficient estimates the correlation among items and their true scores (Abu-Reishah et al., 2023; Panuwatwanich, 2008; Win, 2019). Taber (2018) categorizes Cronbach's alpha coefficients as excellent if above 0.90, very good if above 0.80, and adequate if above 0.70. Additionally, Hair et al. (2019); Wang et al. (2017) suggest that values between 0.60 and 0.70 are at the lower limit of acceptability, with a generally agreed-upon lower limit for Cronbach's alpha being 0.70 (Park et al., 2020).

In this study, all 56 attributes, with 32 responses, underwent simultaneous checks for internal consistency. The resulting Cronbach's alpha value was 0.925, surpassing the threshold of 0.90, indicating excellent internal consistency.

4.4.4.3 Item-total correlation

The item-total correlation denotes the correlation between an attribute and the composite score formed by all attributes constituting the measure of the construct. When all attributes share a common core representing the same construct, the scores of individual attributes and the entire construct should exhibit a high correlation (Omani-Samani et al., 2018; Wang et al., 2017). In SPSS, the corrected value of the item-total correlation is considered. According to Park et al. (2020) (Pett et al., 2003), a correlated item-total correlation value below 0.30 suggests that the attribute measures something distinct from the overall construct and is recommended for deletion. The results of item-total correlations, as presented in **Table 4.2**, indicate the removal of 13 attributes, as they exhibited item-total correlations below 0.30. Additionally, one attribute was deemed ineffective in measuring better CWM. Therefore, 43 attributes were retained within the construct, with corrected item-total correlations ranging from 0.320 (attribute no. 2.23) to 0.797 (attribute no. 2.37). All attributes demonstrated item-total correlations greater than 0.30 (Pett et al., 2003). Furthermore, the alpha coefficient for all these attributes was relatively high (0.961). Thus, the dataset retained 43 attributes for the subsequent processes (Park et al., 2020).

Table 4.2 Item-total correlations of all attributes contributing to better CWM

Attributes: Description	Mean	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
2.1. Awareness of the impact of construction waste (CW) on sustainable construction	4.31	**0.114***	0.926
2.2. Effective and efficient site management	4.44	0.478	0.923
2.3. Effective coordination and communication with project stakeholders	4.28	0.366	0.924
2.4. Senior management's commitment to implementing waste management (WM) practices	4.28	0.362	0.924
2.5. Implementing an effective organizational structure for WM	4.09	0.409	0.924
2.6. Supervision of WM activities with clear instructions	4.28	0.435	0.923
2.7. Effective implementation of the WM plan	4.31	0.464	0.923
2.8. Action to reduce CW generation	4.25	**0.152***	0.926
2.9. Action to reuse CW	4.06	**0.101***	0.926
2.10. Work experience on CWM and waste-minimizing culture within the company	4.34	**0.075***	0.926
2.11. Monitoring and auditing waste management systems periodically	4.47	0.430	0.924
2.12. Ensuring the participation of all stakeholders in WM activities	4.31	**0.297***	0.924
2.13. Ability to integrate CWM into the CWM assessment	3.84	**0.537***	0.923
2.14. Effective training for the engineers and workers on WM	4.44	**0.223***	0.925
2.15. Tasking workers with the exclusive responsibility of waste minimization	4.13	**0.286***	0.925
2.16. Having a sufficient number of skilled workers in every project	4.03	0.324	0.924
2.17. Quality of construction workmanship	3.88	**0.285***	0.925
2.18. Establishing a strict policy on CWM within the company (including the CWM system)	4.47	0.433	0.923
2.19. Establishing an appropriate waste management plan in the earlier stage of each construction project	4.28	0.429	0.923
2.20. Setting waste reduction targets for every project by maximizing the reduction of materials usage (e.g., normally contractor added 15% for waste generation, and now they need only 10% additionally)	4.25	0.422	0.924
2.21. Setting waste reuse target for every project by maximizing the reuse of materials	4.13	**0.122***	0.926
2.22. Including subcontractor responsibilities for WM targets in the contract	4.03	0.507	0.923
2.23. Offering incentives for waste minimization efforts to the project team (e.g., money, certificate)	3.97	0.310	0.924
2.24. Seeking and receiving client support on WM	3.91	**0.156***	0.925
2.25. Preventing site accidents (fire)	4.25	0.314	0.925
2.26. Preventing ordering errors and purchasing appropriate material sizes and quantities	4.34	0.462	0.923
2.27. On-time and accurate quantification of materials/bills of quantities	4.31	0.433	0.923
2.28. Use of quality, durable, and standardized materials	4.25	0.442	0.923

Attributes: Description	Mean	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
2.29. Adopt Just in Time (JIT) delivery system	3.94	0.420	0.924
2.30. Adequate protection of material transportation and handling (loading and unloading)	4.25	0.491	0.923
2.31. Precise on-site material control (e.g., inspecting the materials when they arrive, etc.)	4.34	0.447	0.923
2.32. Having central areas for cutting and storage of materials	4.00	**0.296***	0.925
2.33. Adequate protection of different categories of materials during storing and stacking	4.13	0.555	0.923
2.34. Strong security at the project site (i.e., prevent theft and loss of materials)	4.16	0.535	0.923
2.35. Ensure the availability of equipment required for every project (i.e., tools, machines, and vehicles)	4.22	0.731	0.921
2.36. Ensure the quality of all equipment to be used in every project	4.06	0.580	0.922
2.37. Be familiar with the usage of all equipment	4.22	0.797	0.921
2.38. Utilize scaffolding and formwork that can be reused many times (e.g., metal, plastic, etc.)	4.31	0.543	0.923
2.39. Utilize BIM for the project and be familiar with its application	4.06	0.378	0.924
2.40. Utilize other related information technologies for the project and be familiar with their application	3.97	0.461	0.923
2.41. Adequate site space and the site layout are cleared for materials movement	4.06	0.581	0.922
2.42. Adopt prefabricated structural elements (e.g., precast slab)	3.81	**0.250***	0.925
2.43. Adopt preassembled components such as bathroom and kitchen pods	3.72	0.383	0.924
2.44. Efficient use of materials and minimizing the uneconomical cutting shapes and length	4.28	0.464	0.923
2.45. Minimizing waste from application processes (e.g., overpreparation of mortar)	4.25	0.484	0.923
2.46. Minimizing rework at the construction site	4.41	0.430	0.923
2.47. Bins are installed on every floor	3.81	0.504	0.923
2.48. Set up separated bins according to the waste type and sort out waste at the site	4.31	0.447	0.923
2.49. Store waste in easily accessible areas	4.13	0.539	0.923
2.50. Effective document control of CWM (amounts, kinds, etc.)	4.13	0.451	0.924
2.51. Detailed study and thorough understanding of specifications and drawings	4.25	0.625	0.922
2.52. Professional quality management and certification (e.g., ISO, GREEN, etc.)	4.06	0.387	0.924
2.53. Lessons learned repository on CWM	4.13	0.639	0.922
2.54. Preventing shop drawing detailing errors	4.13	0.518	0.923
2.55. Minimizing design changes during construction	4.03	0.451	0.923
2.56. Minimizing variation orders (VO)	3.72	0.532	0.923

Note: *Items were removed as Item-total correlation < 0.3 or they are not influencing on CWM

4.4.5 Results of verified attributes

The verified attributes retained from the internal consistency and items-total correlation are shown in the following **Table 4.3**.

Table 4.3 Verified attributes contributing to better CWM

Attributes: Description	Mean	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
2.2. Effective and efficient site management	4.44	0.478	0.923
2.3. Effective coordination and communication with project stakeholders	4.28	0.366	0.924
2.4. Senior management's commitment to implementing waste management (WM) practices	4.28	0.362	0.924
2.5. Implementing an effective organizational structure for WM	4.09	0.409	0.924
2.6. Supervision of WM activities with clear instructions	4.28	0.435	0.923
2.7. Effective implementation of the WM plan	4.31	0.464	0.923
2.11. Monitoring and auditing waste management systems periodically	4.47	0.430	0.924
2.16. Having a sufficient number of skilled workers in every project	4.03	0.324	0.924
2.18. Establishing a strict policy on CWM within the company (including the CWM system)	4.47	0.433	0.923
2.19. Establishing an appropriate waste management plan in the earlier stage of each construction project	4.28	0.429	0.923
2.20. Setting waste reduction targets for every project by maximizing the reduction of materials usage (e.g., normally contractor added 15% for waste generation, and now they need only 10% additionally)	4.25	0.422	0.924
2.22. Including subcontractor responsibilities for WM targets in the contract	4.03	0.507	0.923
2.23. Offering incentives for waste minimization efforts to the project team (e.g., money, certificate)	3.97	0.310	0.924
2.25. Preventing site accidents (fire)	4.25	0.314	0.925
2.26. Preventing from ordering errors and purchasing appropriate material sizes and quantities	4.34	0.462	0.923
2.27. On-time and accurate quantification of materials/bills of quantities	4.31	0.433	0.923
2.28. Use of quality, durable, and standardized materials	4.25	0.442	0.923
2.29. Adopt Just in Time (JIT) delivery system	3.94	0.420	0.924
2.30. Adequate protection of material transportation and handling (loading and unloading)	4.25	0.491	0.923
2.31. Precise on-site material control (e.g., inspecting the materials when they arrive, etc.)	4.34	0.447	0.923
2.33. Adequate protection of different categories of materials during storing and stacking	4.13	0.555	0.923

Attributes: Description	Mean	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
2.34. Strong security at the project site (i.e., prevent theft and loss of materials)	4.16	0.535	0.923
2.35. Ensure the availability of equipment required for every project (i.e., tools, machines, and vehicles)	4.22	0.731	0.921
2.36. Ensure the quality of all equipment to be used in every project	4.06	0.580	0.922
2.37. Be familiar with the usage of all equipment	4.22	0.797	0.921
2.38. Utilize scaffolding and formwork that can be reused many times (e.g., metal, plastic, etc.)	4.31	0.543	0.923
2.39. Utilize BIM for the project and be familiar with its application	4.06	0.378	0.924
2.40. Utilize other related information technologies for the project and be familiar with their application	3.97	0.461	0.923
2.41. Adequate site space and the site layout are cleared for materials movement	4.06	0.581	0.922
2.43. Adopt preassembled components such as bathroom and kitchen pods	3.72	0.383	0.924
2.44. Efficient use of materials and minimizing the uneconomical cutting shapes and length	4.28	0.464	0.923
2.45. Minimizing waste from application processes (e.g., overpreparation of mortar)	4.25	0.484	0.923
2.46. Minimizing rework at the construction site	4.41	0.430	0.923
2.47. Bins are installed on every floor	3.81	0.504	0.923
2.48. Set up separated bins according to the waste type and sort out waste at the site	4.31	0.447	0.923
2.49. Store waste in easily accessible areas	4.13	0.539	0.923
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2.52. Professional quality management and certification (e.g., ISO, GREEN, etc.)	4.06	0.387	0.924
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2.54. Preventing shop drawing detailing errors	4.13	0.518	0.923
2.55. Minimizing design changes during construction	4.03	0.451	0.923
2.56. Minimizing variation orders (VO)	3.72	0.532	0.923

4.5 Conclusion of expert verification process

Out of the total of 56 attributes put for expert verification, 13 attributes were removed and retained, with a total of 43 attributes for further study process. After this preliminary study, the next phase was the Surveying and Factor analysis. To do so, the questionnaire for further data collection was developed in English and then translated into Khmer (Cambodian) and Thai. The respondents of 304 construction management professionals were involved and answered the survey questionnaire via an online platform. The responses were analyzed as shown in subsequence sections.

CHAPTER 5
DESCRIPTIVE ANALYSIS

5.1 Introduction

With a focus on a descriptive analysis of the survey data, this chapter describes the quantitative portion of the study. This study's main goal was to verify the data's basic qualities and ensure it was suitable for the later statistical methods used throughout the analysis phases. Section 5.2 commences with details about the questionnaire survey and profiling of the respondents. Subsequently, Section 5.3 detailed the techniques and outcomes of data screening, encompassing aspects such as missing data analysis, assessment of normality test, outlier screening, and assessment of standard deviations and standard errors of the mean. Section 5.4 follows, providing an interpretation of the preliminary findings derived from the mean values of each measured attribute. Lastly, Section 1.1.1 detailed the consistency test conducted among the groups of respondents.

5.2 Questionnaire survey and respondent profiles

5.2.1 Questionnaire survey

From August 19th to September 2nd, 2023, a questionnaire survey was administered in Cambodia and Thailand. Survey packages, which included a cover letter elucidating the survey's objectives, Part 1 for gathering background information, and Part 2 for rating the effect level of attributes on the improved performance of construction waste management, were distributed to 711 individual construction professionals. Among these, 506 individuals were sent via online plateforms including Facebook Messenger, Line, and Telegram. Additionally, survey packages were forwarded to construction professionals in public groups such as the Project Management Institute Thailand Chapter (250 members via email) and the Cambodian Society of Civil Engineers (1,388 members in Telegram). Of the questionnaires dispatched, 304 were fully returned, resulting in a response rate of 42.75 percent, a level considered satisfactory for research in the construction industry (Hardie et al., 2005; Panuwatwanich, 2008). Generally, responses ranging from 20% to 30% are deemed acceptable for surveys, with rates exceeding 30% considered good (Alreck et al., 1995; Fowler Jr, 2013). The subsequent section offers a comprehensive overview of the profiles of the survey respondents.

5.2.2 Demographic of respondents

The respondents' demographic analysis aimed to evaluate how well the sample represented the larger survey population. The following criteria were used to classify the respondents categorically:

- The country in which the company is located in, i.e., Cambodia or Thailand
- Respondent's position in the company
- Level of education
- Years of experience in the construction industry
- Years of experience working as a contractor(s)
- Years of experience related to CWM
- Area(s) of expertise
- Professional qualifications/affiliations
- Current organization type, i.e., Contractor, consultant (Project management), Academia or other

The total responses are 304, with 196 (64.5%) working in Cambodia and 108 (35.5%) working in Thailand. The demographics results are shown in **Figure 5.1** to **Figure 5.2** bellow.

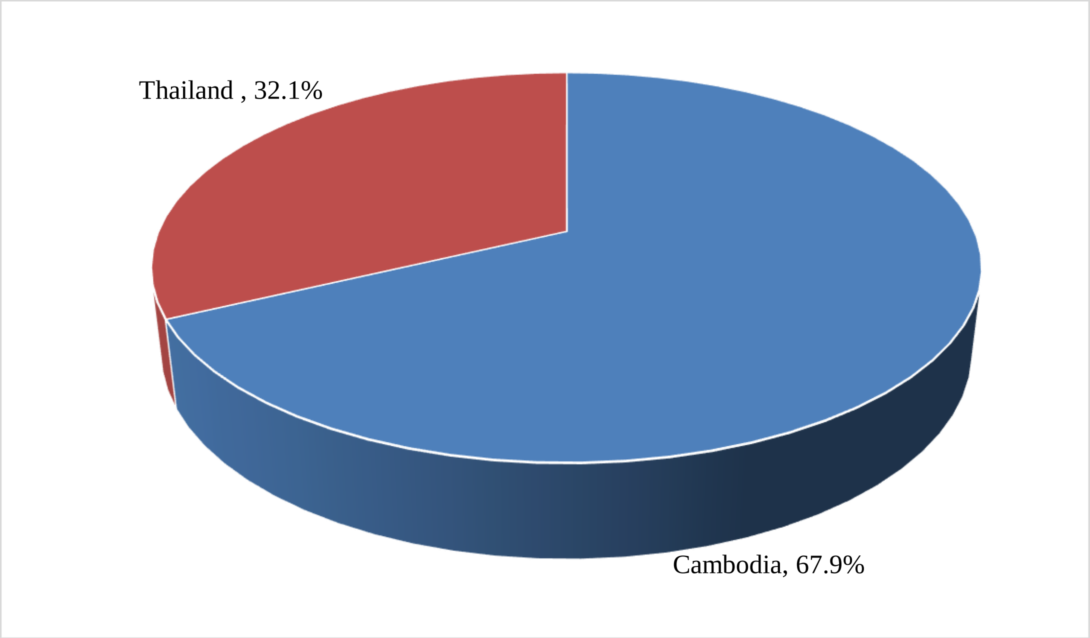

Figure 5.1 Country

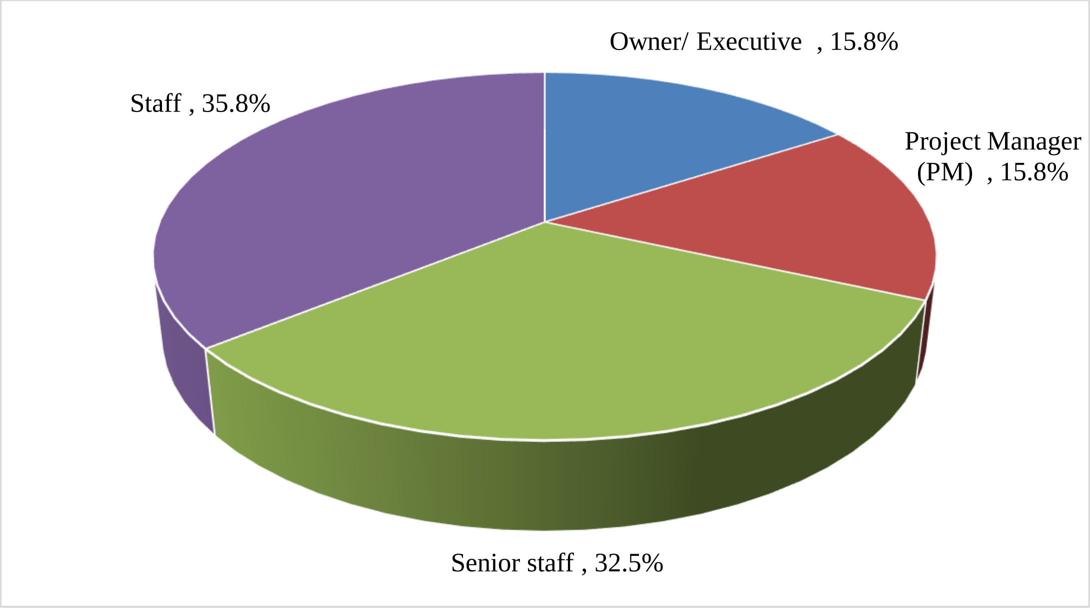

Figure 5.2 Position in company

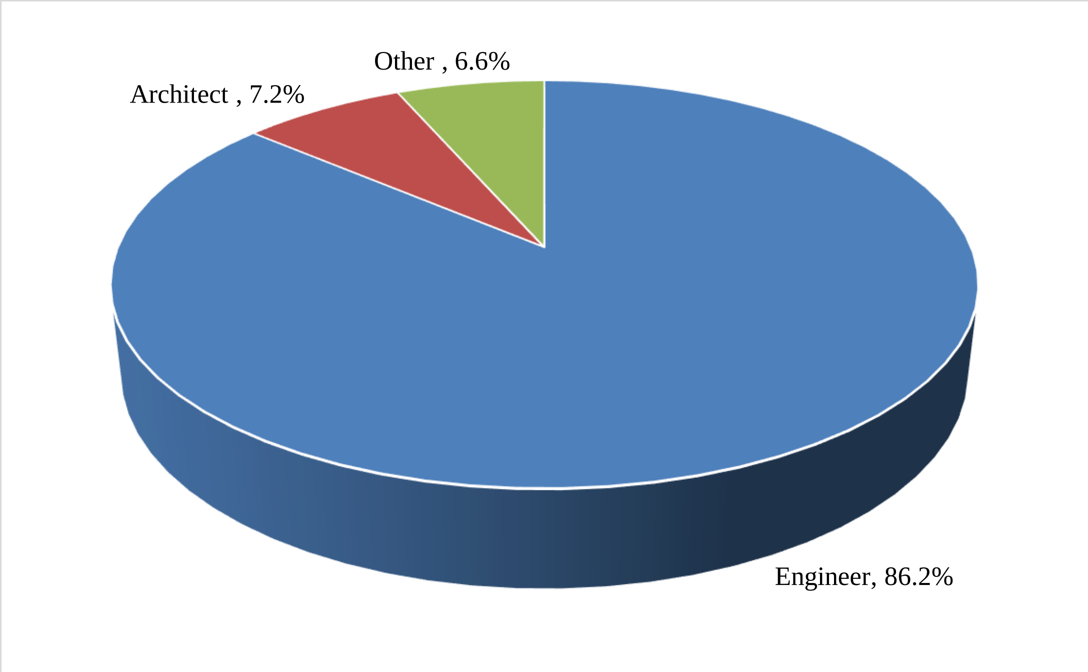

Figure 5.3 Professional role in company

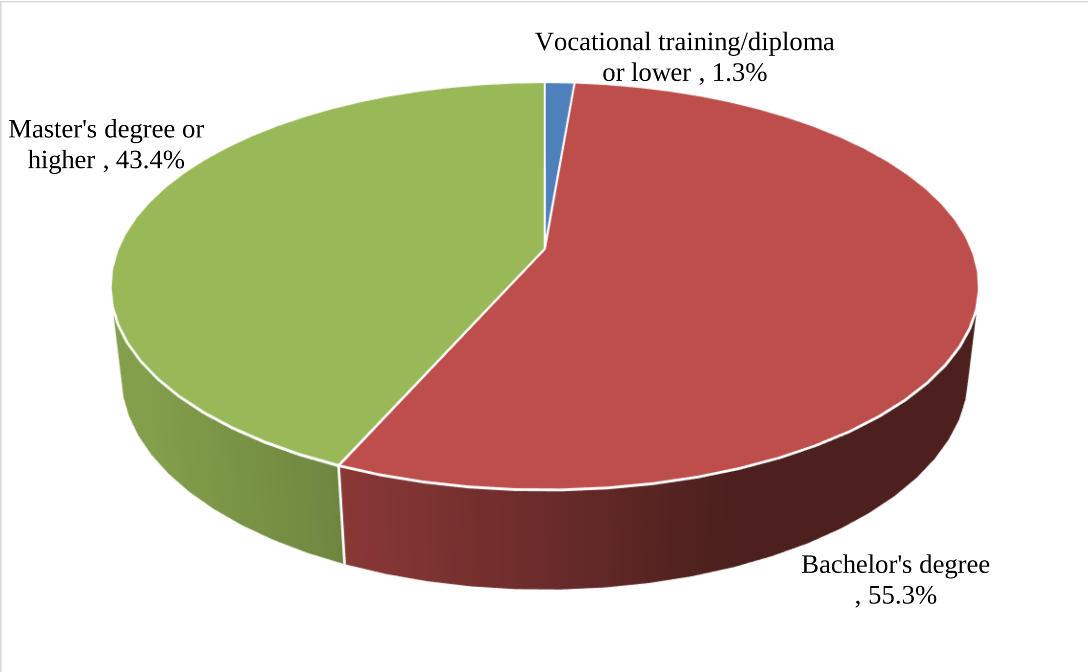

Figure 5.4 Level of education

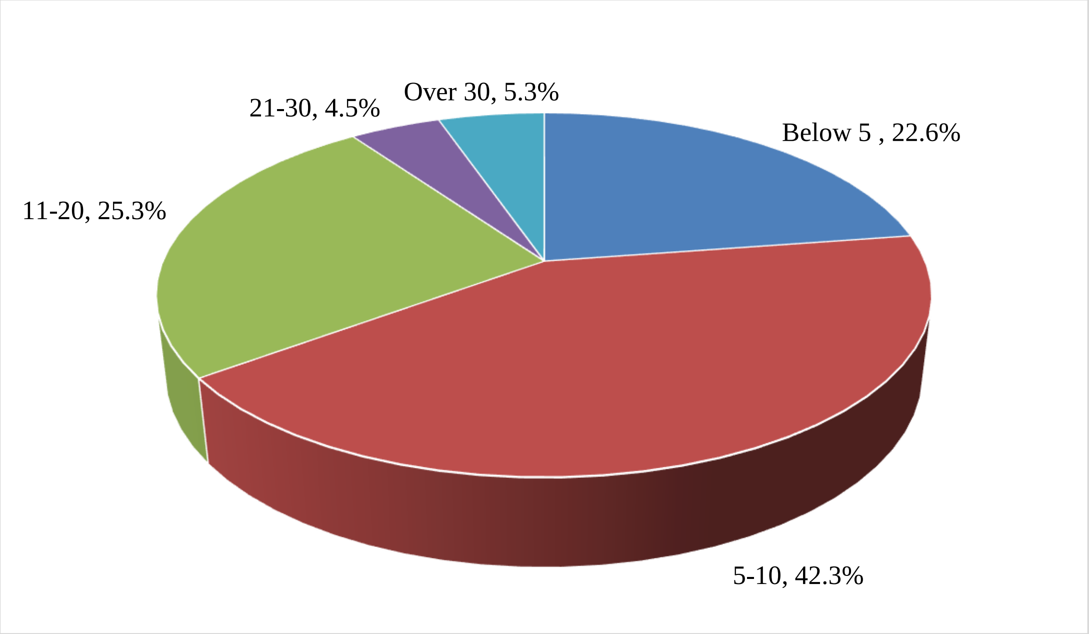

Figure 5.5 Years of experience in the construction industry

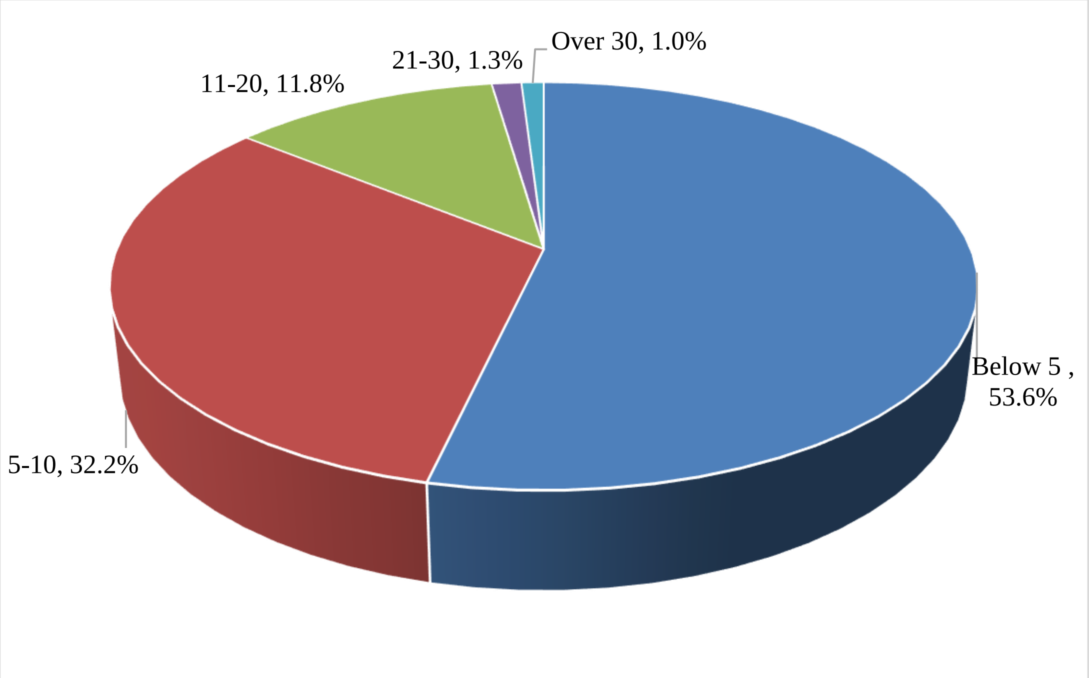

Figure 5.6 Years of experience working as contractor(s)

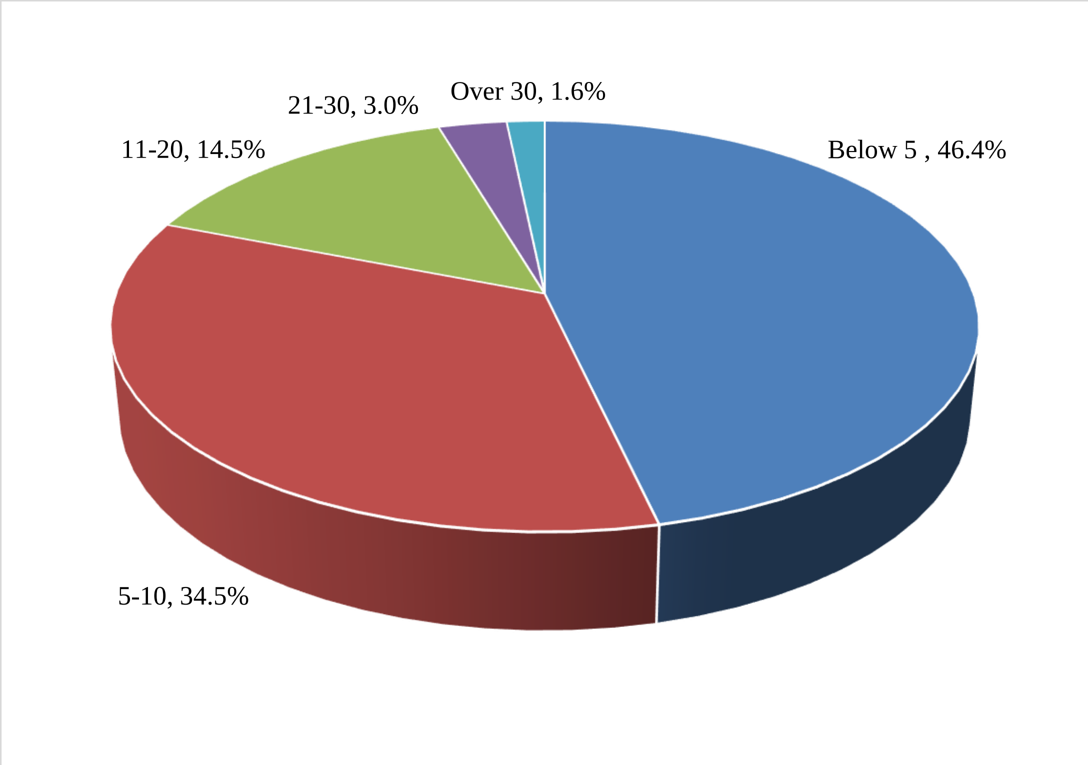

Figure 5.7 Years of experience working in building construction Project(s)

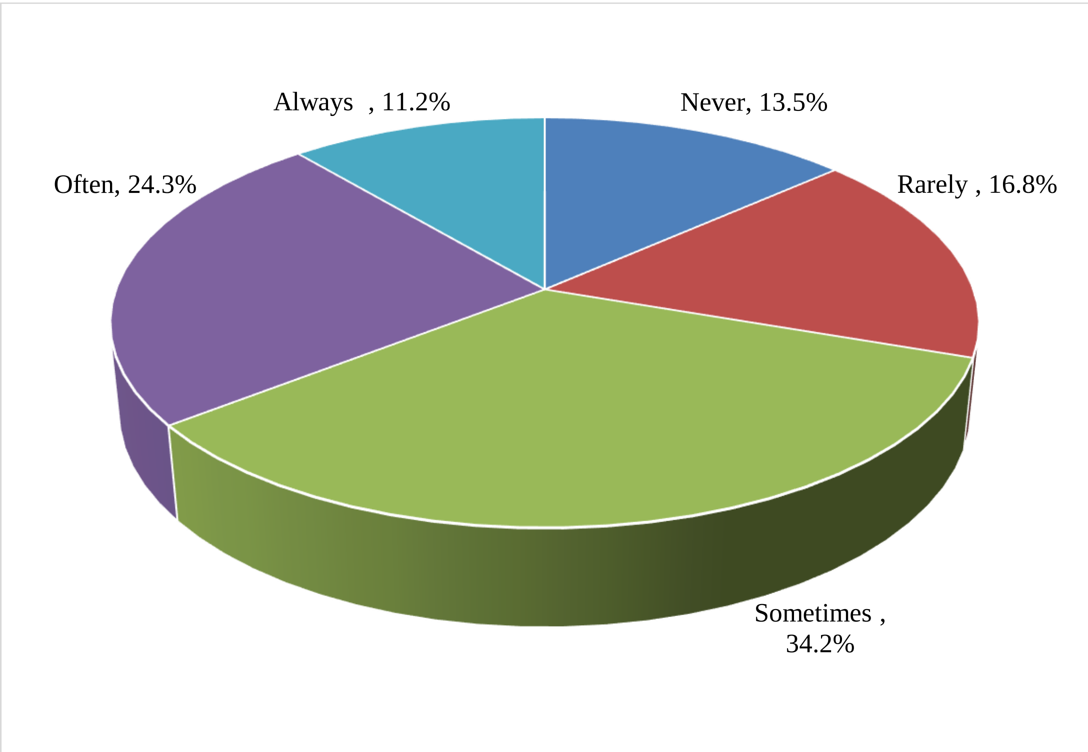

Figure 5.8 Involvement in CWM in building construction project(s)

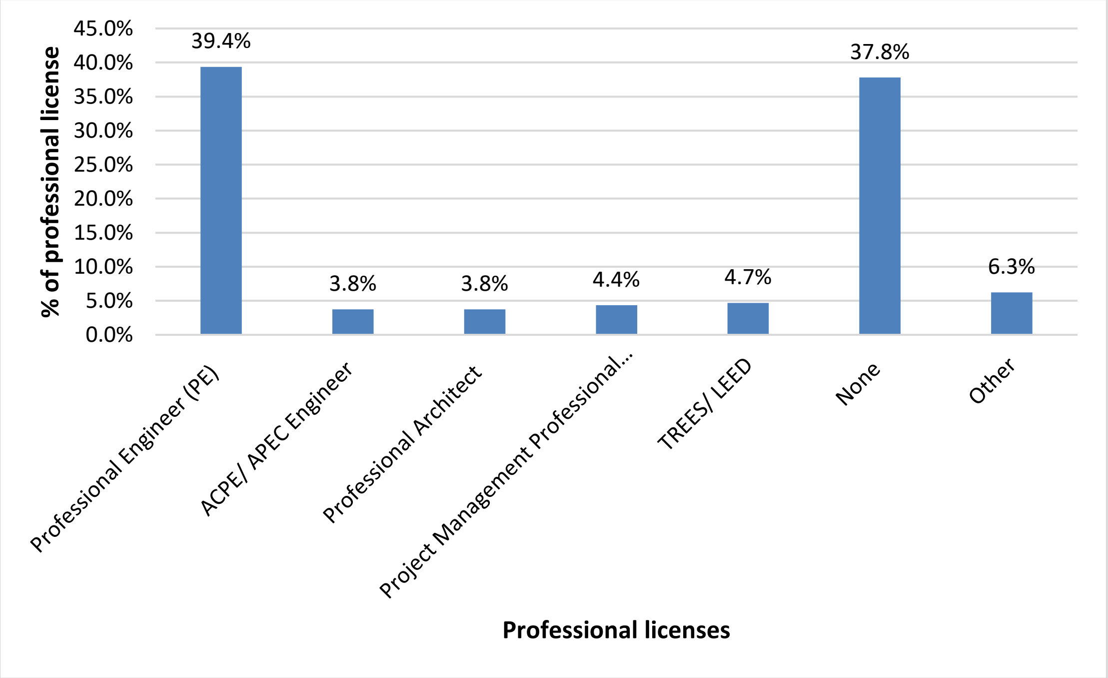

Figure 5.9 Professional qualification(s)

5.3 Screening of data

5.3.1 Missing data analysis

Missing observations are a typical occurrence in datasets from different data collection procedures. A smaller sample size can be used for analysis as a practical result of eliminating missing data (Hair et al., 2019). For instance, as a primary solution to address incomplete datasets, attributes with missing data are often excluded from the analysis, leading to a decrease in the sample size. This reduction may cause the sample to be inadequate for many statistical analyses, particularly those involving multivariate techniques (Hair et al., 2019).

This current study conducted the survey online using a questionnaire developed through the licensed platform “https://shout.com”. The questionnaire design ensured that each question was mandatory for respondents to answer, thus enabling progression to subsequent sections and the questionnaire submission. Due to this structure, incomplete responses were impossible, as respondents were required to answer all questions before submission. To make sure, the frequency analysis through SPSS version 27 was also done, and it showed there is zero missing data among all 304 responses, as shown **Table 5.1**.

5.3.2 Assessment of normality

The statistical methods used in this study were based on the assumption of normality; hence, verifying normality was an essential step. There are two sorts of normality: multivariate and univariate. Multivariate normality refers to a normal joint distribution of many attributes, whereas univariate normality is the degree to which the data distribution of one attribute follows a normal distribution (Hair et al., 2019; West et al., 1995). In order to do an initial assessment and provide an illustration of the data distribution for each attribute, this section explores univariate normality, which serves as justification for the application of particular statistical analysis techniques.

"Kurtosis" and "skewness" are frequently used by researchers as key markers of normality (Tabachnick et al., 2007). According to Hair et al. (2019), kurtosis determines how peaked a distribution is, whereas skewness quantifies symmetry. Comparatively few large values are indicated by a positively skewed distribution's tail pointing to the right, whereas comparatively few small values are indicated by a negatively skewed distribution's tail going off to the left (Hair et al., 2019). Skewness and kurtosis readings should preferably fall within ±2.00 to validate data regularity (Garson, 2012). SPSS version 27 was used to test the total normality of 304 datasets. All datasets had skewness and kurtosis values within acceptable ranges, according to the analysis results shown in **Table 5.1**, confirming the univariate normal distribution of the gathered data.

5.3.3 Outliers test

Outliers are cases with scores that considerably differ from the rest of the data in statistical analysis. Finding outliers in the data is essential because they might bias the mean and inflate the standard deviation (Hair et al., 2019). Outliers are defined as cases with scores greater than three standard deviations above the mean, according to Huck et al. (1974); Kline (2023). The scores for each of the 43 attributes across all cases in the current study were transformed into standardized z-scores to identify extreme deviations. Outliers were defined as cases with an absolute z-score ($|z|$) higher than 3.29, equal to three standard deviations at $p < 0.01$. Additionally, according to Field (2013), there shouldn't be more than 1% of outliers for every given attribute.

There were outliers in the dataset for six attributes in this study, as shown by cases with absolute z-scores higher than 3.29 (**Table 5.1**). These outliers ranged in percentage from 0.33 to 0.99 percent but stayed below the permissible one percent threshold. The difference between the mean and the "5% trimmed mean" of each attribute was looked at to ensure outliers did not significantly corrupt the data, especially in biasing the means. The cases that score in the top and bottom five percent are subtracted to end up at the 5% trimmed mean. Traditionally, potential problems resulting from outliers are indicated by a significant difference (> 0.20) between the mean and the 5% trimmed mean (Tabachnick et al., 2007). The computed mean differences (ΔMean) in the dataset ranged from 0.02 to 0.09 (**Table 5.1**). These findings imply that the dataset was not affected negatively by the outliers that were found. As a result, all 304 cases were kept for further analysis.

5.3.4 Assessment of standard deviations and mean standard errors

In statistical analysis, the standard error of the mean (SE) offers information about how well a specific sample represents the population, while the standard deviation (SD) is utilized to indicate how well the mean represents the observed data. A high standard deviation (SD) implies that the scores are not closely distributed around the mean, suggesting that the mean may not accurately represent the data (Field, 2013). A small standard deviation, on the other hand, denotes a smaller variation of data points around the mean, leading to a more precise representation of the data. A large SE indicates significant variation between the means of multiple samples, implying that the sample is less representative of the population. The SE expresses the variability of the sample mean. On the other hand, a small SE suggests that most sample means closely correspond to the population mean, indicating that the population is accurately represented. All of this study's attributes had minor SD values, and the SE values were moderate in relation to the means (**Table 5.1**). Thus, it makes sense to conclude that the mean values for each attribute in the dataset can be regarded as representative scores. The low SE values imply that the study's sample sufficiently represented the general population.

5.4 Preliminary findings in Phase 2

All attributes had standard deviation values that were not very high, as was mentioned in the section above. It was decided that the mean values adequately represented the collective reaction for each attribute. The assessment and interpretation of the mean values for each of the 43 attributes which were calculated using the entire sample, are the main topics of this section **Table 5.1** shows an overview of the mean values. The five-point Likert scale response format, with a score of five (5) representing the highest rating and a score of one (1) representing the lowest rating for all questionnaire items (attributes), was used to interpret these mean values.

Table 5.1 Descriptive statistics of the attributes contributing to better CWM

Attributes: Description	Missing Value (%)	Cases with lzl > 3.29 (%)	Mean	5% Trimmed Mean	ΔMean*	SD †	SE‡	Skewness	Kurtosis
A1: Effective site management	0.0	0.3	4.08	4.12	0.04	0.81	0.05	-0.59	0.01
A2: Effective communication with all stakeholders	0.0	0.3	4.02	4.06	0.04	0.81	0.05	-0.53	0.00
A3: Senior management's commitment to implementing waste management (WM) practices	0.0	0.7	3.96	4.02	0.06	0.88	0.05	-0.54	-0.13
A4: Implementing an effective organizational structure for WM	0.0	0.3	3.85	3.89	0.05	0.85	0.05	-0.44	-0.05
A5: Supervision of WM activities with clear instructions	0.0	0.7	3.97	4.03	0.06	0.90	0.05	-0.62	-0.10
A6: Properly following a WM plan	0.0	1.0	4.01	4.07	0.06	0.89	0.05	-0.64	0.08
A7: Monitoring and auditing waste management systems periodically (e.g., every 3 months)	0.0	0.0	3.70	3.75	0.05	0.98	0.06	-0.47	-0.17
B1: Having enough skilled workers in every project	0.0	0.0	3.92	3.96	0.04	0.84	0.05	-0.28	-0.70
C1: Establishment of a strict CWM policy within the company (including the CWM system)	0.0	0.0	3.83	3.87	0.04	0.89	0.05	-0.36	-0.34
C2: Establishment of an appropriate WM plan in the earlier stage of each construction project	0.0	0.0	3.85	3.89	0.04	0.90	0.05	-0.34	-0.56
C3: Setting a "Waste Reduction Target" for every project by maximizing the reduction of materials usage (e.g., reducing wastage from 15% to 10% of all materials usage)	0.0	0.0	3.69	3.71	0.02	0.86	0.05	-0.34	-0.32
C4: Including subcontractor responsibilities for WM targets in the contract	0.0	0.0	3.84	3.90	0.06	0.93	0.05	-0.67	0.24
C5: Offering incentives for waste minimization efforts to the project team (e.g., money, certificate)	0.0	0.0	3.65	3.71	0.06	1.03	0.06	-0.53	-0.13
C6: Preventing site accidents (e.g., fires and deaths causing material waste and project delays)	0.0	0.0	4.02	4.09	0.07	0.92	0.05	-0.82	0.42

*ΔMean = Mean – 5% trimmed mean; †Standard deviation; ‡Standard error of the mean; H Highest mean value; L Lowest mean value.

Attributes: Description	Missing Value (%)	Cases with lzl > 3.29 (%)	Mean	5% Trimmed Mean	ΔMean*	SD †	SE‡	Skewness	Kurtosis
D1: Precise material purchasing (i.e., preventing order errors, right sizes and quantities)	0.0	0.0	4.12	4.19	0.07	0.82	0.05	-0.91	0.97
D2: On-time and accurate quantification of materials/bills of quantities	0.0	0.0	4.08	4.17	0.09	0.92	0.05	-1.07	1.22
D3: Using quality, durable, and standardized materials (i.e., according to specification)	0.0	0.0	4.00	4.05	0.05	0.85	0.05	-0.57	0.06
D4: Adopting Just in Time delivery (JIT) system	0.0	0.0	3.80	3.84	0.04	0.88	0.05	-0.46	0.00
D5: Adequate protection of material transportation and handling (loading and unloading)	0.0	0.0	3.90	3.96	0.05	0.83	0.05	-0.54	0.22
D6: Precise on-site material control (e.g., inspecting the materials when they arrive, etc.)	0.0	0.0	3.94	4.01	0.07	0.91	0.05	-0.77	0.68
D7: Adequate protection of different categories of materials during storing and stacking	0.0	0.0	3.91	3.95	0.04	0.82	0.05	-0.52	0.26
D8: High level of security at the project site (i.e., prevent theft and loss of materials)	0.0	0.0	3.83	3.89	0.06	0.97	0.06	-0.67	0.19
E1: Ensuring the availability of equipment required for every project (i.e., tools, machines, and vehicles)	0.0	0.0	3.90	3.95	0.05	0.83	0.05	-0.51	0.02
E2: Ensuring the quality of all equipment to be used in every project	0.0	0.0	3.76	3.80	0.03	0.84	0.05	-0.17	-0.44
E3: Be familiar with the usage of all equipment (i.e., persons in charge)	0.0	0.0	3.81	3.84	0.04	0.88	0.05	-0.38	-0.38
E4: Utilizing scaffolding and formwork that can be reused many times (e.g., metal, plastic, etc.)	0.0	0.0	4.06	4.10	0.04	0.79	0.05	-0.63	0.55

*ΔMean = Mean – 5% trimmed mean; †Standard deviation; ‡Standard error of the mean; H Highest mean value; L Lowest mean value.

Attributes: Description	Missing Value (%)	Cases with lzl > 3.29 (%)	Mean	5% Trimmed Mean	ΔMean*	SD †	SE‡	Skewness	Kurtosis
E5: Utilizing Building Information Modeling (BIM) for the project and be familiar with its application	0.0	0.0	3.53	3.59	0.06	1.10	0.06	-0.52	-0.30
E6: Utilizing other related information technologies for the project and be familiar with their application	0.0	0.0	3.58	3.61	0.03	0.91	0.05	-0.41	0.02
F1: Adequate site space and the site layout are cleared for materials movement	0.0	0.0	4.04	4.07	0.03	0.74	0.04	-0.41	-0.15
F2: Adopting preassembled components such as bathroom and kitchen pods	0.0	0.0	3.58	3.62	0.03	0.96	0.06	-0.36	-0.18
F3: Efficient use of materials and minimizing the uneconomical cutting shapes and length	0.0	0.0	3.99	4.03	0.04	0.78	0.04	-0.48	-0.08
F4: Implementing proper method statement for each activity, including minimizing waste from application processes	0.0	0.0	3.97	4.02	0.05	0.79	0.05	-0.61	0.42
F5: Minimizing rework at the construction site	0.0	0.0	4.00	4.06	0.06	0.84	0.05	-0.65	0.16
F6: Bins are installed on every floor	0.0	0.0	3.64	3.68	0.04	0.93	0.05	-0.47	0.01
F7: Setting up separated bins according to the waste type and sort out waste at the site	0.0	0.0	3.60	3.65	0.05	1.04	0.06	-0.50	-0.18
F8: Storing construction waste in easily accessible areas	0.0	0.0	3.88	3.92	0.04	0.83	0.05	-0.34	-0.30
G1: Effective document control of CWM, including tracking the amounts and kinds of CW generated	0.0	0.0	3.69	3.72	0.02	0.87	0.05	-0.30	-0.39
G2: Detailed study and thorough understanding of specifications and drawings	0.0	0.0	3.99	4.04	0.05	0.82	0.05	-0.56	0.08
G3: Professional quality management and certification (e.g., ISO, GREEN, etc.)	0.0	0.0	3.58	3.65	0.06	1.00	0.06	-0.63	0.36
G4: Keeping lessons learned repository about CWM	0.0	0.0	3.68	3.72	0.04	0.90	0.05	-0.47	0.11
G5: Preventing shop drawing detailing errors (i.e., implementing a proper process check)	0.0	0.0	3.90	3.96	0.06	0.88	0.05	-0.61	0.18
G6: Minimizing design changes during construction	0.0	0.0	3.81	3.86	0.06	0.94	0.05	-0.62	0.19
G7: Minimizing variation orders (VO)	0.0	0.0	3.75	3.81	0.06	0.98	0.06	-0.61	0.17

*ΔMean = Mean – 5% trimmed mean; †Standard deviation; ‡Standard error of the mean; [H]Highest mean value; [L]Lowest mean value.

5.4.1 Level of management and leadership (Attributes A1-A7)

The “management and leadership” attributes had mean values that ranged from 3.70 to 4.08 (**Table 5.1**), above the medium level of 3.00. This suggests a positive correlation between the attributes, which are the key attributes for better construction waste management (CWM) performance in building projects. The maximum mean score under this key attribute is 4.08 for A1: Effective site management and the minimum mean score is 3.70 for A7: Monitoring and auditing waste management systems periodically.

- A1: Effective Site Management (Mean: 4.08), respondents express a high level of agreement with the effectiveness of site management practices, as evidenced by the mean score of 4.08. This suggests a consensus among participants regarding the pivotal role of efficient site management in optimizing construction waste processes. The high rating implies that respondents perceive effective site management as a cornerstone for successful waste management implementation.
- A2: Effective Communication with All Stakeholders (Mean: 4.02), the mean score of 4.02 indicates a strong endorsement of the importance of effective communication with all stakeholders. Respondents recognize the significance of precise and efficient communication channels in facilitating successful CWM practices.
- A3: Senior Management's Commitment to Implementing WM Practices (Mean: 3.96), with a mean score of 3.96, respondents acknowledge the importance of senior management's commitment to implementing CWM practices. This rating suggests that participants perceive strong leadership support as vital in driving successful CWM initiatives within construction projects.
- A4: Implementing an Effective Organizational Structure for WM (Mean: 3.85), the mean score of 3.85 reflects a positive evaluation of the role of an effective organizational structure in waste management. Respondents recognize the organizational framework as an essential component in optimizing CWM processes, albeit with a slightly lower endorsement than other attributes in this category.

- A5: Supervision of WM Activities with Clear Instructions (Mean: 3.97), the mean score of 3.97 indicates a favourable perception of the role of supervision with clear instructions in WM activities. Respondents recognize the importance of oversight and clarity in instructions as crucial elements contributing to the effectiveness of WM practices on construction sites.
- A6: Properly Following a WM Plan (Mean: 4.01), with a mean score of 4.01, respondents emphasize the importance of adhering to a CWM. This high rating suggests a shared belief in the positive impact of structured WM plans and the need for consistent adherence to such plans for optimal outcomes.
- A7: Monitoring and Auditing Waste Management Systems Periodically (Mean: 3.70), with a mean score of 3.70, respondents acknowledge the importance of periodic monitoring and auditing of waste management systems. While this rating indicates a moderate endorsement, it suggests that respondents recognize the value of regular assessments in ensuring the ongoing effectiveness of waste management practices.

Therefore, the 'Management and Leadership' category underscores the critical role of effective site management, communication, adherence to WM plans, and senior management commitment in fostering successful construction waste management. The positive evaluations suggest collectively recognising these attributes as pivotal in creating a conducive environment for optimal CWM within construction projects.

5.4.2 Level of manpower (Attribute B1)

The mean values for the B1: Having enough skilled workers in every project, exceeded the midpoint level of 3.00. The mean for this particular attribute is 3.70 (**Table 5.1**), signifying a perception that there is a need for skilled workers available for every project for better CWM. This attribute is the only attribute that represents the key attribute of manpower. This emphasizes the perceived adequacy of skilled personnel, which enhances CWM practices.

5.4.3 Level of policies and strategies (Attributes C1-C6)

The mean values of the 'policies and strategies' attributes were above the medium level of 3.00, ranging from 3.65 to 4.02 (**Table 5.1**), indicating a positive influence on better construction waste management (CWM) performance in building projects. The maximum mean score under this key attribute is 4.02 for C6: Preventing site accidents (e.g., fires and deaths causing material waste and project delays), and the minimum mean score is 3.65 for C5: Offering incentives for waste minimization efforts to the project team.

- C1: Establishment of a Strict CWM Policy within the Company, with a mean score of 3.83, indicates a favourable perception among respondents regarding the importance of establishing a stringent CWM policy within the company. This underscores the acknowledgement of policies' pivotal role in guiding CWM practices within the organizational framework.
- C2: Establish an appropriate WM plan in the earlier stage of each construction project, with a mean score of 3.85. Respondents affirm the significance of developing a well-thought-out Waste Management (WM) plan at the initial stages of construction projects. This highlights the proactive approach needed to integrate waste management considerations early in the project lifecycle.
- C3: Setting a "Waste Reduction Target" for every project, with a mean score of 3.69 indicates a positive perception regarding establishing waste reduction targets for each project. Respondents recognize the importance of maximizing the reduction of materials usage to achieve specific targets, such as reducing wastage from 15% to 10% of all materials usage.
- C4: Including subcontractor responsibilities for WM targets in the contract, the mean score of 3.84 suggests a favourable view on including subcontractor responsibilities for Waste Management (WM) targets within contractual agreements. This reflects an understanding of the collaborative efforts required across stakeholders to ensure effective waste management.
- C5: Offering incentives for waste minimization efforts, with a mean score of 3.65, respondents acknowledge the importance of incentivizing waste minimization

efforts within the project team. This reflects an awareness of the motivational impact that rewards, such as monetary incentives or certificates, can have on encouraging sustainable waste management practices.

- C6: Preventing site accidents, the high mean score of 4.02 indicates strong agreement among respondents regarding the critical role of preventing site accidents in reducing material waste and avoiding project delays. This underscores the interconnection between safety measures and effective CWM practices.

Therefore, the ‘policies and strategies’ attributes in CWM received favourable perceptions from respondents, with mean scores ranging from 3.65 to 4.02. This suggests a positive influence on the overall performance of CWM practices in building projects. Specifically, the emphasis on a stringent CWM policy, the early establishment of comprehensive waste management plans, and the inclusion of waste reduction targets and subcontractor responsibilities underscores the proactive and collaborative approaches required for effective waste management. Furthermore, recognising the significance of offering incentives for waste minimization efforts and the paramount importance of preventing site accidents contributes to a holistic understanding of policies and strategies that can optimise CWM in building construction projects.

5.4.4 Level of materials (Attributes D1-D8)

The mean values of the ‘materials’ attributes were above the medium level of 3.00, ranging from 3.80 to 4.12 (**Table 5.1**), indicating a positive influence on better construction waste management (CWM) performance in building projects. The maximum mean score under this key attribute is 4.12 for D1: Precise material purchasing (i.e., preventing order errors, correct sizes and quantities), and the minimum mean score is 3.80 for D4: Adopting Just in Time (JIT) delivery system.

- D1: Precise material purchasing, with a mean score of 4.12, which underscores the important of collective acknowledgement of the significance of preventing order errors, ensuring the correct sizes, and maintaining accurate quantities in building construction.

- D2: On-time and accurate quantification of materials/bills of quantities, with a mean score of 4.08. This underscores the consensus among respondents on the importance of meticulous assessment of bills of quantities, contributing to better CWM.
- D3: Using quality, durable, and standardized materials, with a mean score of 4.00. Respondents unanimously recognize the need to adhere to specifications, ensuring the use of standardized materials to enhance longevity and performance for better CWM.
- D4: Adopting Just in Time (JIT) delivery system, with a mean score of 3.80, suggests a more nuanced perspective. The variability in responses indicates a diversity of views on the extent to which JIT practices are currently embraced.
- D5: Adequate material transportation and handling protection, with a mean score of 3.90. This highlights the collective recognition of the importance of safeguarding materials throughout the material-moving process.
- D6: Precise on-site material control, with a mean score of 3.94. This underscores the unanimous agreement on meticulous inspection and control of materials upon arrival at the construction site.
- D7: Adequate protection of different categories of materials during storing and stacking. Safeguarding materials during storing and stacking is a shared concern, as evident in the mean score of 3.91. This underscores the collective acknowledgement of the necessity to protect diverse categories of materials adequately.
- D8: High level of security at the project site. While respondents affirm the importance of maintaining a high level of security at the project site with a mean score of 3.83, the nuanced perspective suggests varying degrees of emphasis. The collective recognition of the need to prevent theft and loss of materials is evident, with potential areas for improvement in security measures.

Therefore, the materials category unveils a comprehensive understanding among respondents regarding the critical attributes influencing CWM. The high mean scores underscore the unanimous agreement on the significance of precise material purchasing, accurate quantification, use of quality materials, protection during transportation and handling, on-site control, and security measures. The nuanced perspectives also reveal areas for potential improvement and optimization in certain aspects of materials management.

5.4.5 Level of equipment or tools (Attributes E1-E6)

The mean values of the 'equipment or tools' attributes were above the medium level of 3.00, ranging from 3.53 to 4.06 (**Table 5.1**), indicating a positive influence on better construction waste management (CWM) performance in building projects. The maximum mean score under this key attribute is 4.06 for E4: Utilizing scaffolding and formwork that can be reused many times (e.g., metal, plastic, etc.), and the minimum mean score is 3.53 for E5: Utilizing Building Information Modeling (BIM) for the project and be familiar with its application.

- E1: Ensuring the availability of equipment required for every project. Respondents collectively emphasized the importance of ensuring the availability of necessary equipment, with a mean score of 3.90. This underscores the unanimous acknowledgement of the pivotal role played by tools, machines, and vehicles in successfully executing construction projects.
- E2: Ensuring the quality of all equipment to be used in every project. Quality assurance in equipment emerged as a significant consideration, as reflected in the mean score of 3.76. While respondents recognize the importance of equipment quality, the nuanced perspective suggests varying degrees of emphasis on this aspect.
- E3: Being familiar with the usage of all equipment. The familiarity of personnel in charge with equipment usage is deemed crucial, as indicated by the mean score of 3.81. This underscores the collective recognition of the necessity for individuals overseeing projects to possess comprehensive knowledge of equipment operation.
- E4: Utilizing scaffolding and formwork that can be reused many times. Respondents express a strong inclination toward sustainable practices, as evidenced by the high mean score of 4.06 for the utilization of scaffolding and formwork that can be reused. This reflects a shared commitment to better CWM in building projects.

- E5: Utilizing Building Information Modeling (BIM) for the project and being familiar with its application. While respondents acknowledge the potential benefits of BIM, the mean score of 3.53 suggests a more reserved perspective. This indicates varying degrees of familiarity and endorsement of BIM within the respondent pool.
- E6: Utilizing other related information technologies for the project and being familiar with their application. The mean score of 3.58 highlights a moderate inclination toward using other information technologies for construction projects. Respondents recognize the relevance of these technologies but exhibit diverse views on their application for better CWM in building construction.

Therefore, the ‘equipment or tools’ category reveals a comprehensive understanding among respondents regarding the multifaceted considerations associated with CWM. The high mean score for reusing scaffolding and formwork emphasizes a collective commitment to sustainability. While respondents generally endorse the importance of equipment availability and familiarity, there are nuanced perspectives on equipment quality and adopting advanced technologies such as BIM. These findings underscore the need for targeted interventions and improvements in specific equipment and tools management aspects in building construction projects.

5.4.6 Level of construction method and processes (Attributes F1-F8)

The mean values of the ‘construction method and processes’ attributes were above the medium level of 3.00, ranging from 3.58 to 4.04 (**Table 5.1**), indicating a positive influence on the better performance of CWM in building projects. The maximum mean score under this key attribute is 4.04 for F1: Adequate site space and the site layout are cleared for materials movement, and the minimum mean score is 3.58 for F2: Adopting preassembled components such as bathroom and kitchen pods.

- F1: Adequate site space and site layout cleared for materials movement. Respondents strongly emphasize the importance of providing adequate site space and a layout conducive to materials movement, as reflected in the high mean score of 4.04. This underscores the collective recognition that an organized and spacious site layout is pivotal for optimizing materials handling and minimizing waste.

- F2: Adopting preassembled components such as bathroom and kitchen pods. While the mean score of 3.58 suggests a moderate inclination toward adopting preassembled components, respondents exhibit diverse views. This reflects a nuanced perspective on the feasibility and benefits of integrating preassembled elements like bathroom and kitchen pods into construction projects.
- F3: Efficient use of materials and minimizing uneconomical cutting shapes and length. Respondents express a strong commitment to efficient material use, as indicated by the mean score of 3.99. This underscores a shared belief in the importance of minimizing wastage through strategic planning and using materials in construction activities.
- F4: Implementing proper method statements for each activity, including minimizing waste from application processes. The mean score of 3.97 highlights the significance placed on method statements that address waste minimization during application processes. This indicates a collective understanding of the need for structured procedures to minimize waste generation throughout construction activities.
- F5: Minimizing rework at the construction site. Respondents prioritize the minimization of rework at the construction site, as evidenced by the high mean score of 4.00. This reflects a unanimous acknowledgement of rework's detrimental impact on project timelines and material usage.
- F6: Bins are installed on every floor. While the mean score of 3.64 suggests a moderate inclination toward installing bins on every floor, respondents exhibit varying perspectives on this practice. This indicates diverse opinions on the effectiveness and practicality of readily available bins on each floor.
- F7: Set up separate bins according to waste type and sort out waste at the site. The mean score of 3.60 reflects a moderate inclination toward setting up separated bins and sorting waste at the site. Respondents recognize the importance of waste segregation, but opinions on its implementation vary.
- F8: Storing construction waste in easily accessible areas. The mean score of 3.88 indicates a strong endorsement of storing CW in easily accessible areas. This

underscores the collective belief in strategically placing waste storage areas to facilitate efficient handling and removal.

Therefore, the ‘construction method and processes’ category reveals a comprehensive understanding among respondents regarding the pivotal role of site layout, efficient material use, and waste minimization strategies. The emphasis on minimizing rework and storing waste in accessible areas underscores a commitment to optimizing construction processes. However, opinions on specific practices, such as adopting preassembled components and installing bins on every floor, exhibit diversity. These highlight the need for targeted interventions and improvements in particular aspects of construction methods and processes to enhance CWM practices.

5.4.7 Level of documentation (Attributes G1-G7)

The mean values of the ‘construction method and processes’ attributes were above the medium level of 3.00, ranging from 3.58 to 3.99 (**Table 5.1**), indicating a positive influence on better construction waste management (CWM) performance in building projects. The maximum mean score under this key attribute is 3.99 for G2: Detailed study and thorough understanding of specifications and drawings, and the minimum mean score is 3.58 for G3: Professional quality management and certification (e.g., ISO, GREEN, etc.).

- G1: Effective document control of cwm, including tracking the amounts and kinds of CW generated. The mean score of 3.69 suggests a moderate inclination toward effective document control in CWM. Respondents acknowledge the importance of tracking the amounts and types of CW generated, highlighting the need for meticulous documentation practices to enhance CWM effectiveness.
- G2: Detailed study and thorough understanding of specifications and drawings.
- Respondents express a strong commitment to detailed study and a thorough understanding of specifications and drawings, as reflected in the high mean score 3.99. This underscores the collective recognition of the pivotal role of the comprehensive knowledge of project documentation in minimizing errors and optimizing WM.

- G3: Professional quality management and certification (e.g., ISO, GREEN, etc.). While the mean score of 3.58 indicates a moderate inclination toward professional quality management and certification, respondents exhibit diverse views. This suggests varying perspectives on the role of certifications, such as ISO and GREEN, in enhancing the quality and sustainability of CWM practices.
- G4: Keep the lessons learned in the repository about cwm. The mean score of 3.68 suggests a moderate inclination toward maintaining a lessons-learned repository specific to construction waste management. Respondents recognize the value of capturing and applying insights from previous projects to improve CWM practices, emphasizing the importance of continuous learning.
- G5: Preventing shop drawing detailing errors (i.e., implementing a proper process check). Respondents prioritize preventing shop drawing detailing errors, as indicated by the high mean score of 3.90. This reflects a collective commitment to implementing robust process checks to minimize the mistakes in shop drawings, contributing to effective CWM.
- G6: Minimizing design changes during construction. The mean score of 3.81 suggests a moderate inclination toward minimizing design changes during construction. Respondents recognize the potential impact of design changes on CW generation and highlight the importance of stability in project specifications.
- G7: Minimizing Variation Orders (VO). While the mean score of 3.75 indicates a moderate inclination toward minimizing variation orders (VO), respondents exhibit diverse views. This suggests varying perspectives on the feasibility and benefits of limiting variation orders to enhance CWM.

Therefore, the ‘documentation’ category underscores the crucial role of comprehensive document control, understanding project specifications, and preventing errors in enhancing CWM practices. The emphasis on maintaining a lessons-learned repository reflects a commitment to continuous improvement. However, diverse opinions on aspects such as professional certification and the minimization of variation orders highlight the need for targeted interventions and improvements in specific documentation practices to optimize CWM in building construction projects.

5.4.8 Summary of preliminary finding

Respondents comprehensively understand the diverse attributes contributing to enhanced CWM in building construction. High mean scores across various categories indicate a strong consensus on the significance of these attributes. Notably, all 43 attributes in seven categories received mean scores exceeding 3, emphasizing the perceived importance attributed to better CWM. The attribute with the lowest mean score, at 3.53, pertains to E5: Utilizing Building Information Modeling (BIM) for the project and being familiar with its application. Conversely, the attribute with the highest mean score, reaching 4.12, is associated with D1: Precise material purchasing, highlighting the emphasis on meticulous purchasing practices. This holistic perspective underscores the interconnected nature of management, policies, resource allocation, and operational processes as integral components in achieving better CWM in building construction. **Table 5.1** shows the descriptive statistics of the attributes contributing to better CWM.

5.5 Consistency tests among sample groups

The student's t-test or independent sample T-test and Analysis of Variance (ANOVA) or F-Test are statistical techniques employed for hypothesis testing to compare means among different groups. The Independent t-test compares means between two groups, while One-way ANOVA (F-test) compares means among three or more groups (Cohen, 2013; Mishra et al., 2019; Zhou et al., 2017). It is essential to note that when the sample size is small, the mean can be significantly influenced by outliers, underscoring the importance of maintaining an adequate sample size when applying these methods (Hair et al., 2019; Mishra et al., 2019). Fortunately, this study's sample size is substantial, consisting of 304 observations, which ensures statistical robustness.

The student's t-test, also known as the independent t-test, and the Analysis of Variance (ANOVA), also referred to as the F-test, are statistical methods used in hypothesis testing to compare group means. When comparing means between two groups, the Independent t-test is used; however, when comparing means among three or more groups, the One-way ANOVA (F-test) is utilized (Cohen, 2013; Mishra et al., 2019; Zhou et al., 2017). It is crucial to consider that outliers can substantially impact the mean when the sample size is small, which demonstrates the significance of maintaining an appropriate sample size when using these methods (Hair et al., 2019; Mishra et al., 2019). Fortunately, statistical robustness is guaranteed in the present study due to the large sample size (304 samples).

The T-test and F-test could provide robust results, assuming that each group has the same variances. In this study, the datasets are normally distributed. Still, the sample sizes between the groups to be compared are largely different, which would have a high chance of having different variances that could violate the assumption of homogeneity of variances among the groups, which is not fit for applying classical T-test and F-Test (Baguley, 2012; Lachenbruch et al., 1991; Welch, 1947). Commonly used in statistical analysis, the T-test and F-test require conformance to the fundamental assumptions of homogeneity (similarity of variance) and normality. Mathematical determinations that are biased, inadequate and unreliable may arise from violated assumptions (Erceg-Hurn et al., 2008; Karim et al., 2023).

The heterogeneity of variances is non-parametric data, which highly affects the result of classical T and F values from the T-test and F-test, respectively. This would cause no robust results. If this heterogeneity happened with data sets, Welch’s Test can be done instead of traditional T-test or F-test (Delacre et al., 2019; Karch, 2021; Liu, 2015). Similarly, Vaccari et al. (2019) compared the biochemical parameters in landfills and dumpsites across three continents (Latin America, Asia, and Africa) using Welch's test, which local conditions, consumption patterns, and individual waste management habits may influence more. Ultimately, only Welch’s test results were reported.

The results of the normality test indicated that the data was distributed normally. Also, the homogeneity test was conducted to check whether the data set was homogeneity (same in variances among the groups) or heterogeneity (different variances among the groups). Levene’s Test for equality of variances was conducted to check whether there are significant variances or not. In Levene's Test, the Sig. (P-value) of lesser than or equal to 0.05 is conserved as a significant difference in variances (Delacre et al., 2017; Field, 2013; Garson, 2012; Levene, 1960).

The result showed that the data set was heterogeneity (different in variances for some attributes). We, therefore, applied Welch’s t-test and Welch’s F-test, the robust statistical method for comparing means to address the assumption of homoscedasticity and generate reliable results, and their output was considered valid for interpretation (Delacre et al., 2017; Erceg-Hurn et al., 2008; Karch, 2021; Vaccari et al., 2019).

The value of the mean difference, sig. (P-value) and effect size were considered for interpreting the output. According to Chen (2007), the difference is considered significant if the mean difference is greater than one response category. However, this mean difference will be determined in depth whether it is significant or not by checking with P-value and effect size.

The p-value can be considered significant when the sig. (p-value) is less than or equal to 0.05 for a 95% confidence interval from both Welch's T-test and Welch's F-test, indicates for at least one pair, between which the mean difference was statistically significant (Baguley, 2012; Field, 2013; Welch, 1938).

In Welch's T-test, the effect size denoted by absolute Cohen's d or $|d| > 0.8$ were considered as large effect size (Cohen, 2013; Field, 2013; Welch, 1938; Welch, 1947), while in Welch's F-test, the effect size (Omega-squared) > 0.14 were considered as large effect size (Albers et al., 2018; Field, 2013; Karim et al., 2023; Welch, 1938).

For Welch's T-test, the effect size can be calculated as (Cohen, 2013; Field, 2013; Welch, 1938; Welch, 1947),

Cohen's d = d = $\frac{M_2 - M_1}{SD_{Pooled}}$

Whereas,

$S_{Pooled} = \sqrt{\frac{SD_1^2 + SD_2^2}{2}}$

M_1: Mean 1

M_2: Mean 2

SD_1: Standard deviation 1

SD_2: Standard deviation 2

For Welch's F-test, the effect size can be calculated as (Albers et al., 2018; Welch, 1938):

Omega-squared =

$$\omega^2 = \frac{SS_B - df_B \times MS_W}{SS_T + MS_W}$$

Whereas,

SS_B: Sum of squares between groups

df_B: Degrees of freedom between groups

MS_W: Mean square within groups (residual mean square)

SS_T: Total sum of squares

According to Okada (2017), the Omega-squared (ω^2) derived from Welch's F-test can be negative, indicating that the sampling distributions of ω^2 encompass ranges below zero. This phenomenon arises due to bias correction, whereas the uncorrected estimator, η^2, derived from the classical F-test, never be below zero. While a negative variance ratio lacks real-world interpretation, as the ratio of explained to total variance should fall between 0 and 1, practical applications typically involve reporting such negative estimates (Kenny et al., 2020; Olejnik et al., 2000). Wickens et al. (2004) also recommend setting ω^2 to zero when it yields a negative value.

The subsequent section of this study compares groups of respondents to assess how their perspectives impact the overall results, utilizing Welch's T-test and Welch's F-test. This analysis was conducted with various groupings of survey respondents to ensure that the collected data could be treated as a single sample.

5.5.1 Country where companies are located

The comparative analysis between two construction professionals groups, including respondents from Thailand (n=108) and Cambodia (n=196), aimed to examine their opinions on attributes contributing to better CWM. The normality test confirmed a normal distribution of the data across these groups. Subsequently, Levene's Test for equality of variances was employed to assess homogeneity. The results of Levene's Test, as shown in **Table 5.2.**, indicated heterogeneity in variances for eight attributes (A2, A7, C6, D8, E5, F2, G3, and G4) that had variances significant differences (p-value ≤ 0.05). Then, Welch's T-test was applied with a significant homogeneity of variances (Sig.) less than 0.05. This led to the adoption of Welch's T-test as a robust statistical method to compare means, ensuring reliability under the assumption of different variances. In fact, in SPSS Version 27, the classical T-test and Welch's T-test are part of the same process, accessible with a single analysis click.

The results of Welch's T-test, also shown in **Table 5.2** indicated that 25 attributes (A1, A2, A3, A5, A6, A7, C1, C2, C3, C4, C5, E1, E2, E3, E4, E5, E6, F1, F2, F3, F7, F8, G1, G3, and G4) had p-values less than 0.05, suggesting that the mean values of these attributes were significantly different between the groups. This initially suggested that there was a significant difference in the mean values of these attributes between the two groups. Nevertheless, only one attribute, "F2", had a substantial impact size (absolute Chohen's d > 0.8) and was considered for eliminating from the data set. No other typical attribute had a large mean difference between Cambodian and Thailand (ΔMean > 1.00).

Additionally, alternative comparative analysis techniques such as T-test, F-Test, and Welch's F-test were also conducted to validate and compare the results obtained from Welch's T-test. All of them yielded results consistent with those of Welch's T-test.

Thus, in this study, comparing two groups using Welch's T-test and Welch's F-test produced the same results, which was recommended to remove "F2" from the data set while keeping the remaining attributes in the data set for further analysis. However, in comparing the groups, "F2" is kept for the sake of analysis uniformity. It will be eliminated after completing all comparative analyses across all groups.

Table 5.2 Levene's Test and Welch's T-test results for construction professionals in Cambodia and Thailand

Attributes	Homogeneity of variances (Sig.)	Sig.	Mean		ΔMean	Cohen's d
			Cambodia	Thailand		
A1	0.276	0.021	3.99	4.22	0.23	0.28
A2	0.025	0.011	3.93	4.19	0.26	0.31
A3	0.638	0.003	3.85	4.17	0.31	0.36
A4	0.803	0.459	3.82	3.90	0.08	0.09
A5	0.755	0.001	3.84	4.20	0.36	0.41
A6	0.854	0.014	3.91	4.18	0.26	0.30
A7	0.038	0.001	3.57	3.94	0.37	0.39
B1	0.057	0.666	3.93	3.89	0.04	0.05
C1	0.244	0.002	3.71	4.04	0.33	0.37
C2	0.236	0.000	3.67	4.18	0.51	0.59

Attributes	Homogeneity of variances (Sig.)	Sig.	Mean		∆Mean	Cohen's d
			Cambodia	Thailand		
C3	0.120	0.003	3.58	3.89	0.31	0.37
C4	0.659	0.006	3.73	4.05	0.32	0.34
C5	0.316	0.014	3.54	3.85	0.31	0.30
C6	0.003	0.412	4.05	3.95	0.10	0.10
D1	0.539	0.191	4.08	4.20	0.13	0.16
D2	0.565	0.466	4.05	4.13	0.08	0.09
D3	0.545	0.504	3.98	4.05	0.07	0.08
D4	0.551	0.415	3.83	3.74	0.09	0.10
D5	0.771	0.965	3.90	3.91	0.00	0.01
D6	0.301	0.637	3.96	3.91	0.05	0.06
D7	0.712	0.193	3.86	3.99	0.13	0.16
D8	0.007	0.298	3.88	3.75	0.13	0.13
E1	0.316	0.018	3.81	4.06	0.24	0.29
E2	0.930	0.000	3.63	4.01	0.38	0.46
E3	0.080	0.004	3.70	4.00	0.30	0.35
E4	0.834	0.000	3.90	4.34	0.44	0.59
E5	0.005	0.000	3.32	3.91	0.59	0.57
E6	0.688	0.002	3.46	3.80	0.34	0.37
F1	0.804	0.010	3.96	4.19	0.22	0.31
F2	0.001	0.000	3.31	4.07	0.76	0.88**
F3	0.892	0.000	3.83	4.28	0.45	0.60
F4	0.945	0.670	3.96	4.00	0.04	0.05
F5	0.145	0.487	4.03	3.95	0.07	0.08
F6	0.069	0.563	3.62	3.69	0.07	0.07
F7	0.617	0.000	3.43	3.90	0.47	0.46
F8	0.184	0.008	3.79	4.06	0.26	0.32
G1	0.271	0.025	3.61	3.84	0.24	0.27
G2	0.462	0.459	3.96	4.04	0.07	0.09
G3	0.017	0.000	3.44	3.84	0.40	0.42
G4	0.017	0.000	3.54	3.94	0.39	0.45
G5	0.154	0.862	3.91	3.89	0.02	0.02
G6	0.278	0.396	3.77	3.87	0.10	0.10
G7	0.355	0.237	3.70	3.84	0.14	0.14

*Large difference between the mean values (∆Mean > 1.00); **Large effect size (Cohen's d > 0.8)

5.5.2 Professional roles

The comparative analysis among three groups of construction professionals, which included engineers (n=265), architects (n=22), and others (n=20), aimed to examine their opinions on attributes contributing to better CWM. The normality test confirmed a normal distribution of the data across these groups. Subsequently, Levene's Test for equality of variances was employed to assess homogeneity. The results of Levene's Test, as shown in **Table 5.3**, indicated heterogeneity in variances for three attributes

(C3, F2, and G7) with a significant homogeneity of variances (Sig.) less than 0.05. This led to the adoption of Welch’s F-test as a robust statistical method to compare means, ensuring reliability under the assumption of different variances.

The results of Welch’s F-test, also shown in **Table 5.3**, indicated that two attributes (D2 and D7) had p-values less than 0.05, suggesting that the mean values of these attributes were significantly different between the groups. However, none of the attributes had a large mean difference between groups of respondents who had professional roles as “architects” and “engineers”, between “other roles” and “engineers”, and between “architects” and “other roles” (ΔMean > 1.00), along with a large effect size ($\omega^2 > 0.14$).

An alternative comparative analysis technique, i.e., the F-Test, was also conducted to validate and compare the results obtained from Welch’s F-test. It yielded results consistent with Welch’s F-test.

As a result, the opinions of the group of “architects” and “other roles” did not exhibit a significant difference from those of the group of “engineers”. Consequently, their responses were included in the dataset for subsequent analyses.

Table 5.3 Levene's test and Welch's F-Test for comparing among roles (Architect, Engineer, and Other)

Attributes	Homogeneity of variances (Sig.)	Sig.	Mean			ΔMean			ω^2
			Architect	Other	Engineer	Arch Vs. Engr	Other Vs. Engr	Arch Vs. Other	
A1	0.143	0.988	4.09	4.05	4.08	0.01	0.04	0.04	-0.01
A2	0.323	0.356	4.23	4.05	4.00	0.23	0.18	0.18	0.00
A3	0.889	0.768	4.00	4.10	3.95	0.05	0.10	0.10	0.00
A4	0.227	0.585	3.64	3.90	3.86	0.23	0.26	0.26	0.00
A5	0.638	0.806	4.09	4.00	3.96	0.13	0.09	0.09	-0.01
A6	0.826	0.407	4.23	3.90	4.00	0.23	0.33	0.33	0.00
A7	0.911	0.822	3.82	3.75	3.69	0.13	0.07	0.07	-0.01
B1	0.143	0.822	3.82	3.85	3.93	0.11	0.03	0.03	0.00
C1	0.868	0.924	3.82	3.90	3.82	0.00	0.08	0.08	-0.01
C2	0.527	0.650	3.91	4.00	3.83	0.08	0.09	0.09	0.00
C3	0.011	0.290	3.77	3.90	3.66	0.11	0.13	0.13	0.00
C4	0.215	0.150	4.14	3.70	3.83	0.31	0.44	0.44	0.00
C5	0.465	0.209	3.95	3.85	3.61	0.34	0.10	0.10	0.00
C6	0.423	0.189	4.32	4.15	3.98	0.34	0.17	0.17	0.00
D1	0.330	0.890	4.18	4.10	4.12	0.06	0.08	0.08	-0.01

Attributes	Homogeneity of variances (Sig.)	Sig.	Mean			ΔMean			ω^2
			Architect	Other	Engineer	Arch Vs. Engr	Other Vs. Engr	Arch Vs. Other	
D2	0.776	0.018	4.50	3.85	4.06	0.44	0.65	0.65	0.01
D3	0.363	0.940	4.00	3.95	4.01	0.01	0.05	0.05	-0.01
D4	0.366	0.297	4.00	3.60	3.79	0.21	0.40	0.40	0.00
D5	0.486	0.999	3.91	3.90	3.90	0.00	0.01	0.01	-0.01
D6	0.758	0.299	4.14	3.70	3.94	0.19	0.44	0.44	0.00
D7	0.846	0.026	4.32	3.75	3.89	0.43	0.57	0.57	0.01
D8	0.723	0.732	3.91	3.70	3.84	0.07	0.21	0.21	0.00
E1	0.727	0.442	4.09	4.00	3.87	0.22	0.09	0.09	0.00
E2	0.562	0.232	4.05	3.80	3.74	0.31	0.25	0.25	0.00
E3	0.982	0.713	3.95	3.75	3.80	0.16	0.20	0.20	0.00
E4	0.106	0.600	4.23	4.05	4.04	0.19	0.18	0.18	0.00
E5	0.879	0.768	3.64	3.65	3.51	0.12	0.01	0.01	0.00
E6	0.692	0.519	3.77	3.65	3.56	0.22	0.12	0.12	0.00
F1	0.364	0.423	4.23	3.95	4.03	0.19	0.28	0.28	0.00
F2	0.011	0.123	3.77	3.85	3.55	0.23	0.08	0.08	0.00
F3	0.919	0.268	4.23	4.00	3.97	0.26	0.23	0.23	0.00
F4	0.769	0.983	3.95	3.95	3.98	0.02	0.00	0.00	-0.01
F5	0.204	0.397	3.91	3.75	4.03	0.12	0.16	0.16	0.00
F6	0.510	0.871	3.59	3.55	3.65	0.06	0.04	0.04	-0.01
F7	0.722	0.189	3.91	3.85	3.55	0.36	0.06	0.06	0.01
F8	0.087	0.277	4.09	3.95	3.86	0.23	0.14	0.14	0.00
G1	0.490	0.730	3.82	3.75	3.68	0.14	0.07	0.07	0.00
G2	0.731	0.349	4.09	3.80	4.00	0.09	0.29	0.29	0.00
G3	0.683	0.575	3.68	3.75	3.56	0.12	0.07	0.07	0.00
G4	0.070	0.213	3.59	3.95	3.67	0.08	0.36	0.36	0.00
G5	0.476	0.931	3.86	3.85	3.91	0.04	0.01	0.01	-0.01
G6	0.909	0.770	3.95	3.75	3.80	0.16	0.20	0.20	0.00
G7	0.031	0.260	3.86	4.00	3.72	0.14	0.14	0.14	0.00

*Large difference between the mean values (ΔMean > 1.00); **Large effect size (ω^2 > 0.14)

5.5.3 Level of involvement in construction waste management

The comparative analysis among five groups of construction professionals, which included respondents who were never involved in CWM (n=41), rarely involved (n=51), sometimes involved (n=104), often involved (n=34), and always involved (n=34), aimed to examine their opinions on attributes contributing to better CWM. The normality test confirmed a normal distribution of the data across these groups. Subsequently, Levene's Test for equality of variances was employed to assess homogeneity. The results of Levene's Test, as shown in **Table 5.4**, indicated heterogeneity in variances for nine attributes (A2, A3, A4, A5, A6, E6, F4, F5, and G2) with a significant homogeneity of variances (Sig.) less than 0.05. This led to the adoption of Welch's F-test as a robust statistical method to compare means, ensuring reliability under the assumption of different variances.

The results of Welch's F-test, also shown in **Table 5.4**, indicated that five attributes (B1, D1, D6, E1 and G7) had p-values less than 0.05, suggesting that the mean values of these attributes significantly differed between the groups. However, none of the attributes had a large mean difference between groups of respondents who were "never involved in CWM" and "rarely involved", between "never involved in CWM" and "sometimes involved", between "never involved in CWM" and "often involved" and between "never involved in CWM" and "always involved" (ΔMean > 1.00), along with a large effect size ($\omega^2 > 0.14$).

An alternative comparative analysis technique, i.e., the F-Test, was also conducted to validate and compare the results obtained from Welch's F-test. It yielded results consistent with Welch's F-test.

As a result, the opinions of the group of respondents who were never involved in CWM did not show a significant difference from those groups who were rarely involved, sometimes involved, often involved, and always involved. Consequently, their responses were included in the dataset for subsequent analyses.

Table 5.4 Levene's test and Welch's F-Test for comparing the level of professionals' involvement in CWM

Attributes	Homogeneity of variances (Sig.)	Sig.	Mean					ΔMean				ω^2
			Never	Rarely	Sometimes	Often	Always	Never Vs. Rarely	Never Vs. Sometimes	Never Vs. Often	Never Vs. Always	
A1	0.216	0.140	3.95	4.16	3.96	4.15	4.29	0.21	0.01	0.20	0.34	0.01
A2	0.030	0.478	4.05	4.08	3.91	4.07	4.12	0.03	0.14	0.02	0.07	0.00
A3	0.000	0.303	3.78	3.96	3.99	3.93	4.18	0.18	0.21	0.15	0.40	0.00
A4	0.000	0.075	3.63	3.76	3.79	4.00	4.09	0.13	0.15	0.37	0.45	0.02
A5	0.007	0.143	3.83	3.80	3.93	4.16	4.09	0.03	0.10	0.33	0.26	0.01
A6	0.020	0.540	3.88	4.02	3.98	4.15	3.91	0.14	0.10	0.27	0.03	0.00
A7	0.263	0.675	3.61	3.63	3.66	3.80	3.85	0.02	0.05	0.19	0.24	-0.01
B1	0.414	0.046	3.83	3.73	3.86	4.07	4.18	0.10	0.03	0.24	0.35	0.02
C1	0.058	0.153	3.51	3.82	3.82	4.00	3.85	0.31	0.31	0.49	0.34	0.01

Attributes	Homogeneity of variances (Sig.)	Sig.	Mean					ΔMean				ω^2
			Never	Rarely	Sometimes	Often	Always	Never Vs. Rarely	Never Vs. Sometimes	Never Vs. Often	Never Vs. Always	
C2	0.933	0.675	3.71	3.76	3.86	3.93	3.94	0.06	0.15	0.23	0.23	-0.01
C3	0.879	0.354	3.49	3.65	3.70	3.72	3.88	0.16	0.21	0.23	0.39	0.00
C4	0.154	0.649	3.85	3.67	3.89	3.86	3.88	0.19	0.04	0.01	0.03	-0.01
C5	0.690	0.103	3.51	3.73	3.74	3.74	3.24	0.21	0.23	0.23	0.28	0.01
C6	0.677	0.173	4.10	3.90	3.90	4.20	4.03	0.20	0.19	0.11	0.07	0.01
D1	0.500	0.018	4.17	4.06	3.96	4.22	4.44	0.11	0.21	0.05	0.27	0.02
D2	0.770	0.112	4.24	4.06	3.91	4.12	4.32	0.19	0.33	0.12	0.08	0.01
D3	0.839	0.054	3.90	3.84	3.96	4.08	4.32	0.06	0.06	0.18	0.42	0.01
D4	0.407	0.871	3.68	3.86	3.78	3.84	3.79	0.18	0.10	0.15	0.11	-0.01
D5	0.906	0.211	3.95	3.92	3.84	3.84	4.18	0.03	0.11	0.11	0.23	0.00
D6	0.792	0.041	3.88	3.84	3.85	4.01	4.29	0.03	0.03	0.14	0.42	0.01
D7	0.737	0.726	3.93	3.86	3.85	3.95	4.06	0.06	0.08	0.02	0.13	-0.01
D8	0.331	0.463	3.83	3.65	3.81	3.95	3.94	0.18	0.02	0.12	0.11	0.00
E1	0.988	0.039	4.00	3.71	3.79	4.01	4.15	0.29	0.21	0.01	0.15	0.02
E2	0.583	0.219	3.95	3.63	3.67	3.81	3.91	0.32	0.28	0.14	0.04	0.01
E3	0.147	0.746	3.76	3.75	3.76	3.89	3.91	0.01	0.00	0.14	0.16	-0.01
E4	0.137	0.947	4.10	4.08	4.02	4.09	4.00	0.02	0.08	0.00	0.10	-0.01
E5	0.101	0.468	3.68	3.71	3.43	3.50	3.44	0.02	0.25	0.18	0.24	0.00
E6	0.024	0.979	3.59	3.55	3.56	3.59	3.65	0.04	0.03	0.01	0.06	-0.01
F1	0.155	0.277	4.02	4.06	3.96	4.05	4.26	0.03	0.06	0.03	0.24	0.00
F2	0.450	0.796	3.63	3.69	3.50	3.61	3.56	0.05	0.13	0.03	0.08	-0.01
F3	0.478	0.805	4.02	3.94	3.93	4.07	4.03	0.08	0.09	0.04	0.01	-0.01
F4	0.003	0.415	3.80	4.02	3.91	4.05	4.12	0.21	0.11	0.25	0.31	0.00
F5	0.009	0.071	3.76	4.02	3.90	4.18	4.18	0.26	0.15	0.42	0.42	0.02
F6	0.119	0.415	3.34	3.65	3.67	3.73	3.71	0.31	0.33	0.39	0.36	0.00
F7	0.153	0.989	3.56	3.61	3.63	3.55	3.59	0.05	0.07	0.01	0.03	-0.01
F8	0.205	0.720	3.90	3.75	3.89	3.95	3.91	0.16	0.01	0.04	0.01	-0.01
G1	0.271	0.999	3.68	3.69	3.68	3.69	3.74	0.00	0.00	0.01	0.05	-0.01
G2	0.015	0.036	3.85	3.94	4.02	3.91	4.32	0.09	0.17	0.05	0.47	0.01
G3	0.334	0.946	3.61	3.55	3.53	3.64	3.65	0.06	0.08	0.03	0.04	-0.01
G4	0.684	0.930	3.63	3.67	3.69	3.65	3.79	0.03	0.06	0.01	0.16	-0.01
G5	0.364	0.351	3.76	3.78	3.95	3.91	4.09	0.03	0.20	0.15	0.33	0.00
G6	0.156	0.771	3.68	3.86	3.81	3.76	3.97	0.18	0.12	0.07	0.29	-0.01
G7	0.126	0.684	3.76	3.78	3.71	3.68	3.97	0.03	0.04	0.08	0.21	-0.01

*Large difference between the mean values (ΔMean > 1.00); **Large effect size ($\omega^2 > 0.14$)

5.5.4 Professional qualifications

The comparative analysis among five groups of construction professionals, which included respondents who hold no professional license (n=119), Professional Engineer (PE) (n=126), ACPE or APEC Engineer (n=5), Professional Architect (PA) (n=12), Project Management Professional (PMP) (n=12), TREES or LEED (n=10), and Other (n=20), aimed to examine their opinions on attributes contributing to better CWM. The normality test confirmed a normal distribution of the data across these groups. Subsequently, Levene's Test for equality of variances was employed to assess homogeneity. The results of Levene's Test, as shown in **Table 5.5**, indicated heterogeneity in variances for three attributes (C3, F2, and G7) with a significant homogeneity of variances (Sig.) less than 0.05. This led to the adoption of Welch's F-test as a robust statistical method to compare means, ensuring reliability under the assumption of different variances.

The results of Welch's F-test, also shown in **Table 5.5**, indicated that two attributes had p-values less than 0.05, suggesting that the mean values of these attributes were significantly different between the groups. However, none of the attributes had a large mean difference between groups of respondents who hold "none-professional license" and "PE", between "none-professional license" and "ACPE or APEC Engineer", between "none-professional license" and "PA", between "none-professional license" and "PMP", between "none-professional license" and "TREES or LEED", and between "none-professional license" and "Other profession" (ΔMean > 1.00), along with a large effect size ($\omega^2 > 0.14$). An alternative comparative analysis technique, i.e., the F-test, was also conducted to validate and compare the results obtained from Welch's F-test. It yielded results consistent with Welch's F-test.

As a result, the opinions from the group of respondents who hold a none-professional license did not show a significant difference from those groups who hold PE, ACPE or APEC, PA, PMP, TREES or LEED, and Others. Consequently, their responses were included in the dataset for subsequent analyses.

Table 5.5 Levene's test and Welch's F-Test for comparing levels of professionals' licenses in construction and management

Attributes	Homogeneity of variances (Sig.)	Sig.	Mean							ΔMean						ω^2
			None	PE	ACPE/APEC	PA	PMP	TREES/ LEED	Other	None Vs. PE	None Vs. ACPE/APEC	None Vs. PA	None Vs. PMP	None Vs. TREE/	None Vs. Others	
A1	0.082	0.232	3.94	4.15	3.80	4.42	4.25	4.30	4.05	0.21	0.14	0.48	0.31	0.36	0.11	-0.02
A2	0.092	0.245	3.87	4.11	3.80	4.33	4.25	4.10	4.00	0.24	0.07	0.46	0.38	0.23	0.13	-0.02
A3	0.388	0.153	3.82	4.07	4.00	4.08	4.42	4.00	3.80	0.26	0.18	0.27	0.60	0.18	0.02	-0.02
A4	0.011	0.226	3.74	3.98	3.80	3.75	3.83	4.20	3.60	0.24	0.06	0.01	0.09	0.46	0.14	-0.02
A5	0.037	0.005	3.81	4.13	3.80	4.58	3.75	4.10	3.65	0.33	0.01	0.78	0.06	0.29	0.16	-0.02
A6	0.376	0.004	3.86	4.11	3.80	4.67	3.83	4.20	3.90	0.25	0.06	0.81	0.02	0.34	0.04	-0.02
A7	0.017	0.158	3.58	3.85	3.40	4.17	3.50	3.30	3.65	0.27	0.18	0.59	0.08	0.28	0.07	-0.02
B1	0.455	0.176	3.81	4.03	3.40	3.83	3.75	4.20	4.00	0.23	0.41	0.03	0.06	0.39	0.19	-0.02
C1	0.260	0.050	3.64	4.04	3.80	4.08	3.50	3.80	3.65	0.40	0.16	0.44	0.14	0.16	0.01	-0.02
C2	0.373	0.064	3.66	4.01	3.80	4.25	3.83	4.10	3.65	0.35	0.14	0.59	0.18	0.44	0.01	-0.02
C3	0.379	0.011	3.47	3.90	3.80	3.92	3.58	4.00	3.35	0.43	0.33	0.45	0.11	0.53	0.12	-0.01
C4	0.098	0.052	3.66	3.96	4.00	4.33	3.50	4.00	3.95	0.30	0.34	0.67	0.16	0.34	0.29	-0.02
C5	0.961	0.386	3.52	3.76	3.80	4.17	3.33	3.60	3.60	0.24	0.28	0.65	0.19	0.08	0.08	-0.02
C6	0.938	0.410	4.00	4.07	3.60	4.17	3.75	4.40	3.75	0.07	0.40	0.17	0.25	0.40	0.25	-0.02
D1	0.973	0.070	4.00	4.29	3.60	4.25	4.25	4.00	3.80	0.29	0.40	0.25	0.25	0.00	0.20	-0.02
D2	0.713	0.522	3.97	4.18	4.00	4.42	4.08	4.00	3.95	0.22	0.03	0.45	0.12	0.03	0.02	-0.02
D3	0.997	0.672	3.94	4.11	3.60	3.83	3.92	4.00	3.95	0.17	0.34	0.11	0.02	0.06	0.01	-0.02
D4	0.424	0.723	3.72	3.90	3.60	3.83	3.67	3.80	3.65	0.18	0.12	0.11	0.06	0.08	0.07	-0.02
D5	0.541	0.259	3.84	3.95	4.20	3.83	3.75	4.40	3.80	0.11	0.36	0.01	0.09	0.56	0.04	-0.02
D6	0.417	0.790	3.87	4.00	4.00	3.83	3.83	4.30	3.95	0.13	0.13	0.03	0.03	0.43	0.08	-0.02
D7	0.916	0.588	3.82	3.97	4.20	4.17	3.67	4.10	3.90	0.15	0.38	0.35	0.15	0.28	0.08	-0.02
D8	0.051	0.317	3.72	3.92	3.80	3.67	3.58	4.30	3.95	0.20	0.08	0.06	0.14	0.58	0.23	-0.02
E1	0.850	0.330	3.87	3.98	3.40	4.00	3.50	4.00	3.80	0.12	0.47	0.13	0.37	0.13	0.07	-0.02
E2	0.873	0.202	3.69	3.84	3.40	4.17	3.33	4.00	3.70	0.15	0.29	0.48	0.36	0.31	0.01	-0.02
E3	0.333	0.308	3.71	3.94	3.40	4.08	3.50	3.90	3.65	0.23	0.31	0.38	0.21	0.19	0.06	-0.02
E4	0.663	0.037	3.94	4.18	4.00	4.58	3.83	4.10	3.75	0.24	0.06	0.64	0.11	0.16	0.19	-0.02
E5	0.539	0.122	3.34	3.77	3.20	3.67	3.58	3.20	3.25	0.43	0.14	0.32	0.24	0.14	0.09	-0.02
E6	0.359	0.285	3.42	3.73	3.20	3.75	3.75	3.50	3.50	0.31	0.22	0.33	0.33	0.08	0.08	-0.02
F1	0.624	0.084	4.02	4.13	4.00	4.33	3.50	4.00	3.80	0.12	0.02	0.32	0.52	0.02	0.22	-0.02
F2	0.611	0.003	3.34	3.83	3.80	4.08	3.83	3.60	3.00	0.49	0.46	0.75	0.50	0.26	0.34	0.01
F3	0.374	0.013	3.86	4.16	3.80	4.50	3.92	3.90	3.55	0.30	0.06	0.64	0.06	0.04	0.31	-0.01
F4	0.615	0.181	3.92	4.12	3.60	3.92	3.58	3.70	3.85	0.19	0.32	0.01	0.34	0.22	0.07	-0.02
F5	0.397	0.324	3.91	4.13	3.80	3.67	4.17	4.10	3.80	0.23	0.11	0.24	0.26	0.19	0.11	-0.02
F6	0.613	0.156	3.51	3.83	3.80	3.42	3.75	3.60	3.30	0.31	0.29	0.10	0.24	0.09	0.21	-0.02
F7	0.042	0.002	3.43	3.78	3.00	4.33	3.75	3.50	3.10	0.35	0.43	0.90	0.32	0.07	0.33	-0.01
F8	0.678	0.067	3.78	3.98	4.20	4.17	4.00	4.20	3.45	0.19	0.42	0.39	0.22	0.42	0.33	-0.02
G1	0.028	0.005	3.52	3.88	2.80	3.92	3.83	4.10	3.30	0.36	0.72	0.40	0.31	0.58	0.22	0.00
G2	0.814	0.117	3.86	4.13	3.80	3.92	3.83	4.40	3.85	0.28	0.06	0.06	0.02	0.54	0.01	-0.02
G3	0.088	0.252	3.50	3.74	3.60	3.67	3.33	3.50	3.25	0.24	0.10	0.17	0.16	0.00	0.25	-0.02

Attributes	Homogeneity of variances (Sig.)	Sig.	Mean							ΔMean						ω^2
			None	PE	ACPE/APEC	PA	PMP	TREES/ LEED	Other	None Vs. PE	None Vs. ACPE/APEC	None Vs. PA	None Vs. PMP	None Vs. TREE/	None Vs. Others	
G4	0.367	0.181	3.51	3.87	3.60	3.75	3.67	3.70	3.50	0.35	0.09	0.24	0.15	0.19	0.01	-0.02
G5	0.369	0.174	3.92	3.98	3.20	3.42	3.58	4.30	3.70	0.06	0.72	0.51	0.34	0.38	0.22	-0.02
G6	0.589	0.662	3.73	3.91	3.20	3.75	3.83	4.00	3.65	0.18	0.53	0.02	0.10	0.27	0.08	-0.02
G7	0.950	0.712	3.66	3.87	3.60	3.67	3.58	3.90	3.60	0.21	0.06	0.00	0.08	0.24	0.06	-0.02

*Large difference between the mean values (ΔMean > 1.00); **Large effect size ($\omega^2 > 0.14$)

5.5.5 Summary of consistency tests among groups of respondents

In summary, following the consistency tests assessing the variations in opinions among groups of respondents across four categories (Country of company location, Professional roles, Level of involvement in CWM, and Professional qualifications), only one attribute (F2) was excluded as it had a substantial impact size (absolute Chohen’s d > 0.8) identified in the comparative analysis (Welch’s T-test) of respondents from Cambodia and Thailand. Theerefore, one attribute (F2) was eliminated from the data set for subsequent data analyses.

CHAPTER 6

EXPLORATORY AND CONFIRMATORY FACTOR ANALYSES

6.1 Reliability

Internal consistency and item-total correlations were examined as part of the reliability test. The following sections explain each assessment process and the results in the following sections.

6.1.1 Internal consistency test

The degree of consistency across responses from different items (attributes) on a single measurement scale is known as internal consistency. The Cronbach's alpha coefficient, which estimates the correlation between a set of items and their actual scores, is widely used to evaluate internal consistency (Abu-Reishah et al., 2023; Cronbach, 1951). An alpha coefficient above 0.90 is regarded as excellent, above 0.80 as very good, and 0.70 as satisfactory, according to Taber (2018). Furthermore, it is suggested by Hair et al. (2019); Wang et al. (2017) that values in the range of 0.60 to 0.70 represent the lowest level of acceptability. Nonetheless, it is generally accepted that Cronbach's alpha should not fall below 0.70 (Park et al., 2020).

Internal consistency was checked for all 42 attributes (excluding F2) and 304 responses in the current assessment, and Cronbach's alpha value of 0.961 above the 0.9 threshold made internal consistency excellent.

6.1.2 Item-total correlation

The item-total correlation assesses the correlation of an attribute with the composite score of all attributes constituting the measure of the construct. When all attributes share a common core representing the same construct, the scores of each attribute and that of the entire construct should have a high correlation (Omani-Samani et al., 2018; Wang et al., 2017). In SPSS, the item-total correlation value is corrected. According to Park et al. (2020); Pett et al. (2003), a corrected item-total correlation value below 0.30 or above 0.70 suggests that the attribute measures something different from the overall construct and is recommended for deletion. The results of item-total correlations are presented in **Table 6.1**, which shows that all the attributes within each construct as their corrected item-total correlations ranged from 0.430 (F6) to 0.682 (E2).

A correlation between an attribute and the composite score of all the attributes that make up the construct measure is assessed by the item-total correlation. The scores of each attribute and the overall construct should have a high correlated when all of the attributes share a common core that represents the same construct (Omani-Samani et al., 2018; Wang et al., 2017). The item-total correlation value is adjusted in SPSS. A corrected item-total correlation value below 0.30 or over 0.70 indicates that the attribute measures something different from the overall construct and should be deleted, according to Park et al. (2020); Pett et al. (2003). The item-total correlation data is shown in **Table 6.1**, demonstrating that the corrected item-total correlations for each attribute within each construct ranged from 0.430 (F6) to 0.682 (E2).

Attribute ‘F6: Bins are installed on every floor’ with the minimum items-total correlation of 0.430, and it is the only attribute that had items-total correlation less than 0.5. The rest of the attributes had an items-total correlation of more than 0.5, and the attribute named ‘E2: Ensuring the quality of all equipment to be used in every project’ had the maximum items-total correlation of 0.682. The items-total correlation of all attributes was greater than 0.30 (Pett et al., 2003). Furthermore, the alpha coefficient for all these attributes was relatively high (0.961). As no items were identified for deletion based on the ‘correlated item-total correlation’, the examination of ‘Cronbach’s Alpha if item deleted’ was not conducted. Consequently, all items were retained in the dataset for subsequent analyses (Park et al., 2020).

Table 6.1 Item-total correlations of all 42 attributes contributing to better CWM

Attributes: Description	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
A1: Effective site management	0.548	0.961
A2: Effective communication with all stakeholders	0.550	0.961
A3: Senior management's commitment to implementing waste management (WM) practices	0.558	0.961
A4: Implementing an effective organizational structure for WM	0.637	0.960
A5: Supervision of WM activities with clear instructions	0.640	0.960
A6: Properly following a WM plan	0.614	0.960
A7: Monitoring and auditing waste management systems periodically (e.g., every 3 months)	0.604	0.960
B1: Having enough skilled workers in every project	0.549	0.961
C1: Establishment of a strict CWM policy within the company (including the CWM system)	0.578	0.960
C2: Establishment of an appropriate WM plan in the earlier stage of each construction project	0.618	0.960
C3: Setting a “Waste Reduction Target” for every project by maximizing the reduction of materials usage (e.g., reducing wastage from 15% to 10% of all materials usage)	0.584	0.960
C4: Including subcontractor responsibilities for WM targets in the contract	0.639	0.960
C5: Offering incentives for waste minimization efforts to the project team (e.g., money, certificate)	0.535	0.961
C6: Preventing site accidents (e.g., fires and deaths causing material waste and project delays)	0.538	0.961
D1: Precise material purchasing (i.e., preventing order errors, right sizes and quantities)	0.627	0.960
D2: On-time and accurate quantification of materials/bills of quantities	0.622	0.960
D3: Using quality, durable, and standardized materials (i.e., according to specification)	0.644	0.960
D4: Adopting Just in Time (JIT) delivery system	0.617	0.960
D5: Adequate protection of material transportation and handling (loading and unloading)	0.575	0.960
D6: Precise on-site material control (e.g., inspecting the materials when they arrive, etc.)	0.596	0.960
D7: Adequate protection of different categories of materials during storing and stacking	0.677	0.960
D8: High level of security at the project site (i.e., prevent theft and loss of materials)	0.544	0.961
E1: Ensuring the availability of equipment required for every project (i.e., tools, machines, and vehicles)	0.657	0.960
E2: Ensuring the quality of all equipment to be used in every project	0.682	0.960
E3: Be familiar with the usage of all equipment (i.e., persons in charge)	0.641	0.960
E4: Utilizing scaffolding and formwork that can be reused many times (e.g., metal, plastic, etc.)	0.559	0.961
E5: Utilizing Building Information Modeling (BIM) for the project and be familiar with its application	0.592	0.961
E6: Utilizing other related information technologies for the project and be familiar with their application	0.658	0.960

Attributes: Description	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
F1: Adequate site space and the site layout are cleared for materials movement	0.601	0.960
F3: Efficient use of materials and minimizing the uneconomical cutting shapes and length	0.630	0.960
F4: Implementing proper method statement for each activity, including minimizing waste from application processes	0.655	0.960
F5: Minimizing rework at the construction site	0.595	0.960
F6: Bins are installed on every floor	0.430	0.961
F7: Setting up separated bins according to the waste type and sort out waste at the site	0.565	0.961
F8: Storing construction waste in easily accessible areas	0.605	0.960
G1: Effective document control of CWM, including tracking the amounts and kinds of CW generated	0.646	0.960
G2: Detailed study and thorough understanding of specifications and drawings	0.654	0.960
G3: Professional quality management and certification (e.g., ISO, GREEN, etc.)	0.590	0.960
G4: Keeping lessons learned repository about CWM	0.649	0.960
G5: Preventing shop drawing detailing errors (i.e., implementing a proper process check)	0.657	0.960
G6: Minimizing design changes during construction	0.539	0.961
G7: Minimizing variation orders (VO)	0.541	0.961

Note: 1) *To be compared with Cronbach's alpha of 0.961; **Correlation < 0.300.

2) Excluded 'F2'

6.2 Exploratory Factor Analysis

This study used exploratory factor analysis (EFA) to reduce all attributes into a more manageable grouping (Bandalos et al., 2018; Hair et al., 2019; Williams et al., 2010). R-factor analysis or Q-factor analysis is often used to carry out EFA. In contrast to the Q-type, which deals with grouping many individuals into separate groups within a broader population, the R-type factor analysis finds a latent dimension within a wide range of attributes (Hair et al., 2019). Since the primary goal of this analysis stage was to aggregate attributes into a new set of composite dimensions rather than categorizing individual respondents, the most popular R-type was selected. According to Gerbing et al. (1988), EFA is beneficial as a first analysis when there isn't a sufficiently thorough theory explaining how attributes relate to the underlying construct. Since these attributes had not been thoroughly operationalized within the construction context, EFA was deemed necessary even though the majority of the measured attributes in the construct were drawn from earlier research and a thorough literature review. Detailed explanations of the analysis are given in subsequent sections.

6.2.1 Data factorability

The appropriateness of the data to be factorized regarding the intercorrelation between the attributes is referred to as factorability. Large values for the correlation were required in a factorable correlation matrix since it was assumed that all of the attributes included in the analysis measured the same underlying construct (Hair et al., 2019). To assess the factorability of such a matrix, two often used methods are Bartlett's test of sphericity and the Kaiser-Meyer-Olkin measure of sample adequacy (KMO) (Pett et al., 2003).

Table 6.2 shows that the sample adequacy was demonstrated by the Kaiser-Meyer-Olkin (KMO) value of 0.945, which is significantly higher than the minimum acceptable level of 0.60 (Shrestha, 2021). Furthermore, the 304 cases in this study exceeded the prerequisite of having at least five times as many cases as the attributes to be examined and satisfied the minimum acceptable sample size of 100 (Hair et al., 2019). For this study, a total of 43 x 5 = 215 samples were needed. Subsequently, suitable correlations between the attributes included in the analysis were suggested by the very significant results of Bartlett's test of sphericity statistic at the $p < 0.001$ level (Field, 2013). These results supported the conducted EFA's factorability (Hair et al., 2019).

Table 6.2 KMO and Bartlett's Test of Sphericity

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.945
Bartlett's Test of Sphericity	Approx. Chi-Square	8298.550
	df	861
	Sig.	0.000

6.2.2 Factor extraction and rotation

The EFA involves two critical processes to produce a good solution that explains a sufficient number of factors representing a construct: (1) factor extraction and (2) factor rotation and interpretation (Hair et al., 2019; Pett et al., 2003). The study used "Principal Component Analysis (PCA)" for factor extraction, a commonly used technique to identify the factors required to reflect the structure of the attributes. The following requirements were used in the extraction process: Four requirements were identified: "(1) Latent root (eigenvalue) criterion; (2) Cattell's scree test; (3) the percentage of variance criterion; and (4) a priori criterion" (Hair et al., 2019; Pett et al., 2003). Factors with eigenvalues larger than one are deemed significant by the Latent Root Criterion, whereas those with eigenvalues less than one are excluded. Using a graphic representation of eigenvalues against the number of factors, the Cattell's scree test determines the maximum number of factors to be retrieved by looking for a sudden change in slope (Cattell, 1965; Hair et al., 2019; Kim et al., 1978). In social science research, a solution that explains sixty percent (or less) of the total variance is typically considered by the percentage of variance criterion, which guarantees practical significance. The a priori criterion involves knowing the number of factors prior to analysis, which is suitable for replicating another researcher's findings. Hair et al. (2019) advise combining theoretical foundations with empirical data to find the right number of factors.

It was critical to look at the attributes loadings onto these factors after the factors were extracted (Field, 2013). Factors rotation was used for more straightforward and significant solutions; Varimax orthogonal rotation was the favoured technique (Hair et al., 2019; Tabachnick et al., 2007). To assure practical importance upon rotation, a cut-off factor loading of 0.45 was used (Chinda, 2016; Soewin et al., 2022; Taherdoost et al., 2022; Williams et al., 2010).

The scree plot suggested extracting five components or factors (Cattell, 1965; Hair et al., 2019; Kim et al., 1978), explaining 59.781% of the total variance, slightly below the recommended threshold of 60%, which is fully accepted. Following these results, EFA was conducted by specifying the number of factors to be extracted (Field, 2013), removing four attributes (B1, E2, F1, and F3). The remaining 39 attributes were retained for subsequent analysis. The following sections provide an in-depth review of the EFA's findings.

6.2.3 EFA results

The EFA was conducted using SPSS version 27 on a dataset of 304 responses comprising 42 attributes. The analysis utilized standard techniques and criteria to identify underlying factor structures, as mentioned in **Section 6.2**. The results evaluated using the scree test (see **Figure 6.1**) revealed five distinct factors that accounted for 59.079% of the total variance, which is considered acceptable given the recommended threshold of 60%. Most attributes exhibited significant factor loadings, exceeding the threshold of 0.50, except for 13 attributes (E1, E2, E3, C6, E4, C3, C5, B1, G5, F5, F3, F1, and G1) showing low loadings or cross-loading issues. Consequently, these attributes were removed, resulting in 29 retained attributes. These retained attributes were grouped into five factors, labeled as (1) Governance and policies (GP); (2) Materials and equipment (ME); (3) Requirements and specifications (RS); (4) Construction information systems (CIS); and (5) Waste collection facilities (WCF). These attributes were assigned new codes based on the EFA results. The cumulative variance supports the appropriateness of the factor solution. Furthermore, the internal consistency, measured by Cronbach's alpha at 0.945, was substantial, exceeding the commonly accepted threshold of 0.70. **Table 6.3** presents the rotated factor loadings for the refined 29 attributes and their respective factors. **Table 6.4** and **Figure 6.2** represent the core concepts for naming factors aligning with CWM.

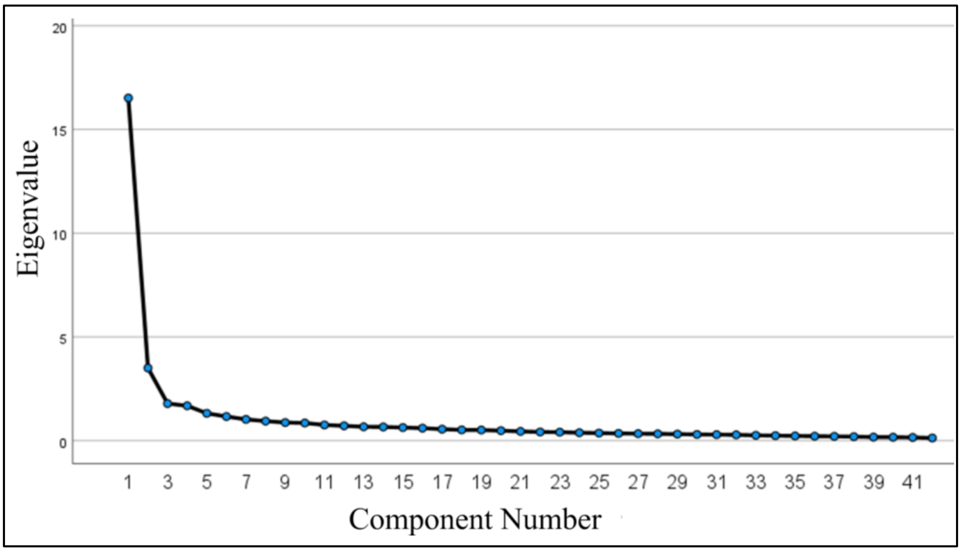

Figure 6.1 Scree plot

Table 6.3 Rotated factor loadings

Attributes: Description		Rotated Component				
		1	2	3	4	5
GP	**Governance and policy:**					
GP1	A6: Properly following a WM plan	0.831				
GP2	A5: Supervision of WM activities with clear instructions	0.805				
GP3	C1: Establishment of a strict CWM policy within the company (including the CWM system)	0.717				
GP4	A4: Implementing an effective organizational structure for WM	0.700				
GP5	A7: Monitoring and auditing waste management systems periodically (e.g., every 3 months)	0.687				
GP6	C2: Establishment of an appropriate WM plan in the earlier stage of each construction project	0.678				
GP7	A3: Senior management's commitment to implementing waste management (WM) practices	0.674				
GP8	A1: Effective site management	0.643				
GP9	C4: Including subcontractor responsibilities for WM targets in the contract	0.626				
GP10	A2: Effective communication with all stakeholders	0.570				
ME	**Materials and equipment:**					
ME1	D6: Precise on-site material control (e.g., inspecting the materials when they arrive, etc.)		0.834			
ME2	D5: Adequate protection of material transportation and handling (loading and unloading)		0.766			
ME3	D7: Adequate protection of different categories of materials during storing and stacking		0.730			
ME4	D8: High level of security at the project site (i.e., prevent theft and loss of materials)		0.710			
ME5	D4: Adopting Just in Time (JIT) delivery system		0.658			
ME6	D1: Precise material purchasing (i.e., preventing order errors, right sizes and quantities)		0.657			

Attributes: Description		Rotated Component				
		1	2	3	4	5
ME7	D3: Using quality, durable, and standardized materials (i.e., according to specification)		0.652			
ME8	D2: On-time and accurate quantification of materials/bills of quantities		0.639			
RS	**Requirements and specifications:**					
RS1	G6: Minimizing design changes during construction			0.758		
RS2	G7: Minimizing variation orders (VO)			0.699		
RS3	G2: Detailed study and thorough understanding of specifications and drawings			0.546		
RS4	F4: Implementing proper method statement for each activity, including minimizing waste from application processes			0.495		
CIS	**Construction information systems:**					
CIS1	E5: Utilizing Building Information Modeling (BIM) for the project and be familiar with its application				0.743	
CIS2	E6: Utilizing other related information technologies for the project and be familiar with their application				0.682	
CIS3	G3: Professional quality management and certification (e.g., ISO, GREEN, etc.)				0.605	
CIS4	G4: Keeping lessons learned repository about CWM				0.506	
WCF	**Waste collection facilities:**					
WCF1	F6: Bins are installed on every floor					0.788
WCF2	F8: Storing construction waste in easily accessible areas					0.665
WCF3	F7: Setting up separated bins according to the waste type and sort out waste at the site					0.638
Note:	Cumulative variance explained = 59.781%; KMO=0.945; Cronbach's alpha = 0.945 13 attributes were removed (E1, E2, E3, C6, E4, C3, C5, B1, G5, F5, F3, F1, G1) due to cross-loading and factor loading less than 0.5 29 attributes remained					

Table 6.4 Core concepts for naming factors aligning with CWM

No.	Name of factor	References
1	Governance and policy (GP)	(Bao et al., 2021; Cha et al., 2009; Newaz et al., 2022; Yeheyis et al., 2012)
2	Material and equipment (ME)	(Cha et al., 2009; Kolaventi et al., 2018a; Kolaventi et al., 2020; Yeheyis et al., 2012)
3	Requirements and specifications (RS)	(Ajayi et al., 2018; Cha et al., 2009; Kolaventi et al., 2020; Poon et al., 2004)
4	Construction information system (CIS)	(Cha et al., 2009; Kolaventi et al., 2018a; Menegaki et al., 2018)
5	Waste collection facilities (WCF)	(Doust et al., 2020; Wang et al., 2010; Yeheyis et al., 2012)

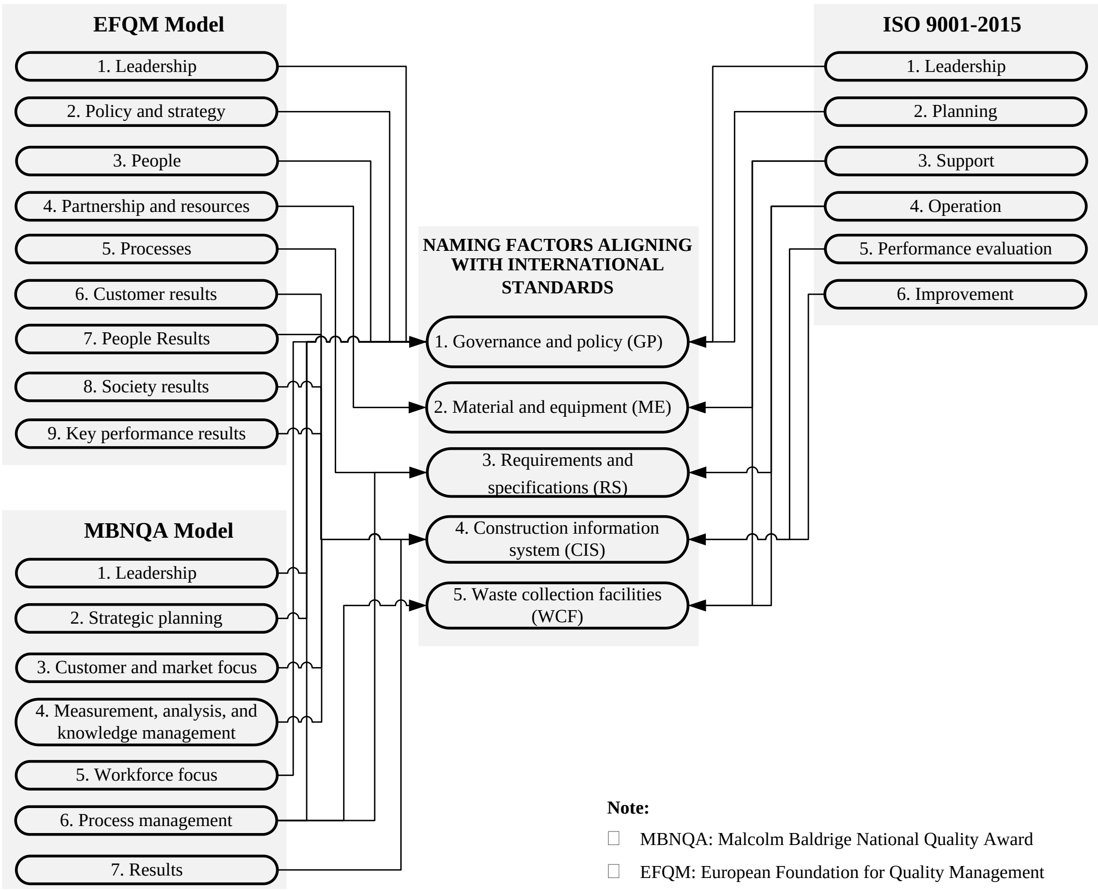

Figure 6.2 Naming factors aligning with international standards (Adaped from Bou-Llusar et al. (2009); Young Kim et al. (2010))

6.2.4 Summary of EFA results

In summary, the EFA's result showed that, after 13 attributes were eliminated from the 42 data sets, 29 attributes were retained for subsequence analysis. The EFA generated five factors, namely, (1) Governance and policy (GP), comprising 10 attributes; (2) Material and equipment (ME), comprising of 8 attributes; (3) Requirements and specifications (RS), comprising 4 attributes; (4) Construction information system (CIS), comprising 4 attributes; and (5) Waste collection facilities (WCF), comprising 3 attributes.

The cumulative proportion of the variance extracted, 59.781%, provided evidence for the correctness of the factor solution. Furthermore, the internal consistency of Cronbach's alpha coefficient was strong, exceeding the 0.70 threshold.

6.2.5 Test of common method variance

Using Harman's one-factor test, the EFA was employed to assess common method variance and determine the number of factors (Harman, 1976). If one general factor or one factor from the factor analysis accounts for a majority of the covariance among the attributes, then this method finds considerable common method variance (Harman, 1976; Podsakoff et al., 1986).

Using criteria comparable to the previous factor analysis, the EFA was applied to all 29 attributes in order to conduct the test. A total of 29 components (attributes) were extracted, according to the results as shown in **Table 6.5**. The first attribute explained 39.825 percent of the total, less than the 50% threshold (Aguirre-Urreta et al., 2019; Eichhorn, 2014). This finding suggests the common method variance in this study was not significantly concerned.

Table 6.5 EFA results for common method variance

	Initial Eigenvalues		
Component	**Total**	**% of Variance**	**Cumulative %**
1	11.549	39.825	39.825
2	3.065	10.570	50.394
3	1.655	5.706	56.100
4	1.524	5.255	61.356
5	1.081	3.729	65.084
6	0.860	2.965	68.049
7	0.794	2.737	70.786
8	0.694	2.392	73.178
9	0.681	2.348	75.526
10	0.600	2.068	77.594
11	0.585	2.016	79.610
12	0.555	1.914	81.524
13	0.506	1.745	83.269
14	0.484	1.669	84.938
15	0.426	1.468	86.407
16	0.404	1.394	87.801

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
17	0.388	1.337	89.138
18	0.374	1.290	90.428
19	0.350	1.206	91.634
20	0.338	1.164	92.797
21	0.303	1.043	93.841
22	0.288	0.994	94.835
23	0.270	0.932	95.767
24	0.263	0.906	96.672
25	0.217	0.749	97.421
26	0.207	0.715	98.136
27	0.203	0.700	98.835
28	0.185	0.639	99.475
29	0.152	0.525	100.000

6.3 Confirmatory factor analysis

Two consecutive procedures were used to assess the measuring scale's validity and reliability: (1) Exploratory Factor Analysis (EFA) and (2) Confirmatory Factor Analysis (CFA) (Bandalos et al., 2018; Hair et al., 2019), as stated in the previous section. EFA is regarded as an exploratory method even though it assisted in determining the number of factors and supported the validity of the underlying measuring scales. This is due to the fact that EFA does not offer an in-depth assessment of unidimensionality and construct validity, which are crucial elements of measurement theory (Gerbing et al., 1988; Hair et al., 2019). According to Gerbing et al. (1988); Hair et al. (2019), unidimensionality indicates the existence of a single construct underlying a set of measured attributes, whereas construct validity refers to the degree to which measured attributes accurately reflect the theoretical construct. A modern analytical technique called confirmatory CFA was used to test construct validity and unidimensionality thoroughly. Because it offers a stricter interpretation, CFA is chosen over exploratory approaches (e.g., item-total correlation and EFA) (Bandalos et al., 2018; Gerbing et al., 1988). CFA effectively assesses how well an established factor structure and the loading pattern that goes along with it fit the data that was examined (Hair et al., 2019; Kline, 2023). It could improve an established theoretical framework, validate a well-established structure, and assess dimensional consistency among different populations (DiStefano et al., 2005). CFA was used to further refine and validate the identified factor structure after the initial EFA-identified factor structure. In order to determine unidimensionality and construct validity, this procedure comprised assessing how well the factor structure appropriate the data and analyzing model parameters (Hair et al., 2019). In order to show how the measured attributes reflected a latent factor, the factor structure was presented as a CFA model (Hair et al., 2019). Although the EFA and CFA model specifications were similar, the primary distinction was that the CFA model required prior specification of the number of factors and the correlations between the attributes and factors (Hair et al., 2019). The details of the analysis are elaborated on in subsequent sections.

6.3.1 Assessment of model fit and estimation methods

CFA's principal characteristic lies in its ability to assess how well the specified factor model represents the data. This evaluation is conducted through an examination of model fit indices. Generally, a model is accepted if the fit indices indicate goodness; however, rather than being rejected, a model with unsatisfactory fit indices is typically respecified to improve its fit. Fit indices are commonly categorized as either absolute or incremental (Hair et al., 2019; Hoyle, 1995; Kline, 2023), as outlined below.

(1) Absolute fit indices: These indices concern the extent to which the hypothesized model reproduces the sample (Hair et al., 2019; Shah et al., 2006). The Chi-square (χ^2) statistic is a fundamental index in this category, incorporating values such as χ^2, degrees of freedom (df), and significance level (p-value). Conventionally, a non-significant χ^2 suggests model-data fit acceptance, while a significant χ^2 ($p < 0.05$) implies the model did not fit the data and is recommended for rejection. However, interpreting χ^2 is complex due to various issues, such as sensitivity and bias in large sample sizes (Hoyle, 1995, 2012; Kline, 2023). Therefore, alternative fit indices like relative Chi-square (χ^2/df), goodness-of-fit index (GFI), adjusted-goodness-of-fit index (AGFI), standardized root mean square residual (SRMR), and root mean square error of approximation (RMSEA) have been introduced to quantify model fit (Hair et al., 2019; Kline, 2023; Shah et al., 2006).

(2) Incremental fit indices: These indices assess how well the model performs compared to alternative models, such as the null model and a model perfectly fitting the data (Hair et al., 2019; Hoyle, 1995; Shah et al., 2006). Normed-fit index (NFI), Tucker-Lewis index (TLI), comparative-fit index (CFI), and incremental-fit index (IFI) are popular in this category (Hair et al., 2019; Kline, 2023).

An appropriate estimation method is necessary to compute model parameters and fit indices accurately. Various methods are available, including maximum likelihood (ML), generalized least square (GLS), weighted least square (WLS), asymptotically distribution-free (ADF), and ordinary least square (OLS) (Hair et al., 2019; Kline, 2023; Shah et al., 2006). The choice depends on data distribution, model complexity, and sample size. ML is widely used, followed by GLS, which assumes both univariate and multivariate normality (Hoyle, 1995). WLS and ADF do not require normal distribution but demand a large sample size. OLS is robust but lacks fit indices and standard errors (Shah et al., 2006).

As outlined in **Section 5.3.2**, the data utilized in this study was univariate normal distribution. It is important to note that the assumption of multivariate normal distribution of the data was likely violated, given that univariate normality is a prerequisite for multivariate normality. Regarding the sample size concern, including 304 cases in this study was deemed substantial for both EFA and CFA (Kline, 2023). Considering these data characteristics, Maximum Likelihood (ML) was considered the most appropriate estimation method, given that ML requires univariate normality in data distribution (Hoyle, 1995). Additionally, the data characteristics justified using specific model fit indices, including χ^2/df, GFI, TLI, CFI, IFI, and RMSEA. A simulation conducted by Shah et al. (2006) suggested that these fit indices are not substantially biased even under conditions of nonnormality when employing the ML estimation method. To assess the model fit acceptability, all six indices were evaluated against the following criteria: (1) χ^2/df < 3.0 (Hair et al., 2019; Kline, 2023); (2) GFI > 0.8: reasonable fit (Cheng, 2011; Doll et al., 1994); (3) TLI > 0.9 (Hoyle, 1995; Kline, 2023; Xia et al., 2019); (4) CFI >0.90 (Hoyle, 1995; Kline, 2023; Xia et al., 2019); (5) IFI > 0.90 (Browne et al., 1992; Hoyle, 1995; Kline, 2023); and RMSEA < 0.08 (Browne et al., 1992; Hair et al., 2019; Xia et al., 2019).

6.3.2 Assessment of construct validity and unidimensionality

Assessing construct validity through CFA concerning both convergent validity and discriminant validity. Convergent validity is about assessing the extent to which measured attributes within a specific construct share a substantial amount of common variance, while discriminant validity is about the distinctiveness of a construct from others (Hair et al., 2019).

Convergent validity assessment focused on the magnitude and significance of standardized factor loadings. Larger factor loadings with corresponding significant t-values provide stronger evidence that the measured attributes accurately represent the underlying construct (Bollen, 1989). As a guideline, Hair et al. (2019) suggest factor loadings exceeding 0.50 as a guideline. Koufteros (1999) argues that significant t-values alone suffice to demonstrate convergent validity. Additionally, attributes should exhibit adequate reliability, assessed by examining the value of R^2 (squared multiple correlation, SMC). Bollen (1989) and Kline (2023) recommend R^2 values greater than 0.50 to demonstrate acceptable reliability. Kline (2023) suggests assessing the correlation coefficient between each pair of factors for discriminant validity. If the correlation coefficient is excessively high (i.e., exceeding 0.850), the factors may represent the same concept and should be considered as a single factor.

Unidimensionality indicates that attributes load on only one construct and can be assessed through model fit indices (Koufteros, 1999). Unidimensionality can be established if the model fit indices, considering all factors specified for loading on a single construct, and meets the criteria mentioned above satisfactorily. The subsequent section presents the initial and final CFA results.

6.3.3 CFA results

The AMOS program (version 24), an extension of SPSS, was utilized for the CFA, with the default use of the covariance matrix as input data (Kline, 2023; Shah et al., 2006). The findings, presented in **Table 6.6**, include factor loadings, t-values, and significance levels for each attribute to assess convergent validity, while R^2 values measure attributes' reliability.

The initial CFA results showed that most fit indices were close to their recommended thresholds. However, two attributes (GP10 and GP8) had very low R^2 values of 0.329 and 0.377, respectively. These two attributes were thus removed to enhance the model fit, and the model was re-estimated with 27 attributes.

The final CFA results depicted in the standard measurement model (**Figure 6.3**), demonstrated an improvement in all fit indices: χ^2 = 861.88, df = 314, χ^2/df = 2.745, GFI = 0.821, TLI = 0.876, CFI = 0.889, IFI = 0.890, NFI = 0.837, RMSEA = 0.076, and SRMR = 0.072. The χ^2/df ratio was acceptable, falling below the threshold of 3.00. The GFI and NFI were above the threshold of 0.80, and the TLI, CFI, and IFI were close to the threshold of 0.90, while the RMSEA and SRMR were within the threshold of 0.08, indicating acceptable model fit (refer to Table **Table 3.4** for reference). All factor loadings ranged from 0.639 to 0.853, exceeding the 0.50 threshold, and were significant at $p < 0.001$, suggesting convergent validity. The R^2 values were either greater than or close to 0.50, indicating the reliability of the attributes. Furthermore, the discriminant validity of the construct was supported, as all correlation coefficients between each pair of factors ranged from 0.437 to 0.665 (**Table 6.7**), which were less than 0.850, thereby upholding unidimensionality.

In summary, the factor structure specified by the EFA was refined and confirmed by the final CFA results, as shown in **Table 6.8**. The final Cronbach's alpha value, which indicated the reliability of the construct, was high at 0.949. Therefore, the CFA process produced the final factor structure that is sufficiently reliable, valid, and unidimensional, consisting of five factors with 27 attributes.

Table 6.6 CFA results

Factors/ Attributes	Factor loadings	t-value (C.R)	R^2
1. Governance and policies (GP)			
GP1	0.849	f.p.	0.722
GP2	0.853	18.828	0.728
GP3	0.751	15.389	0.564
GP4	0.724	14.577	0.524
GP5	0.774	16.107	0.599
GP6	0.758	15.611	0.575
GP7	0.675	13.224	0.455
GP9	0.716	14.346	0.512
2. Materials and equipment (ME)			
ME1	0.821	f.p.	0.675
ME2	0.776	15.359	0.603

Factors/ Attributes	Factor loadings	t-value (C.R)	R^2
ME3	0.804	16.116	0.646
ME4	0.672	12.674	0.451
ME5	0.712	13.664	0.507
ME6	0.731	14.145	0.534
ME7	0.731	14.142	0.534
ME8	0.718	13.823	0.516
3. Requirements and specifications (RS)			
RS1	0.836	f.p.	0.699
RS2	0.809	15.104	0.654
RS3	0.677	12.25	0.458
RS4	0.639	11.417	0.408
4. Construction information systems (CIS)			
CIS1	0.788	f.p.	0.622
CIS2	0.811	14.405	0.658
CIS3	0.705	12.356	0.497
CIS4	0.713	12.509	0.508
5. Waste collection facilities (WCF)			
WCF1	0.699	f.p.	0.488
WCF2	0.773	11.266	0.597
WCF3	0.791	11.413	0.625

Note: f.p., fixed parameter for estimation; ***p < 0.001.
GP10 and GP8 were removed due to the low R^2 value

Table 6.7 Correlation between factors of CFA results

Correlation between factors			
GP	<-->	ME	0.480
GP	<-->	WCF	0.623
GP	<-->	RS	0.437
GP	<-->	CIS	0.636
ME	<-->	RS	0.665
ME	<-->	CIS	0.577
ME	<-->	WCF	0.506
RS	<-->	CIS	0.657
RS	<-->	WCF	0.471
CIS	<-->	WCF	0.627

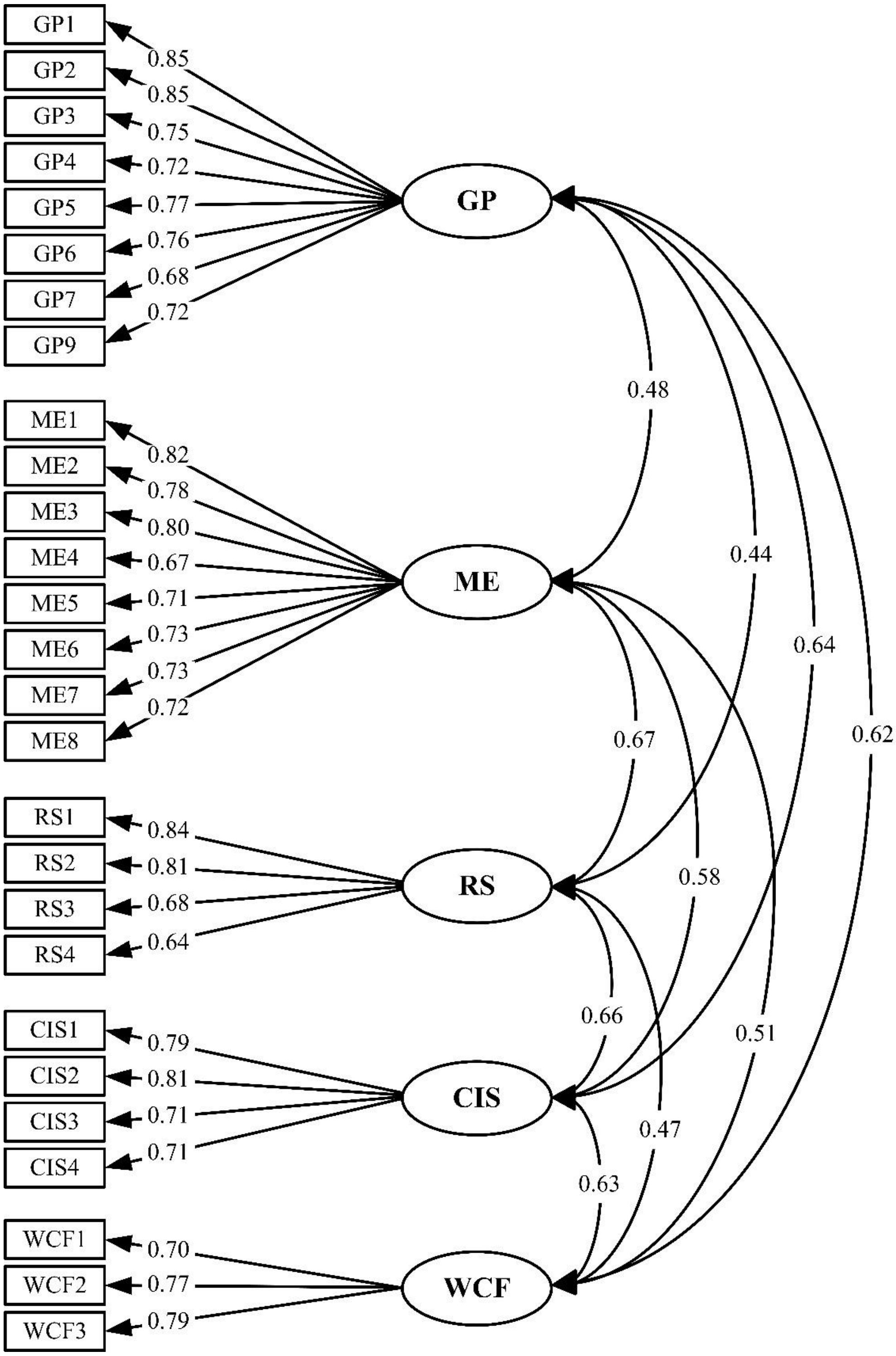

Figure 6.3 CFA measurement model

Table 6.8 Model fit indices

Fit indices	Threshold and references	Initial model	Final model
Chi-square(χ^2)	-	1,037.96	861.88
Df	-	367	314
p-value	-	0.00	0.00
x2/Df	< 3 (Hair et al., 2019; Kline, 2023)	2.828	2.745
GFI	> 0.8 (Cheng, 2011; Doll et al., 1994)	0.803	0.821
TLI	> 0.9 (Hoyle, 1995; Kline, 2023; Xia et al., 2019)	0.860	0.876
CFI	> 0.9 (Hoyle, 1995; Kline, 2023; Xia et al., 2019)	0.873	0.889
IFI	> 0.9 (Hoyle, 1995; Kline, 2023)	0.874	0.890
NFI	> 0.8 (Bentler et al., 1980; Simon et al., 2010)	0.818	0.837
RMSEA	< 0.08 (Hair et al., 2019; Xia et al., 2019)	0.078	0.076
SRMR	< 0.08 (Bagozzi et al., 2012; Hu et al., 1999)	0.074	0.072

6.3.4 Summary of CFA results

In summary, the factor structures identified in the EFA were validated by the CFA results, with just two attributes eliminated to improve model fit indices, as shown in **Table 6.9**. The final Cronbach's alpha value, which showed the construct's dependability, was remarkably high at 0.949. Construct validity was confirmed by the significant and substantial loadings that every attribute showed on its corresponding factor with acceptable reliability. Furthermore, every fit index showed positive outcomes, supporting the model construct's unidimensionality. So, the comprehensive CFA processes produced final factor structures that were sufficiently reliable, valid, and unidimensional for the model construct.

Table 6.9 Summary of CFA results

Factors	Number of attributes		Model Fit Indices									
	EFA	CFA	χ^2	df	χ^2 /df	GFI	TLI	CFI	IFI	NFI	RMSEA	SRMR
Governance and policies (GP)	10	8	861.884	314	2.745	0.821	0.876	0.889	0.890	0.837	0.076	0.072
Materials and equipment (ME)	8	8										
Requirements and specifications (RS)	4	4										
Construction information systems (CIS)	4	4										
Waste collection facilities (WCF)	3	3										
Total	**29**	**27**										

Note: Final Cronbach's alpha (α) = 0.949

CHAPTER 7

BEST WORST METHOD FOR WEIGHING ATTRIBUTES

7.1 Introduction

The analysis and results of the study were presented in two parts: the demographic profile of the expert participants and the BWM pairwise comparison. The demographic information of the construction professional experts was based on the experts' backgrounds in the pairwise comparison interview. The second part focused on the analysis and results of the BWM pairwise comparison, which determined the local and global weights of the attributes influencing CWM performance for contractors in building construction.

7.2 Demographic information of experts

The experts involved in this study comprised 10 experienced construction professionals from Cambodia and Thailand (five from each country). Most of the experts (6 out of 10) were project managers, while the positions of managing director, technical director, project architect, lecturer, and researcher in construction management accounted for one. All the experts had more than 10 years of experience in the building construction industry and were involved in CWM in building construction projects. Among them, five had 10-15 years of experience, two had 16-20 years of experience, and three had over 20 years of experience. The educational backgrounds of the experts included at least a Bachelor of Engineering degree. Most experts (6) hold a Master of Engineering in construction engineering management or civil engineering, followed by a Bachelor of Engineering (3) and a Ph.D. in construction engineering and management (1). Most experts also held professional qualifications. Specifically, six were Professional Engineers (PE). At the same time, the remainder held qualifications such as Professional Safety Management, ASEAN Chartered Professional Engineer (ACPE), APEC Engineer, Associate Professional Architect, Registered Civil Engineer, or none. The details of the experts' demographic information are presented in **Table 7.1**.

Table 7.1 Detailed of experts' demographic

Expert No.	Position	Years of experiences	Education level	Professional qualification	Country
1	Managing director	11	B.Eng. in Civil engineering	Professional engineer	Cambodia
2	Project architect	10	M.Eng. in Housing management	Associate professional architect	Thailand
3	Lecturer and researcher in CEM	25	Ph.D. in Construction engineering and management	Professional engineer	Thailand
4	Project manager	11	M.Eng. in Civil engineering	Professional engineer	Cambodia
5	Technical director	18	B.Eng. in Civil engineering	Registered civil engineer	Cambodia
6	Project manager	14	M.Eng. in Civil engineering	Registered civil engineer	Cambodia
7	Project manager	11	M.Eng. in Construction engineering and management	Professional engineer and Professional safety management	Thailand
8	Project manager	20	M.Eng. in Construction engineering and management	Professional engineer, ACPE, APEC engineer	Thailand
9	Project manager	25	B.Eng. in Civil engineering	None	Cambodia
10	Project manager	22	M.Eng. in Civil engineering	Professional engineer	Thailand

7.3 Result of pairwise comparisons

7.3.1 Local weight

The pairwise comparison inputs obtained from each expert were analyzed. The first step was to determine the local weight of each attribute and factor using the BWM Solvers (Rezaei, 2015, 2016, 2022). The local weights were calculated for 27 attributes across five factors: eight attributes for "Governance and policies", eight attributes for "Materials and equipment", four attributes for "Requirements and specifications", four attributes for "Construction information systems", and three attributes for "Waste collection facilities". The local weights were calculated separately from the pairwise comparison inputs provided by each expert, and the average local weights of attributes were determined by taking the geometric mean of the local weights across all experts. The same approach was used to calculate the local weights for all five factors. The local weights were calculated separately for all attributes within each of the five factors and for the five factors themselves. The local weight represents the relative importance of each attribute within its respective factor, and the local weight of each factor represents its relative importance within the overall contractors' CWM performance in building construction. Calculating the local weights formed the basis for further determining the global weights of each attribute in the overall hierarchy. The results of the local weight for each factor and attribute are presented in **Table 7.2** and **Table 7.3**, respectively.

Table 7.2 Local weights of factors by geometric mean

Code	Factors	Local weight of factors										
		Expert number										Geometric mean
		1	2	3	4	5	6	7	8	9	10	
GP	Governance and policies	0.32	0.36	0.36	0.45	0.48	0.35	0.45	0.27	0.35	0.41	**0.377**
ME	Materials and equipment	0.32	0.11	0.20	0.17	0.18	0.13	0.17	0.27	0.21	0.15	**0.183**
RS	Requirements and specifications	0.12	0.40	0.20	0.13	0.08	0.06	0.17	0.31	0.21	0.15	**0.160**
CIS	Construction information systems	0.06	0.04	0.11	0.08	0.14	0.10	0.08	0.08	0.09	0.06	**0.079**
WCF	Waste collection facilities	0.18	0.09	0.13	0.17	0.11	0.35	0.13	0.06	0.14	0.23	**0.142**

7.3.2 Global weight

The global weight of each attribute from each expert was calculated. The local weights of attributes under each factor were multiplied by the local weights of their respective factors to calculate the global weights. The global weights were calculated using the geometric mean for each attribute. However, the sum of the global weights of all attributes was 0.82 or 82%. Therefore, the global weight of each attribute was normalized to ensure the sum is 1.00 or 100% (Chitsaz et al., 2017; Rezaei, 2015; Saaty, 2004). These normalized global weights are also known as standardized weights, and the sum of all standardized weights was equal to 1.00 or 100%, representing the finalized weight of each attribute (Chitsaz et al., 2017). The global weights of the attributes, including the normalized or standardized global weights, are presented in **Table 7.4**.

Overall, the analysis of global weights revealed that Governance and policies-related attributes were the most critical, followed by waste collection facilities and requirements and specifications-related attributes. Though still important, the Materials and equipment and Construction information systems-related attributes were relatively less critical for contractors' CWM performance. A radar chart, as shown in **Figure 7.1**, presents the standardized global weights of all 27 attributes across the five factors.

Table 7.3 Local weights of attributes by geometric mean

Code (Attributes)	Local weight of attributes										
	Expert number										Geometric mean
	1	2	3	4	5	6	7	8	9	10	
GP											
GP1	0.10	0.19	0.03	0.18	0.09	0.08	0.03	0.08	0.10	0.08	**0.082**
GP2	0.06	0.07	0.06	0.19	0.06	0.08	0.06	0.03	0.08	0.11	**0.071**
GP3	0.19	0.19	0.16	0.19	0.23	0.21	0.3	0.32	0.25	0.08	**0.200**
GP4	0.10	0.05	0.09	0.04	0.09	0.14	0.08	0.06	0.06	0.04	**0.070**
GP5	0.10	0.11	0.16	0.03	0.09	0.05	0.09	0.07	0.08	0.16	**0.085**
GP6	0.19	0.19	0.16	0.21	0.20	0.21	0.13	0.21	0.08	0.08	**0.157**
GP7	0.19	0.03	0.16	0.02	0.20	0.08	0.13	0.10	0.08	0.29	**0.101**
GP9	0.07	0.19	0.16	0.14	0.03	0.14	0.19	0.14	0.25	0.16	**0.130**
ME											
ME1	0.25	0.13	0.07	0.08	0.07	0.24	0.32	0.06	0.16	0.07	**0.120**
ME2	0.16	0.21	0.11	0.18	0.06	0.11	0.08	0.10	0.04	0.07	**0.101**
ME3	0.11	0.25	0.11	0.15	0.10	0.13	0.10	0.13	0.06	0.07	**0.113**
ME4	0.06	0.09	0.11	0.06	0.10	0.04	0.07	0.03	0.12	0.03	**0.065**
ME5	0.03	0.04	0.03	0.04	0.03	0.05	0.06	0.20	0.03	0.18	**0.051**
ME6	0.25	0.09	0.17	0.33	0.21	0.05	0.03	0.07	0.24	0.12	**0.122**
ME7	0.08	0.13	0.11	0.08	0.10	0.13	0.21	0.33	0.12	0.12	**0.129**
ME8	0.05	0.07	0.28	0.08	0.33	0.24	0.14	0.08	0.24	0.32	**0.148**
RS											
RS1	0.39	0.09	0.13	0.14	0.13	0.15	0.53	0.47	0.09	0.06	**0.169**
RS2	0.39	0.14	0.17	0.14	0.09	0.08	0.31	0.26	0.18	0.08	**0.159**
RS3	0.14	0.27	0.45	0.63	0.61	0.54	0.1	0.17	0.36	0.31	**0.304**
RS4	0.08	0.50	0.26	0.08	0.17	0.23	0.06	0.11	0.36	0.55	**0.179**
CIS											
CIS1	0.35	0.55	0.39	0.58	0.53	0.35	0.60	0.33	0.20	0.49	**0.417**
CIS2	0.23	0.22	0.36	0.23	0.14	0.11	0.06	0.38	0.15	0.07	**0.166**
CIS3	0.16	0.06	0.11	0.06	0.17	0.19	0.11	0.19	0.55	0.26	**0.152**
CIS4	0.26	0.16	0.14	0.14	0.17	0.35	0.23	0.10	0.10	0.18	**0.168**
WCF											
WCF1	0.13	0.11	0.17	0.25	0.13	0.08	0.1	0.17	0.08	0.11	**0.124**
WCF2	0.60	0.31	0.29	0.11	0.23	0.67	0.16	0.54	0.38	0.19	**0.297**
WCF3	0.27	0.58	0.54	0.64	0.65	0.25	0.74	0.29	0.54	0.70	**0.485**

Table 7.4 Global weights of attributes by geometric mean

Code (Attributes)	Local weight		Global weight	
	Attributes	Factors	Non-normalized	Normalized
GP		0.374		
GP1	0.082		0.031	**0.037**
GP2	0.071		0.026	**0.032**
GP3	0.200		0.075	**0.091**
GP4	0.070		0.026	**0.032**
GP5	0.085		0.032	**0.039**
GP6	0.157		0.059	**0.072**
GP7	0.101		0.038	**0.046**
GP9	0.130		0.049	**0.059**
ME		0.186		**0.000**
ME1	0.120		0.022	**0.027**
ME2	0.101		0.019	**0.023**
ME3	0.113		0.021	**0.026**
ME4	0.065		0.012	**0.015**
ME5	0.051		0.010	**0.012**
ME6	0.122		0.023	**0.028**
ME7	0.129		0.024	**0.029**
ME8	0.148		0.028	**0.034**
RS		0.161		
RS1	0.169		0.027	**0.033**
RS2	0.159		0.026	**0.031**
RS3	0.304		0.049	**0.060**
RS4	0.179		0.029	**0.035**
CIS		0.081		
CIS1	0.417		0.034	**0.041**
CIS2	0.166		0.013	**0.016**
CIS3	0.152		0.012	**0.015**
CIS4	0.168		0.014	**0.017**
WCF		0.135		
WCF1	0.124		0.017	**0.021**
WCF2	0.297		0.040	**0.049**
WCF3	0.485		0.066	**0.080**
		Total	**0.820**	**1.000**

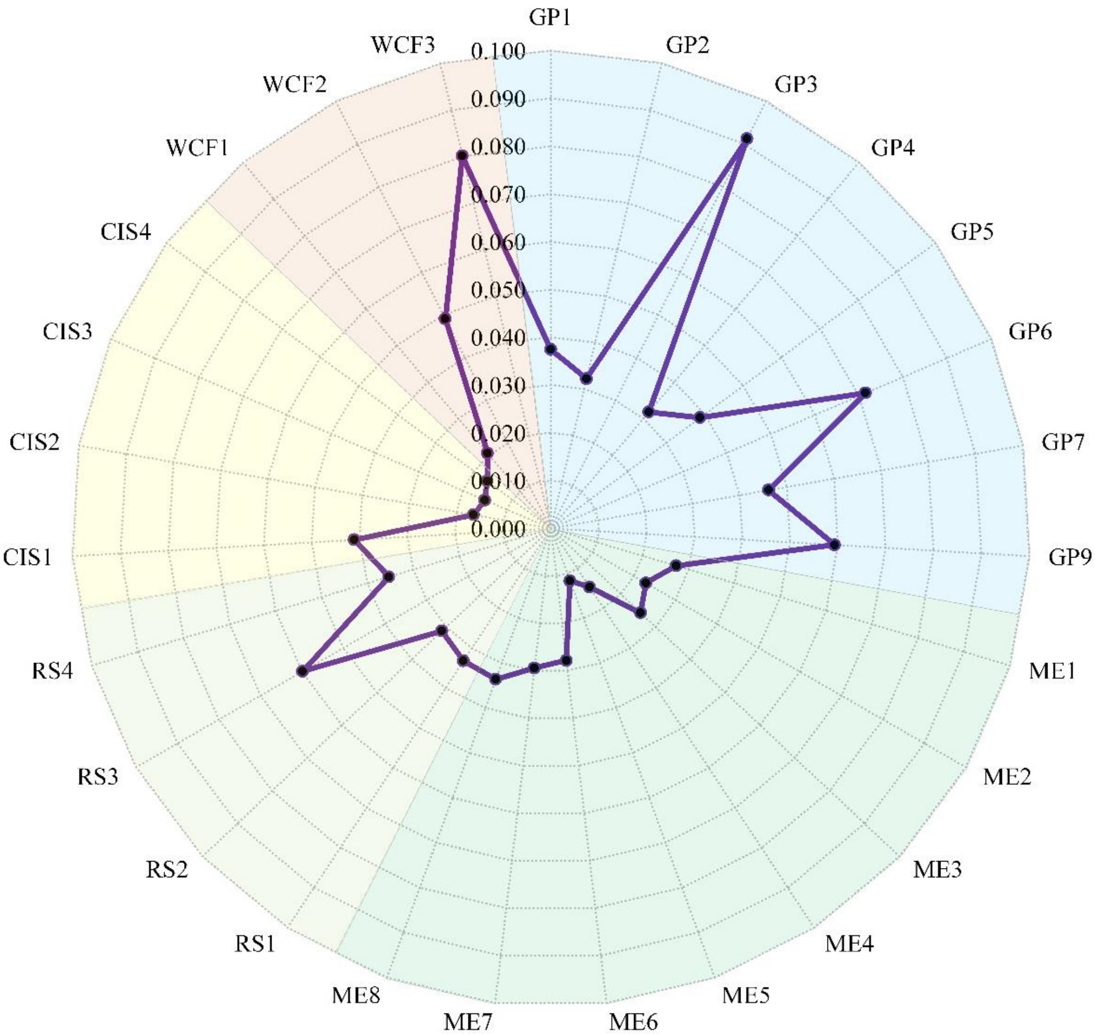

Figure 7.1 Standardized global weight of all 27 attributes

7.3.3 Ranking of attributes

The attributes were ranked based on their standardized global weights, with the highest-weighted attribute ranked first and the lowest ranked last. The five attributes with highest standardized global weights were GP3 “Establishment of a strict CWM policy within the company” (0.091), WCF3 “Setting up separated bins according to the waste type and sort out waste at the site” (0.080), GP6 “Establishment of an appropriate WM plan in the earlier stage of each construction project” (0.072), and RS3 “Detailed study and thorough understanding of specifications and drawings” (0.060). GP9 “Including subcontractor responsibilities for WM targets in the contract” (0.059). These top five attributes out of the total 27 had standardized global weights exceeding 0.05 or 5%. The five attributes with the lowest standardized global weights were ME5 “Adopting Just in Time delivery system” (0.012), CIS3 “Professional quality management and certification” (0.015), and ME4 “High level of security at the project site” (0.015). CIS2, “Utilizing other related information technologies for the project and be familiar with their application,” and CIS4, “Keeping lessons learned repository about CWM”, had standard global weights of 0.016 and 0.017, respectively. The remaining attributes had standardized global weights ranging between 0.02 and 0.05.

The cumulative standardized weight of the top 17 attributes from GP3 to ME7 accounted for approximately 80% of the total standardized weight, while the remaining 10 attributes make up the final of approximately 20%. This distribution is reasonable, as the majority (over 60%) of the high-weight attributes contributed to 80% of the cumulative standardized weight, indicating a sensible weighting allocation. The top-ranked attribute is GP3: Establishing a strict construction waste management policy within the company, while the attribute with the lowest standardized global weight is ME5: Adopting a Just-in-Time delivery system. The detailed ranking of the attributes is presented in **Table 7.5** and **Figure 7.2**. This suggests that most attributes play an essential role in improving CWM.

Table 7.5 Cumulative standardized global weight and ranking of attributes

Code	Standardized global weight	Cumulative weight	Ranking
GP3	0.091	0.091	1
WCF3	0.080	0.171	2
GP6	0.072	0.243	3
RS3	0.060	0.303	4
GP9	**0.059**	**0.362**	**5**
WCF2	0.049	0.411	6
GP7	0.046	0.457	7
CIS1	0.041	0.498	8
GP5	0.039	0.537	9
GP1	0.037	0.575	10
RS4	0.035	0.610	11
ME8	0.034	0.643	12
RS1	0.033	0.677	13
GP2	0.032	0.709	14
GP4	0.032	0.741	15
RS2	0.031	0.772	16
ME7	**0.029**	**0.801**	**17**
ME6	0.028	0.829	18
ME1	0.027	0.856	19

Code	Standardized global weight	Cumulative weight	Ranking
ME3	0.026	0.882	20
ME2	0.023	0.905	21
WCF1	0.021	0.926	22
CIS4	0.017	0.942	23
CIS2	0.016	0.959	24
CIS3	0.015	0.974	25
ME4	0.015	0.988	26
ME5	0.012	**1.000**	27
Total	**1.000**		

Figure 7.2 Ranking of attributes based on standardized global weight

7.4 Discussion

The standardized global weights of 27 attributes across five key factors were evaluated to assess their impact on contractors' CWM performance. These factors consist of "Governance and Policies (GP), Materials and Equipment (ME), Requirements and Specifications (RS), Construction Information Systems (CIS), and Waste Collection Facilities (WCF)". The standardized global weights provide insights into the relative effectiveness of these attributes, helping contractors identify the focus areas for improving their CWM practices in building construction.

7.4.1 Overall weight distribution

The distribution of standardized global weights highlights the prominence of governance and policies and waste collection facilities factors in shaping CWM outcomes. Governance and policies factors hold the highest cumulative weight (0.37), reflecting the central role of strategic planning and regulatory oversight in driving CW reduction. This aligns with the literature that emphasizes the importance of clear policies and top-level management involvement in setting the foundation for effective CWM (Bakshan et al., 2017; Negash et al., 2023; Udawatta et al., 2015; Wang et al., 2014a). The concentration of weight in governance and policy-related attributes suggests that contractors with well-defined WM frameworks are more likely to achieve better CWM and construction sustainability goals than those relying on ad-hoc or reactive approaches. The cumulative weight distribution shows a steep rise (**Figure 7.2**), with the top five attributes accounting for 36.2% of the total standardized global weight, implying that a small number of critical attributes disproportionately influence overall contractors' CWM performance. This phenomenon is often observed in sustainability frameworks, where the majority of impact on the overall comes from a small number of factors (Magon et al., 2018; Mahapatra et al., 2021; Pareto, 1935).

In contrast, the five attributes with the lowest weights, such as those associated with construction information systems and materials and equipment factors, have a less significant influence on CWM. The low-weight attribute, ME5 "Adopting Just in Time delivery system", accounts for only 1.2% of the total standardized global weight, suggesting that while it plays a role, its impact is minimal compared to high-weight attributes in governance and policies factor. The results show that the top 80% of cumulative influence is concentrated in 17 attributes (**Table 7.5** and **Figure 7.2**). This suggests a significant prioritization, with the high-weight attributes receiving the majority of focus and interventions. However, although contributing less individually, low-weight attributes should not be disregarded as they represent critical components of a WM strategy, as indicated by studies on comprehensive approaches to construction sustainability (Daoud et al., 2021; Li et al., 2022).

7.4.2 High-weight attributes

As shown in **Table 7.5** and **Figure 7.2**, the attributes with the highest standardized global weights, GP3 (0.091), WCF3 (0.080), and GP6 (0.072), provide critical insights into the essential attributes of contractors' effective CWM practices. GP3, which refers to establishing a strict CWM policy within the company, holds a high weight, emphasizing the importance of a formalized and structured approach to CWM. This finding aligns with previous research that stressed the need for contractors to establish or adopt clear, enforceable WM policies as a foundation for improving performance (Bakshan et al., 2017; Kolaventi et al., 2020; Udawatta et al., 2015). Such policies ensure compliance with regulations and are crucial for organisational operational practices. A companywide CWM system enables the alignment of CW reduction objectives with overall project goals, thereby reducing inefficiencies and CW generation.

The second high-weight attribute, WCF3, focuses on practical on-site measures such as "setting up separate bins according to waste type and sorting waste at the site". This operational step is vital for reducing the amount of mixed waste, improving waste separation, enabling reuse, facilitating recycling by third parties, and decreasing landfill contributions (Gangolells et al., 2014; Hyvärinen et al., 2020). By allowing better waste sorting, contractors can enhance their WM processes and reduce disposal costs while improving their sustainable construction practices (Ajayi et al., 2015; Newaz et al., 2022). The high weight of this attribute indicates that practical, on-site waste collection practices are crucial, complementing higher-level governance and policies strategies for a comprehensive WM framework.

The third high-weight attribute, GP6, related to "establishing an appropriate WM plan during the early stages of construction," underscores the role of proactive planning in CWM. Early-stage integration of CWM practices ensures that potential waste sources are identified and mitigated before they occur. This aligns with Kolaventi et al. (2020) and Newaz et al. (2022), who suggested that projects that incorporate CWM in their earlier phases are more likely to achieve substantial waste reductions, as planning allows for the allocation of necessary resources and the development of appropriate mitigation strategies. These high-weight attributes suggest that a combination of strategic governance and policy and practical site-level interventions is essential for contractors to enhance CWM performance.

Additionally, other high-weight attributes, such as RS3, “Detailed study and understanding of specifications and drawings”, and GP9 “Including subcontractor responsibilities for WM targets in the contract”, further emphasize the importance of precise planning and contractual commitments in enhancing WM efforts (Janani et al., 2022; Kolaventi et al., 2020; Osmani et al., 2008). These attributes illustrate the balance between high-level governance and policy and on-site operational efficiency in achieving waste reduction goals.

7.4.3 Low-weight attributes

Several low-weight attributes, particularly those related to “materials and equipment (ME)” and “construction information systems (CIS)”, reflect the less significant influence of these factors in the overall CWM framework. The lowest weight is assigned to ME5, “Adopting Just in Time delivery system”, with a standardized global weight of only 0.012. While Just in Time (JIT) delivery is acknowledged as an effective method for reducing overstocking and potential material wastage, it appears that its contribution to waste reduction in the context of CWM is minimal compared to broader governance and policies initiatives (Daoud et al., 2021; Li et al., 2022). This low weight suggests that while JIT has operational benefits, its impact on reducing waste at the source may be limited, possibly due to the complexity of coordination and logistics required for its implementation. Similarly, attributes within the CIS factor, such as CIS3 “Professional quality management and certification”, CIS2 “Utilizing other related information technologies for the project and be familiar with their application”, and CIS4 “Keeping lessons learned repository about CWM”, also rank lower in terms of their standardized global weight. The relatively low contribution of CIS-related attributes could indicate that while technology and certification processes have the potential to support CWM efforts, they are not as integral to immediate waste reduction compared to governance and policies and waste collection facilities (Andersson et al., 2022;

Ghaffar et al., 2020; Kabirifar et al., 2020a). This finding aligns with the view that technological solutions in CWM while promising, require more widespread adoption and integration into broader WM strategies to have a significant impact (Ajayi et al., 2015; Akinade et al., 2018; Andersson et al., 2022; Ganiyu et al., 2020).

It is also noteworthy that ME4, “High level of security at the project site”, with a standardized global weight of 0.015, ranks low in the overall distribution. This suggests that while securing materials and equipment is essential, it is not a primary driver of waste reduction. Effective CWM seems to rely more heavily on early planning, systematic governance and policies than preventing theft or loss at the project site. Although low-weight attributes contribute less individually, they serve as essential components of a comprehensive WM framework, contributing to the higher-weight factors by providing operational and technological support where necessary (Fernández-Sánchez et al., 2010).

7.5 Chapter Summary

This chapter presented the evaluation of the weights of 27 attributes across five key factors influencing the effectiveness of building contractors’ CWM practices. The study in this phase employed MCDA using the BWM based on insights gathered from interviews with 10 experts. The findings revealed that the most influential attribute for effective CWM is GP3, “Developing a comprehensive CWM policy within the organization, including the establishment of a CWM system,” which achieved the highest standardized global weight of 0.091. This underscores the pivotal role of robust internal policies in fostering consistent and effective CWM practices. Closely following this is WCF3, “Setting up segregated bins for different types of waste and sorting waste at the construction site,” with a standardized global weight of 0.080, highlighting the operational importance of on-site waste segregation as a critical measure to reduce construction waste at its source. Other attributes with significant weights include GP6, “Establishing an appropriate waste management plan early in the construction project” (0.072), and RS3, “Thoroughly reviewing and understanding project specifications and drawings” (0.060). These results emphasize the crucial roles of strategic planning and technical precision in the early phases of construction to minimize errors and prevent unnecessary waste generation. Additionally, GP9, “Incorporating waste management responsibilities and targets for subcontractors into contracts” (0.059), underscores the importance of integrating subcontractor accountability into organizational CWM objectives to ensure cohesive and effective waste management practices.

The findings presented in this chapter provide a comprehensive overview of the relative importance and weight of 27 attributes across five factors influencing effective building contractors’ CWM.

CHAPTER 8

MATURITY MODEL DEVELOPMENT

8.1 Definition of each attribute

To ensure clarity and facilitate accurate assessment of CWM by contractors, the specific definitions and measurement boundaries for each attribute are provided in **Table 8.1**. These definitions establish a practical framework for evaluating the attributes, enabling consistent interpretation and application in the assessment process.

Table 8.1 Definition of measuring boundary of each attribute

Code	Attributes	Description/ measuring boundary
GP	**Governance and policy:**	
GP1	Properly following a WM plan	Contractors' effectiveness in consistently implementing the WM plan across all building construction projects, ensuring precise adherence to the plan and procedures.
GP2	Supervision of WM activities with clear instructions	Contractors' effectiveness in overseeing and coordinating WM activities across all building construction projects, ensuring the management team consistently provides clear and precise instructions to the project teams.
GP3	Establishment of a strict CWM policy within the company (including the CWM system)	Contractors' effectiveness in developing and enforcing a comprehensive CWM policy fully integrated into the contractors' overall management system and consistently applied across all building construction projects.
GP4	Implementing an effective organizational structure for WM	Contractors' effectiveness in establishing and adhering to an organizational structure within their company and projects that enhance efficient WM operations across all building construction projects.
GP5	Monitoring and auditing waste management systems periodically (e.g., every 3 months)	Contractors' effectiveness in conducting regular reviews and audits of their WM systems across all building construction projects to ensure compliance and foster continuous improvement company-wide.
GP6	Establishment of an appropriate WM plan in the earlier stage of each construction project	Contractors' effectiveness in ensuring that each construction project under their management develops a comprehensive WM plan during the early stages of each building construction project, adhering to company-wide standards.
GP7	Senior management's commitment to implementing waste management (WM) practices	Contractors' effectiveness in demonstrating strong dedication and actively promoting WM practices across all building construction projects through senior management.
GP9	Including subcontractor	Contractors' effectiveness in incorporating WM obligations and targets in contracts with all subcontractors, ensuring their active

Code	Attributes	Description/ measuring boundary
	responsibilities for WM targets in the contract	participation and accountability across all building construction projects managed by the contractor.
ME	**Material and equipment:**	
ME1	Precise on-site material/ equipment control (e.g., inspecting the materials/ equipment when they arrive, etc.)	Contractors' effectiveness in implementing on-site controls with proper procedures to verify and manage materials/ equipment on construction sites across all building construction projects (e.g., inspecting the materials upon arrival, checking materials in and out of the warehouse or storage).
ME2	Adequate protection of material/ equipment transportation and handling (loading and unloading)	Contractors' effectiveness in ensuring the proper handling and protection of materials/ equipment during transportation, loading, and unloading across all building construction projects.
ME3	Adequate protection of different categories of materials/ equipment during storing and stacking	Contractors' effectiveness in implementing adequate measures to protect various types of materials/ equipment during storing and stacking, ensuring no breakages or mis-categorizations across all building construction projects.
ME4	High level of security at the project site (i.e., prevent theft and loss of materials/ equipment)	Contractors' effectiveness in enforcing robust security measures across all building construction projects to prevent theft, loss, unauthorized removal, or misplacement of materials/ equipment. This includes installing sufficient CCTV coverage and employing security guards at project sites.
ME5	Adopting Just in Time (JIT) delivery system	Contractors' effectiveness in implementing a JIT approach across all building construction projects to minimize on-site storage requirements and reduce waste associated with material/ equipment damage due to over-stacking, exposure to environmental elements such as rain, wind, and sunlight (e.g., steel corrosion, cement degradation), as well as preventing materials from outdated (e.g., cement, painting) when stored for extended periods at the site. This approach ensures materials and equipment are easily accessible when needed, thereby minimizing breakage and waste during construction activities.
ME6	Precise material/ equipment purchasing (i.e., preventing order errors, right sizes and quantities)	Contractors' effectiveness in ensuring precise/ equipment purchasing across all building construction projects by accurately ordering materials/ equipment in the correct sizes and quantities to prevent surplus and waste.
ME7	Using quality, durable, and standardized materials/ equipment (i.e., according to specification)	Contractors' effectiveness in selecting and consistently using high-quality, durable, and standardized materials/ equipment that meet specified requirements across all building construction projects managed by the contractor.
ME8	On-time and accurate quantification of materials or equipment /bills of quantities	Contractors' effectiveness in ensuring timely and accurate quantification of materials/ equipment and bills of quantities across all building construction projects to facilitate precise purchasing and minimize waste.
RS	**Requirements and specifications:**	
RS1	Minimizing design changes during construction	Contractors' effectiveness in minimizing design changes during construction across all building construction projects. This involves the Contractors' capability to effectively communicate with stakeholders to limit design change requests or orders,

Code	Attributes	Description/ measuring boundary
		aiming to reduce the frequency and extent of changes during the construction phase.
RS2	Minimizing variation orders (VO)	Contractors' effectiveness in minimizing VO across all building construction projects. This involves the Contractors' capability to negotiate or persuade stakeholders to limit the number of changes to the original plan as specified in contractual agreements.
RS3	Detailed study and thorough understanding of specifications and drawings	Contractors' effectiveness in conducting detailed studies and achieving a thorough understanding of project specifications and drawings across all building construction projects. This involves ensuring that all project teams within the Contractors' company comprehensively review and deeply understand project specifications and drawings.
RS4	Implementing proper method statement for each activity, including minimizing waste from application processes	Contractors' effectiveness in developing and following to comprehensive method statements for each construction activity across all building construction projects, including minimizing waste during application processes.
CIS	**Construction information system:**	
CIS1	Utilizing Building Information Modeling (BIM) for the project and being familiar with its application	Contractors' effectiveness in utilizing BIM across all building construction projects to enhance the management of construction processes, including improving CWM practices.
CIS2	Utilizing other related information technologies for the project and being familiar with their application	Contractors' effectiveness in utilizing other relevant information technologies (e.g., drones, document control software/apps) across all building construction projects to enhance operational efficiency and improve CWM practices.
CIS3	Professional quality management and certification (e.g., ISO, GREEN, etc.)	Contractor is actively pursuing professional quality management certifications (e.g., ISO, GREEN, etc.) to uphold high standards in construction management quality or waste management practices for building construction professionals. Achieving at least one standardized professional quality management certification at the company level qualifies a contractor for a level 5 maturity rating. For example, the detailed rating breakdown for ISO certification: • Level 1: The contractors have not applied for ISO certification. • Level 2: The contractors have initiated and submitted all required documents for obtaining ISO certification. • Level 3: Contractors' ISO application has been received by the ISO's respective organization and is under consideration. If the application is rejected at this stage, the contractor remains at level 3. If approved, please refer to the level definitions below. • Level 4: Contractors' ISO application is approved and is in the final stages of obtaining ISO certification but has not yet received it. • Level 5: The contractors have been issued the ISO certification.

Code	Attributes	Description/ measuring boundary
CIS4	Keeping lessons learned repository about CWM	Contractors' effectiveness in maintaining and utilizing a centralized repository of lessons learned about CWM across all building construction projects to facilitate continuous improvement of CWM for all projects.
WCF	**Waste collection facilities:**	
WCF1	Bins are installed on every floor	Contractors' effectiveness in ensuring that waste collection bins are installed on every floor of all building project sites managed by the contractor to facilitate easy and organized waste collection across all construction projects.
WCF2	Storing construction waste in easily accessible areas	Contractors' effectiveness in designating and maintaining easily accessible areas for storing CW across all building construction project sites to facilitate easy collection and removal processes.
WCF3	Setting up separated bins according to the waste type and sorting out waste at the site	Contractors' effectiveness in implementing a company-wide system of separated bins for different types of waste and ensuring that waste is sorted at all building construction project sites.

8.2 CW3M maturity model development

The CW3M maturity level was developed through a structured approach that combined a comprehensive literature review, expert verification, factor analysis, multi-criteria decision-making, model tool development, model implementation, and model validation. This model aimed to assess contractors' performance in CWM within building construction projects. The development process began with an extensive literature review to identify attributes relevant to effective CWM concerning contractors in building construction. This was followed by expert verification, which helped verify the list of attributes to be included for further process. The verified attributes were then incorporated into a 5-point Likert scale questionnaire for factor analysis. Both EFA and CFA were employed to finalize attributes and factors. This analysis identified 27 key attributes across five core factors: Governance and policies (8 attributes), Materials and equipment (8 attributes), Requirements and specifications (4 attributes), Construction information systems (4 attributes), and Waste collection facilities (3 attributes). The detailed calculation processes for the weights of all attributes were previously presented in **Section 3.8.5**. The global weights were normalized to ensure the sum of weight was equal to 1.00, resulting in standardized weights (**Table 9.2**), which served as key inputs for developing the CW3M model.

In parallel, a literature review was conducted to identify appropriate maturity levels for contractors' CWM practices in building construction. Five maturity levels were adopted: initial, developing, reactive, proactive, and optimized, reflecting a progression of CWM capabilities from the most basic to the most advanced. Expert interviews were conducted to refine the definitions of these maturity levels and ensure their suitability for assessing contractors' CWM performance in building construction. With the standardized global weights of the 27 attributes and the refined five-level maturity model, the CW3M assessment tool was developed in Microsoft Excel. This tool effortlessly allows contractors to assess their performance in CWM based on the CW3M framework. The tool includes a radar chart to visualize the score of all attributes, providing a clear picture of the Contractors' performance, and a vertical bar chart to display the overall score, with the maximum score set at 5, allowing users to see their maturity level.

The CW3M assessment tool, as presented in **Table 8.2**, provides a detailed overview of the 27 attributes across five factors, along with their standardized weights. The refined maturity levels, illustrated in **Figure 8.1**, represent the progression from initial to optimizing maturity in CWM practices. Furthermore, the radar and vertical bar charts in **Figure 8.2** visually represent the maximum assessment results (score) for each attribute and the total score, serving as a ceiling for contractors seeking to improve their CWM performance in building construction.

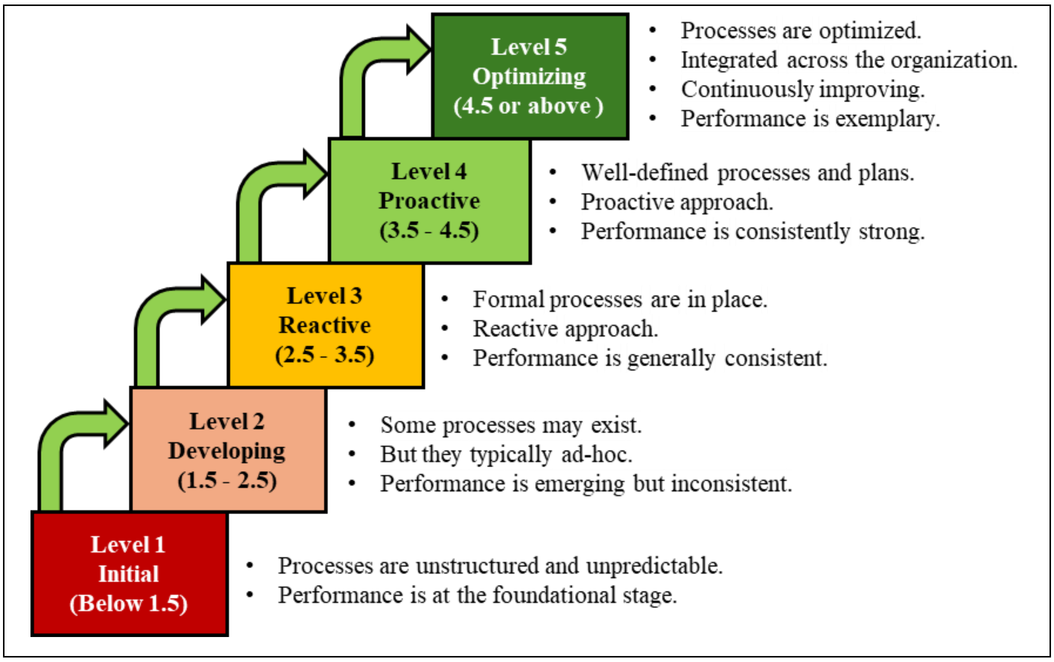

Figure 8.1 Maturity level

Table 8.2 Maturity model for the assessment of CWM (CW3M)

Code	**Factors/Attributes**	**Current level**					**Target level**				
		1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
GP	**Governance and policies:**										
GP1	Properly following a WM plan	○	○	○	○	○	○	○	○	○	○
GP2	Supervision of WM activities with clear instructions	○	○	○	○	○	○	○	○	○	○
GP3	Establishment of a strict CWM policy within the company (including the CWM system)	○	○	○	○	○	○	○	○	○	○
GP4	Implementing an effective organizational structure for WM	○	○	○	○	○	○	○	○	○	○
GP5	Monitoring and auditing waste management systems periodically (e.g., every 3 months)	○	○	○	○	○	○	○	○	○	○
GP6	Establishment of an appropriate WM plan in the earlier stage of each construction project	○	○	○	○	○	○	○	○	○	○
GP7	Senior management's commitment to implementing waste management (WM) practices	○	○	○	○	○	○	○	○	○	○
GP9	Including subcontractor responsibilities for WM targets in the contract	○	○	○	○	○	○	○	○	○	○
ME	**Materials and equipment:**										
ME1	Precise on-site material/ equipment control (e.g., inspecting the materials/ equipment when they arrive, etc.)	○	○	○	○	○	○	○	○	○	○
ME2	Adequate protection of material/ equipment transportation and handling (loading and unloading)	○	○	○	○	○	○	○	○	○	○
ME3	Adequate protection of different categories of materials/ equipment during storing and stacking	○	○	○	○	○	○	○	○	○	○
ME4	High level of security at the project site (i.e., prevent theft and loss of materials/ equipment)	○	○	○	○	○	○	○	○	○	○
ME5	Adopting just in time (JIT) delivery system	○	○	○	○	○	○	○	○	○	○
ME6	Precise material/ equipment purchasing (i.e., preventing order errors, right sizes and quantities)	○	○	○	○	○	○	○	○	○	○
ME7	Using quality, durable, and standardized materials/ equipment (i.e., according to specification)	○	○	○	○	○	○	○	○	○	○
ME8	On-time and accurate quantification of materials or equipment /bills of quantities	○	○	○	○	○	○	○	○	○	○
RS	**Requirements and specifications:**										
RS1	Minimizing design changes during construction	○	○	○	○	○	○	○	○	○	○
RS2	Minimizing variation orders (VO)	○	○	○	○	○	○	○	○	○	○
RS3	Detailed study and thorough understanding of specifications and drawings	○	○	○	○	○	○	○	○	○	○
RS4	Implementing proper method statement for each activity, including minimizing waste from application processes	○	○	○	○	○	○	○	○	○	○
CIS	**Construction information systems:**										
CIS1	Utilizing building information modelling (BIM) for the project and being familiar with its application	○	○	○	○	○	○	○	○	○	○
CIS2	Utilizing other related information technologies for the project and being familiar with their application	○	○	○	○	○	○	○	○	○	○
CIS3	Professional quality management and certification (e.g., ISO, GREEN, etc.)	○	○	○	○	○	○	○	○	○	○
CIS4	Keeping lessons learned repository about CWM (including tracking the types and quantities of CW)	○	○	○	○	○	○	○	○	○	○
WCF	**Waste collection facilities:**										
WCF1	Bins are installed on every floor	○	○	○	○	○	○	○	○	○	○
WCF2	Storing construction waste in easily accessible areas	○	○	○	○	○	○	○	○	○	○

Code	Factors/Attributes	Current level					Target level				
		1	2	3	4	5	1	2	3	4	5
WCF3	Setting up separated bins according to the waste type and sorting out waste at the site”	○	○	○	○	○	○	○	○	○	○

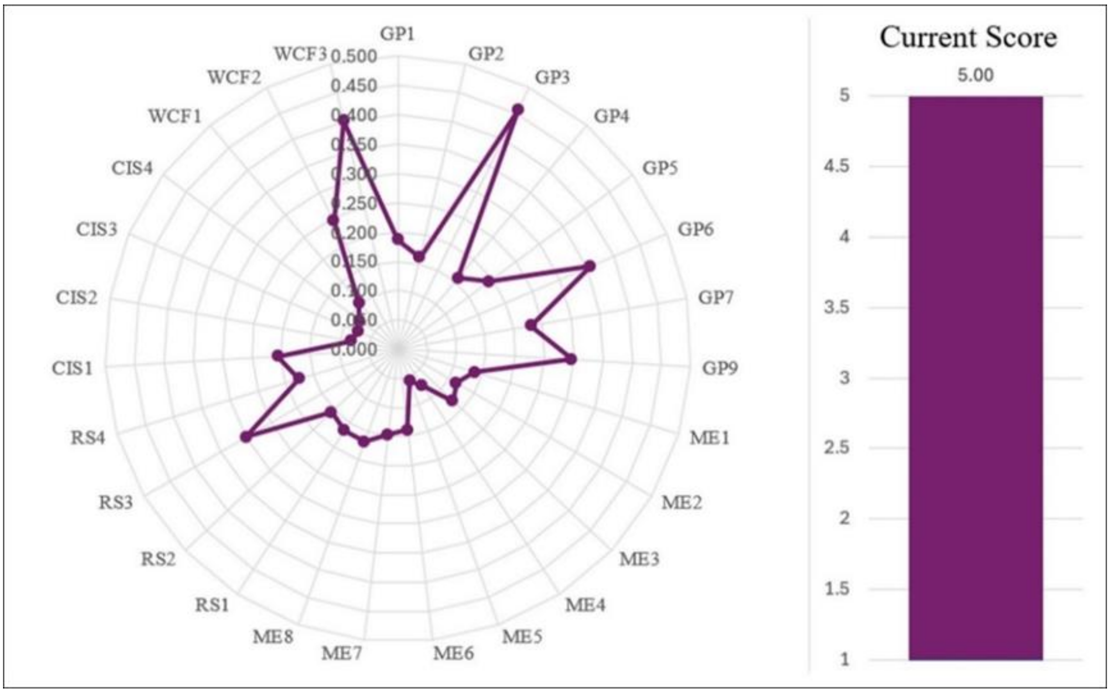

Figure 8.2 Radar chart for the current score of each attribute and total score (maximum score)

CHAPTER 9

MODEL IMPLEMENTATION AND VALIDATION

9.1.1 Demographic information of experts

This study phase involved experts from 16 contractors in Cambodia and Thailand who participated in the model implementation and validation process. These experts had diverse backgrounds in terms of experience and education. In Cambodia, 8 experts from 5 large and 3 medium-sized contractors took part, holding positions such as assistant project director, project manager, assistant project manager, site manager, and technical director. Most experts from Cambodia hold master’s degrees in civil engineering or construction engineering and management. They had between 5 and 19 years of experience in building construction. In Thailand, 8 experts from 7 large and 1 medium-sized contractor participated, including the project manager, company deputy director, head of business development, and estimator. Most of the experts from Thailand held bachelor’s degrees in civil engineering. They had 8 to 37 years of experience in building construction. Overall, the 16 experts averaged 15.9 years of experience in building construction. The representation of medium and large contractors from both countries ensured the model’s applicability was assessed across different company sizes and operational capacities. The experts held diverse project management positions, providing varied perspectives and operational insights for the model implementation and validation. Based on experts' perceptions from 16 contractors, the results indicated that all contractors validated the developed CW3M model as appropriate, reliable, and suitable for contractors to assess their CWM capabilities in building construction. The details of the demographic profiles of experts for model implementation and validation are presented in **Table 9.1**.

Table 9.1 Demographic of experts for model implementation and validation

Contractors		Representative (experts)			Country
No.	**Size**	**Position**	**Education level**	**Experience (years)**	
Contractor 1	Medium	Asst. Project director	M.Eng. Construction engineering and management	5	Cambodia
Contractor 2	Large	Project manager	MSc. Civil engineering	7	Cambodia
Contractor 3	Large	Site manager	B.Eng. Civil engineering	11	Cambodia
Contractor 4	Medium	Technical director	B.Eng. Civil engineering	19	Cambodia
Contractor 5	Medium	Project manager	M.Eng. Civil engineering	14	Cambodia
Contractor 6	Large	Asst. Project manager	M.Eng. CEM	19	Cambodia
Contractor 7	Large	QA/QC	BSc. Civil engineering	5	Cambodia
Contractor 8	Medium	Project manager	M.Eng. Civil engineering	10	Cambodia
Contractor 9	Large	Project manager	Bachelor of interior design	8	Thailand
Contractor 10	Large	Project manager	B.Eng. Civil engineering	22	Thailand
Contractor 11	Large	Project manager	B.Eng. Civil engineering	18	Thailand
Contractor 12	Large	Head of business development	B.Eng. Civil engineering	37	Thailand
Contractor 13	Large	Company deputy director	M.Eng. Construction engineering and management	10	Thailand
Contractor 14	Large	Project manager	B.Eng. Civil engineering	25	Thailand
Contractor 15	Large	Estimator	M.Eng. Construction engineering and management	8	Thailand
Contractor 16	Medium	Project manager	B.Eng. Civil engineering	22	Thailand

Note: Size of companies based on number of employees: micro contractors (1-9); small contractors (10-49); medium contractors (50-249) and large contractors (250 or more)

9.2 CW3M maturity model implementation

After the CW3M model was developed, the experts were provided with the model to use and become familiar with it. The experts were then interviewed and asked to assess their companies' CWM practices using the CW3M model. This assessment involved identifying the current and target levels for each CW3M attribute. The interviews were conducted individually with each expert, and the current and target levels were entered into the CW3M framework to calculate the scores for the 27 attributes across five factors and the total current and target scores. A typical example of a Contractors' assessment score using CW3M is presented, along with the average assessment results for Cambodian and Thai contractors, as detailed in the sections below.

9.2.1 A typical example of an assessment

The typical example of the assessment results (score) of one contractor from Thailand is shown in **Table 9.2**. The contractor evaluated the current and target levels for each of the 27 attributes in the CW3M maturity model. The current score is calculated by multiplying the standardized weight of each attribute by its current level, and the target score is calculated similarly using the target level. The contractor's current score is 3.38, indicating a "Proactive level" or level 4 of CWM maturity (**Figure 9.1**). The target score for this contractor in the next two years is 3.96, indicating a "Proactive level" or level 4 of maturity (**Figure 9.2**), as per the scale defined in the CW3M model. However, the overall score demonstrated the potential for improvement even though the maturity level was not expected to change.

Table 9.2 A typical example of an assessment score using CW3M by a contractor

Factors	Code (Attributes)	Standardized weight	Current level	Target level	Current score	Target score
Governance and policies (GP)	GP1	0.037	3	4	0.112	0.150
	GP2	0.032	3	3	0.097	0.097
	GP3	0.091	3	4	0.274	0.365
	GP4	0.032	2	3	0.064	0.095
	GP5	0.039	3	3	0.116	0.116
	GP6	0.072	3	4	0.215	0.286
	GP7	0.046	4	5	0.185	0.231
	GP9	0.059	3	4	0.178	0.237
Materials and equipment (ME)	ME1	0.027	2	3	0.055	0.082
	ME2	0.023	4	4	0.092	0.092
	ME3	0.026	4	4	0.103	0.103
	ME4	0.015	3	4	0.044	0.059
	ME5	0.012	4	5	0.047	0.058
	ME6	0.028	4	4	0.111	0.111
	ME7	0.029	4	4	0.118	0.118
	ME8	0.034	4	5	0.134	0.168
Requirements and Specifications (RS)	RS1	0.033	4	4	0.133	0.133
	RS2	0.031	3	3	0.094	0.094
	RS3	0.060	4	4	0.239	0.239

Factors	Code (Attributes)	Standardized weight	Current level	Target level	Current score	Target score
	RS4	0.035	3	4	0.106	0.141
Construction information systems (CIS)	CIS1	0.041	3	4	0.123	0.164
	CIS2	0.016	3	4	0.049	0.066
	CIS3	0.015	3	4	0.045	0.060
	CIS4	0.017	3	3	0.050	0.050
Waste collection facilities (WCF)	WCF1	0.021	4	4	0.082	0.082
	WCF2	0.049	4	5	0.196	0.245
	WCF3	0.080	4	4	0.320	0.320

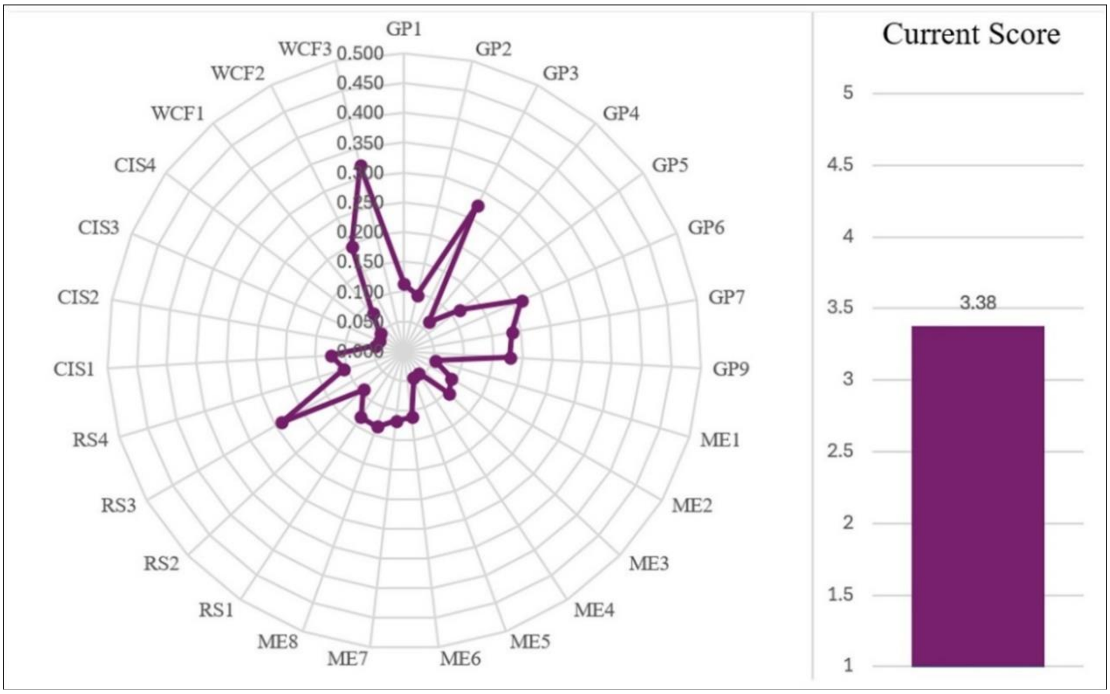

Figure 9.1 A typical assessment result by a contractor in Thailand (Current score)

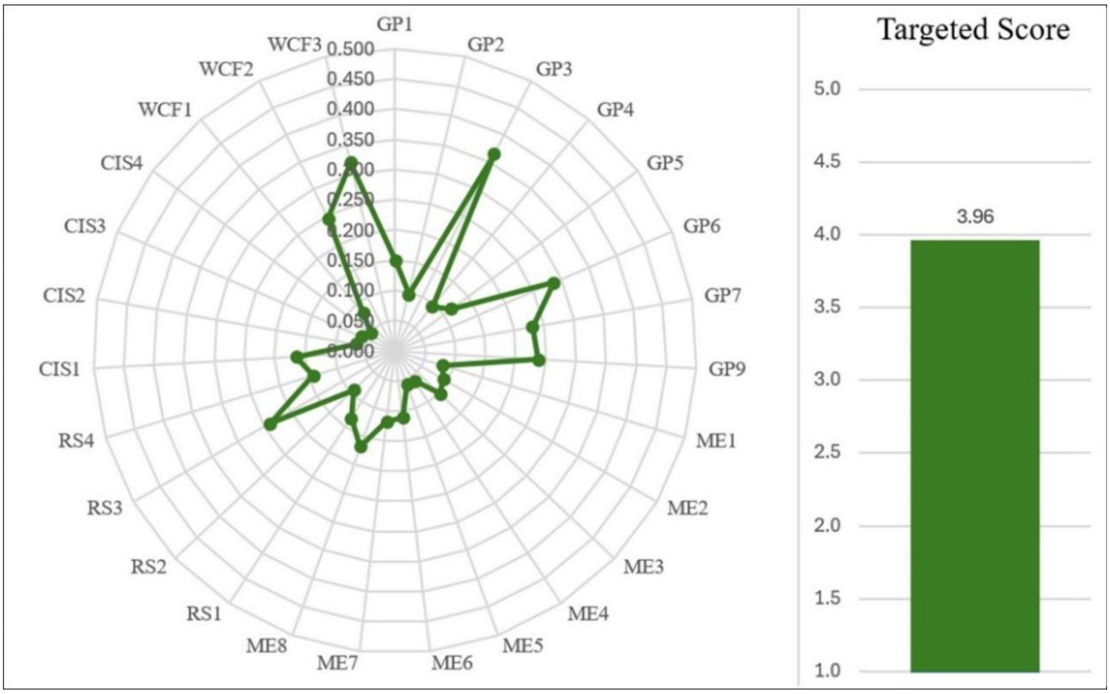

Figure 9.2 A typical assessment result by a contractor in Thailand (Target score)

9.2.2 Average maturity score and level

The self-assessment results using the CW3M model revealed the average scores for the current and target CWM practices of 16 contractors. In Cambodia, contractors currently demonstrate an average score of 2.82, indicating a “Reactive” level of maturity at the lower end of Level 3. These contractors aim to achieve an average score of 3.45 over the next two years, signalling their ambition to move towards the upper end of Level 3 maturity. At Level 3, contractors have formal processes, adopt a reactive approach, and maintain consistent performance. In Thailand, contractors currently demonstrate an average score of 3.58, indicating a “Proactive” level of maturity at the lower end of Level 4. The Thai contractors aim to achieve an average score of 4.29 over the next two years, signalling their ambition to move towards the upper end of Level 4 maturity. At Level 4, contractors have well-defined processes and plans, a proactive approach, and consistently strong performance. The average current maturity level of contractors’ CWM performance in Cambodia is lower than in Thailand, a trend also observed in the target maturity levels, with Cambodia’s contractors aiming lower than Thailand’s contractors. Considering the results for both countries, the current average score of the contractors is 3.20, indicating a "Reactive" level of maturity at the higher end of Level 3. However, the contractors in Cambodia and Thailand aim to achieve an average score of 3.87 over the next two years, signalling their ambition to move towards Level 4 maturity. The assessment results presenting the average scores of contractors' CWM performance are shown in Figure **Figure 9.3** and **Figure 9.4** for Cambodia and Thailand, respectively. Additionally, the average score results for each attribute were converted to the average maturity level, as illustrated in **Figure 9.5** and **Figure 9.6** for Cambodia and Thailand, respectively.

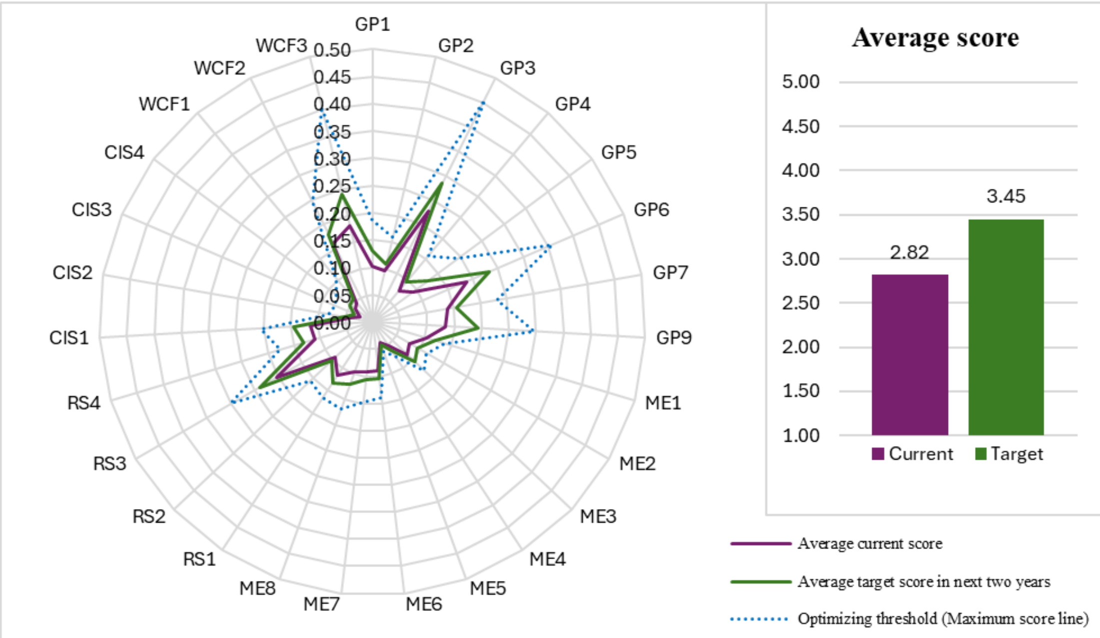

Figure 9.3 Average score of contractors' CWM performance in Cambodia

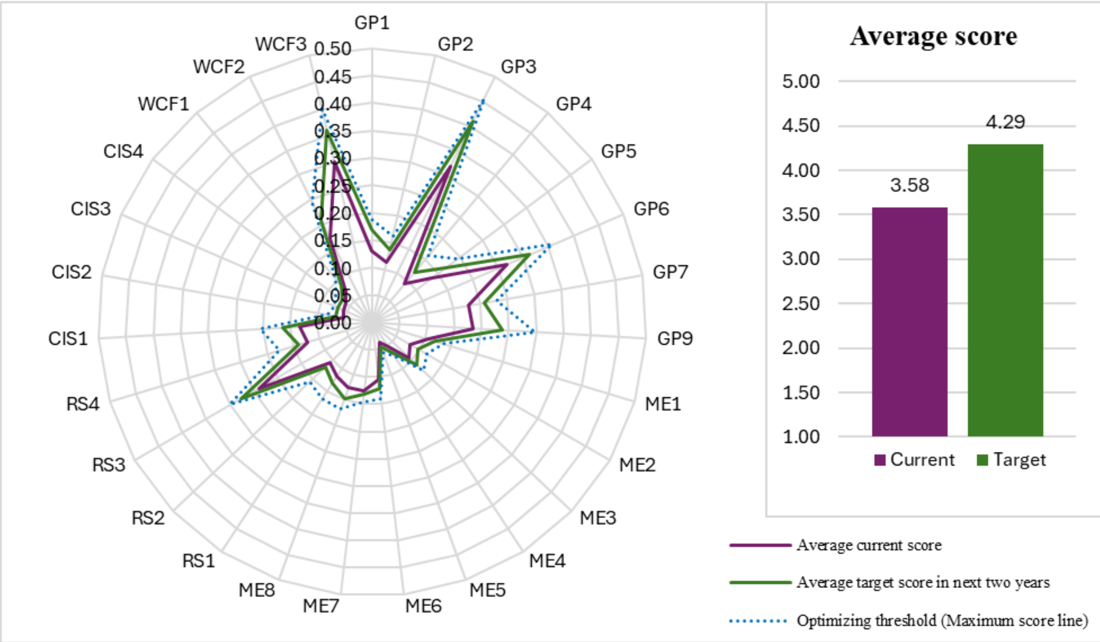

Figure 9.4 Average score of contractors' CWM performance in Thailand

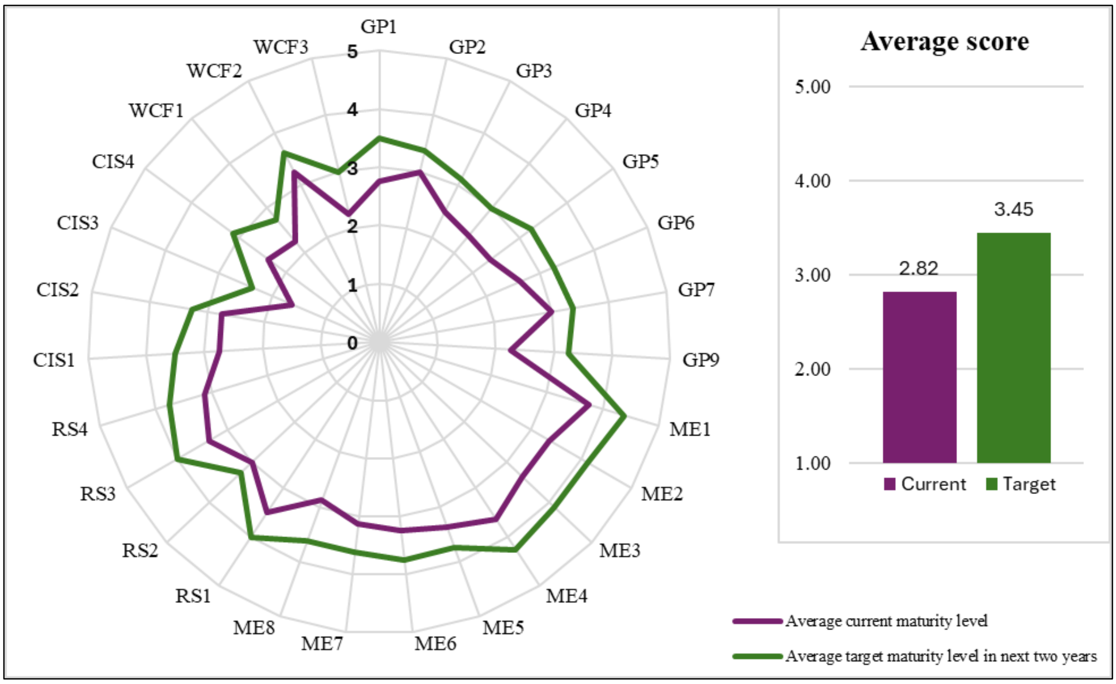

Figure 9.5 Average maturity level of each attribute and overall score of contractors' CWM performance in Cambodia

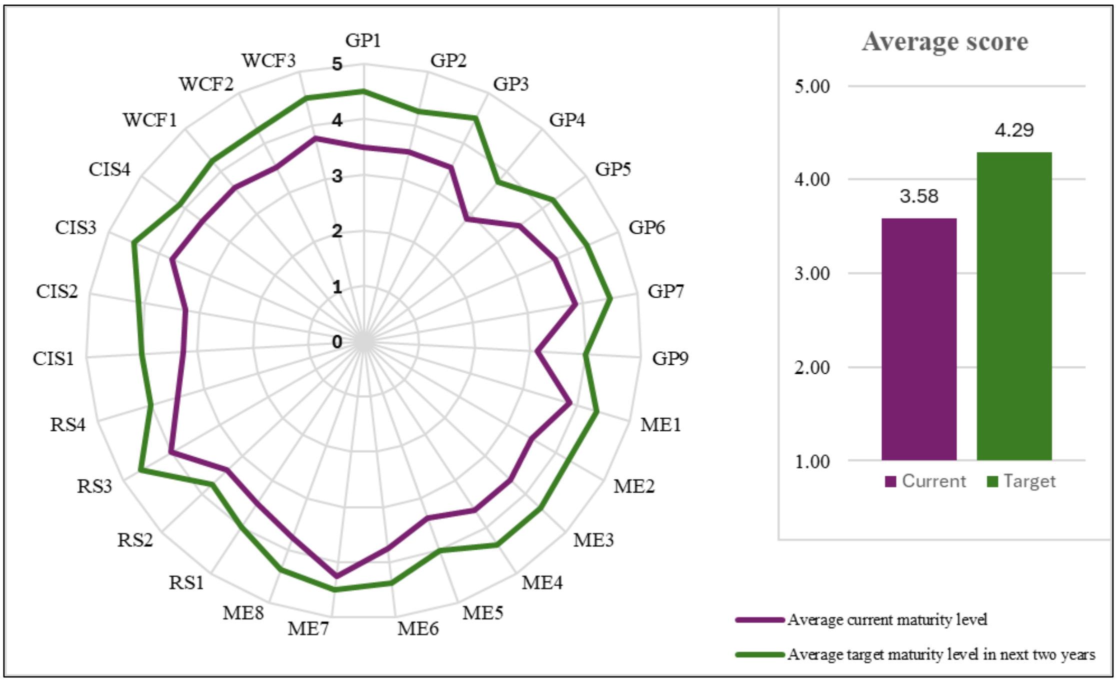

Figure 9.6 Average maturity level of each attribute and overall score of contractors' CWM performance in Thailand

9.3 Model validation

The results of the validation exercise, as shown in **Table 9.3**, reveal that the maturity model's "degree of appropriateness" has the highest mean score of 3.88 among the six assessment criteria. This suggests that the model is perceived as highly suitable and aligned with the needs of contractors in building construction. The second highest-rated aspect, "overall suitability for CWM for contractors in building construction," scored a mean of 3.81, indicating that the model is well-suited for practical application in the industry and offers valuable guidance for contractors to enhance their CWM practices. Furthermore, the "degree of objectivity," "degree of practicality," and "overall reliability" all scored a mean of 3.75, suggesting that the experts find the CW3M to be reasonably objective, practical, and reliable in helping contractors manage CW effectively. However, the "degree of replicability" received the lowest mean score of 3.50, although still above 3 (considered good). The mean score values for all six validation aspects range from 3.50 to 3.88, implying that respondents generally found the maturity model satisfactory across all validation criteria. This suggests that the model has been validated to be appropriate, objective, practical, reliable, and suitable for use by contractors in building construction to improve CWM practices.

Table 9.3 Results of the maturity model validation

No.	**Validation aspects/ questions**	**Experts/ contractors**																**Mean**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	
1	Degree of appropriateness	4	3	3	4	4	4	4	4	4	4	4	4	4	4	5	3	**3.88**
2	Degree of objectivity	4	3	4	3	3	4	4	5	3	4	4	4	5	3	4	3	**3.75**
3	Degree of replicability	4	4	3	3	3	3	3	4	4	4	3	4	4	4	4	2	**3.50**
4	Degree of practicality	3	4	3	3	3	4	4	5	4	5	4	4	3	4	4	3	**3.75**
5	Overall reliability	4	4	4	3	3	3	4	5	3	4	4	4	4	4	4	3	**3.75**
6	Overall suitability for CWM for contractors in building construction	3	4	4	4	3	4	3	5	4	5	4	4	3	4	4	3	**3.81**

Note: 1 representing “poor”, 2 “average”, 3 “good”, 4 “very good”, and 5 “excellent”

CHAPTER 10

DISCUSSION OF MODEL DEVELOPMENT AND VALIDATION

10.1 CW3M maturity model development

This study aimed to develop the construction waste management maturity model (CW3M) to assess contractors' CWM performance in building construction. The model was developed using a systematic process based on established maturity model principles (De Bruin et al., 2005; Myrberg et al., 2024), ensuring a structured pathway for contractors to enhance their CWM capabilities. Grounded in maturity model literature, the CW3M model integrates theoretical with practical industry insights, making it conceptually sound and relevant to the challenges faced by contractors.

The CW3M model comprises five key factors: governance and policies, materials and equipment, requirements and specifications, construction information systems, and waste collection facilities. These factors were identified through an extensive literature review (Min et al., 2023) and expert verification processes (Asah-Kissiedu et al., 2021b). Factor analysis techniques further strengthened The model's development (Lotti Oliva, 2014), ensuring the identified factors and attributes are statistically sound and practically relevant for assessing contractors' CWM practices. The thorough validation process highlights the CW3M model's reliability and capacity to meet contractors' specific needs in the construction industry to enhance CWM in building construction. The CW3M model's attributes were rigorously verified through experts and statistical analysis, ensuring the model's precision and relevance. The BWM was employed to assign weight to each attribute and factor (Rezaei, 2015, 2022), generating standardized global weights that allow contractors to confidently assess their CWM performance across the five critical factors. This data-driven approach ensures the CW3M model identifies areas for improvement and prioritizes them based on their real-world significance.

The CW3M model includes a Microsoft Excel-based assessment tool that provides contractors with a platform to assess their CWM performance (Suprun et al., 2024). This tool uses radar charts and vertical bar charts to visualize the Contractors' performance across 27 attributes, offering a clear and actionable understanding of their current maturity level and future target level. This visual representation is crucial for decision-making, as it highlights strengths and improvement areas. This enables contractors to make informed, strategic choices to enhance their CWM practices. The model's highest maturity score of 5 serves as a threshold, motivating contractors to strive for better performance in CWM by progressively working toward the optimized level.

10.2 Model implementation

The implementation of the CW3M by 16 contractors from Cambodia and Thailand demonstrated its utility as a structured framework for assessing current CWM practices and identifying areas for targeted improvement. The CW3M model provided contractors with a clear path to enhance their CWM performance by benchmarking their current maturity levels and establishing concrete targets. As with other maturity models, such as those described by Röglinger et al. (2012) and Myrberg et al. (2024), this process supports progressive capability development and emphasizes the importance of structured improvement.

According to the self-assessment results, as shown in **Figure 9.3** and **Figure 9.4**, comparing the two countries, Cambodia's contractors consistently showed lower maturity levels than Thailand's contractors, both in their current CWM performance and targeted improvement. This gap reflects broader socio-economic and regulatory differences between the two countries, where Thailand's more developed construction industry and regulatory environment provide more substantial support for higher maturity levels (Aksorn et al., 2008). Nevertheless, the target of Cambodian contractors to improve their CWM performance underscores a growing recognition of the importance of enhancing CWM, even in resource-limited contexts. These results aligned with previous research that has emphasized the critical role that resources and policy frameworks play in shaping an organization's ability to mature (Gibson et al., 2004).

Overall, the average current score of all contractors is 3.20, indicating that contractors in Cambodia and Thailand are currently operating at the higher end of Level 3, the “reactive”. However, the collective target score of 3.87 shows that contractors in both countries aim to move into the “proactive” stage at level 4 over the next two years. This shift reflects a broader industry trend toward more strategic, proactive approaches to CWM as contractors increasingly recognize the economic and environmental benefits of improving WM practices (Zhang et al., 2019).

10.3 Model validation

Contractors provided feedback on the CW3M maturity model as part of the model validation process, as suggested by Myrberg et al. (2024) and Suprun et al. (2024). The validation followed the model’s implementation with a total of experts from 16 contractors, as described in **Section 9.3**. Experts were asked to evaluate the model across six key assessment criteria: appropriateness, objectivity, replicability, practicality, overall reliability, and overall suitability for CWM for contractors in building construction (Babatunde et al., 2016; Cheung, 2009; Osei-Kyei et al., 2018). The results of this validation exercise, presented in **Table 9.3**, show the model’s strong acceptance among industry professionals, confirming its value as an assessment tool for evaluating CWM maturity levels and guiding improvements.

Among the criteria, the “degree of appropriateness” received the highest mean rate of 3.88, indicating that experts view the CW3M model as highly aligned with contractors’ operational realities and needs. This result suggests that the model effectively addresses key concerns in construction waste management, providing a framework that resonates with professionals in the field. The second-highest rate of 3.81 was “overall suitability for CWM for contractors in building construction,” further emphasizing the model’s relevance to real-world practices. This feedback showed that the CW3M model is theoretically sound, practical, and applicable for contractors aiming to enhance their CWM practices. The rates for “degree of objectivity,” “degree of practicality,” and “overall reliability” all at 3.75, indicating that the model is viewed as a balanced and credible tool capable of delivering objective assessments and practical insights. This confirms that the CW3M model is theoretical and can be used reliably by contractors to assess and improve their CWM practices. The model was deemed practical and reliable, suggesting it can be effectively integrated into contractors' operations. However, the "degree of replicability" received the lowest rate of 3.50, though still within a satisfactory range. This lower rate highlights a potential challenge in ensuring consistent implementation across different contexts and contractor sizes. Nevertheless, the rate above 3 suggests that while replicability could be improved, most respondents still consider it acceptable. This rate falls between the ratings suggested by Babatunde et al. (2016), Cheung (2009), and Osei-Kyei et al. (2018), where a rating of 3 represents "good" and 4 is "very good".

Therefore, expert feedback demonstrates that the CW3M model is an appropriate, objective, practical, and reliable tool for assessing and improving the CWM practices of contractors in building construction. The mean rates, ranging from 3.50 to 3.88 across all validation criteria, imply that professionals perceive the model positively, particularly emphasizing its appropriateness and suitability for the building construction industry (Babatunde et al., 2016; Cheung, 2009; Osei-Kyei et al., 2018). This validation process confirms the CW3M model's effectiveness as a comprehensive framework that contractors can use to assess their current CWM maturity levels and set achievable goals for future improvements. The model's potential to drive systematic progress in CWM practices, even in varying contexts, further strengthens its relevance in helping contractors navigate the increasing demands for sustainable CWM in the building construction sector.

CHAPTER 11

CONCLUSION AND RECOMMENDATIONS

This study developed a novel Construction Waste Management Maturity Model (CW3M), a framework designed to assist building contractors in assessing and enhancing their CWM capabilities. The CW3M model bridges a critical gap in the construction industry by offering an actionable tool tailored to the construction phase, focusing on contractor-controlled practices aligned with the 2R strategy (Reduce and Reuse). The key findings and contribution of this study include:

- Developing the model's comprehensive structure, consisting of 27 attributes across five key factors: governance and policies, materials and equipment, requirements and specifications, construction information systems, and waste collection facilities. The CW3M model's five-level maturity framework provides a clear progression path for building contractors, enabling self-assessment and targeted improvement plans for CWM. Understanding the current practice status empowers contractors to target their CWM performance more effectively, thereby minimizing construction waste.
- Through implementation with 16 contractors from Cambodia and Thailand, the CW3M model demonstrated its practicality and relevance. Cambodian contractors currently average a Level 3 (reactive) with a score of 2.82 and aim for higher maturity, while Thai contractors, operating at a Level 4 (proactive) with a score of 3.58, set benchmarks for progression to the upper bounds of Level 4. This underscores the model's versatility and applicability across socio-economic and regulatory contexts.
- The CW3M model's validation results show its appropriateness, reliability, and suitability as a transformative tool for advancing sustainable practices in building construction. Beyond its immediate utility, the CW3M provides a benchmark framework for global building contractors seeking to improve their CWM practices and supports policymakers in promoting circular economy principles in the construction industry.

- The CW3M model's alignment with the United Nations' Sustainable Development Goals (SDGs) No. 8, 9, and 11 further highlights its potential to contribute to sustainable urban development by minimizing construction waste, enhancing resource efficiency, and mitigating environmental impacts.
- This study establishes the CW3M model as a transformative tool for sustainable construction, equipping building contractors with the necessary framework to improve CWM performance, reduce environmental impact, and achieve long-term sustainability goals.
- The findings suggest that implementing the CW3M model has the potential to support more sustainable construction practices by minimizing construction waste, reducing costs, and enhancing operational efficiency. Beyond its immediate benefits to contractors, the model provides valuable insights for policymakers, industry leaders, and researchers seeking to foster sustainable practices, align with circular economy principles, and promote sustainable development.

The CW3M model’s implementation and validation process was limited to experts from Cambodia and Thailand. Future research could expand its applicability by implementing and validating the model in developed countries to account for varying contexts. Furthermore, as digital technology rapidly grows and the construction sector industrializes, new factors and attributes may emerge, requiring updates to the model to ensure its continued relevance and utility in the future.

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APPENDICES

APPENDIX 1

QUESTIONNAIRE FOR EXPERT VERIFICATION (PRELIMINARY STUDY) IN ENGLISH, KHMER, AND THAI

AUN/SEED-Net

EXPERT VERIFICATION QUESTIONNAIRE

Contractor's Attributes Contributing to Effective Construction Waste Management in Building Construction

Dear Sir/ Madam,

Greeting from our research team!

We would like to seek your input in completing a survey that is part of double Ph.D. degree research that seeks to assess effective construction waste management (CWM). This double Ph.D. degree research is sponsored by the AUN/SEED-Net Collaborative Education Program (CEP) under the supervision of Assoc. Prof. Dr. Kriengsak PANUWATWANICH (at Sirindhorn International Institute of Technology, Thammasat University) and Assoc. Prof. Dr. Koji MATSUMOTO (at Hokkaido University).

About this survey
The survey is the initial phase of the development process of the assessment model and is intended for preliminary validation of a set of attributes relevant to effective construction waste management (CWM). You have been identified as someone whose expertise in CWM that fit for the validation exercise.

Confidentiality
The information will be used for academic purposes only. All information collected will be stored securely, and you will not be identified at any point in this research.

Questionnaire structure
This questionnaire contains five pages and consists of two main parts. Part I: Background of you and your company. Part II: Determination of attributes for assessing effective construction waste management (CWM).

Duration of the survey
The survey should take approximately 15 minutes to complete, and it would be very much appreciated if you could kindly finish it on or before 30**th** **March 2023**.

The research team would be most grateful for your time and consideration in contributing to this research.

Please direct any inquiries about this research to:

Mr. Vuthea MIN (Doctoral Researcher), Email: minvuhea@gmail.com, Cell No.: +66-905909078

The Research Team
8th March 2023

Vuthea MIN	Assoc. Prof. Dr. Kriengsak PANUWATWANICH	Assoc. Prof. Dr. Koji MATSUMOTO
SIIT, Thammasat University, Thailand, and Hokkaido University, Japan	SIIT, Thammasat University, Thailand	Hokkaido University, Japan

EXPERT VERIFICATION QUESTIONNAIRE

Part I: Background Information

What is your position in your current organization? (e.g., project manager, lecturer in construction management, etc.)

____

What is your highest level of education?

☐ Bachelor's degree ☐ Master's degree
☐ Doctorate degree ☐ Other (please specify): _______________

How many years of experience do you have in the construction industry?

☐ 0-5 ☐ 6-10 ☐ 11-20 ☐ 21-30 ☐ Over 30

How many years of experience do you have working as contractor(s)?

☐ 0-5 ☐ 6-10 ☐ 11-20 ☐ 21-30 ☐ Over 30

How many years of experience do you have related to construction waste management (CWM)?

☐ 0-5 ☐ 6-10 ☐ 11-20 ☐ 21-30 ☐ Over 30

Please indicate your area(s) of expertise. (Tick as appropriate, multiple options are applicable)

☐ Construction management profession ☐ Environmental management academic
☐ Construction management academic ☐ Other (please specify): _______________
☐ Environmental management profession

Please provide your professional qualifications/affiliations (e.g., PE certified, PMP certified, member of Council of Engineers, etc.)

____

Which of the following best describes your current organization?

☐ Contractor ☐ University/ Academic Institution
☐ Consultant (project management) ☐ Other (please specify): ________________

Part II: Determination of Attributes to Assess the Effective Construction Waste Management

Below is a list of attributes extracted and analyzed from the literature. These attributes were considered **contractor's attributes contributing to effective construction waste management (CWM) in building construction**.

From the best of your knowledge and experience**,** to what extent do you agree or disagree that each of the following should be included ***for assessing the effective construction waste management (CWM) in building construction?*** Please rate (✓) your agreement on the following statements.

Note: **1:** Strongly disagree; **2:** Disagree; **3:** Neutral; **4:** Agree; **5:** Strongly agree.

Attributes	Agreement				
	1	2	3	4	5
i) Management and leadership					
Awareness of the impact of construction waste (CW) on sustainable construction					
Effective and efficient site management					
Effective coordination and communication with project stakeholders					
Senior management's commitment to implementing waste management (WM) practices					
Implementing an effective organizational structure for WM					
Supervision of WM activities with clear instructions					
Effective implementation of the WM plan					
Action to reduce CW generation					
Action to reuse CW					
Work experience on CWM and waste-minimizing culture within the company					
Monitoring and auditing waste management systems periodically					
Ensuring the participation of all stakeholders in WM activities					
Ability to integrate CWM into the assessment					
ii) Manpower					
Effective training for the engineers and workers on WM					
Tasking workers with the exclusive responsibility of waste minimization					
Having a sufficient number of skilled workers					
Quality of workmanship					
iii) Policy and strategy					
Establishing a strict policy on CWM within the company (including the CWM system)					
Establishing an appropriate waste management plan in the earlier stage of each construction					
Setting waste reduction targets for every project by maximizing the reduction of materials					
Setting waste reuse target for every project by maximizing the reuse of materials					
Including subcontractor responsibilities for WM targets in the contract					
Offering incentives for waste minimization efforts to the project team					
Seeking and receiving client support on WM					
Preventing site accidents					
iv) Materials					
Preventing from ordering errors and purchasing appropriate material sizes and quantities					
On-time and accurate quantification of materials/bills of quantities					
Use of quality, durable, and standardized materials					
Adopt Just in Time delivery (JIT) system					
Adequate protection of material transportation and handling (loading and unloading)					
Precise on-site material control (e.g., inspecting the materials when they arrive, etc.)					
Having central areas for cutting and storage of materials					
Adequate protection of different categories of materials during storing and stacking					
Strong security at the project site (i.e., prevent theft and loss of materials)					
v) Equipment or tools					
Ensure the availability of equipment required for every project (i.e., tools, machines, and vehicles)					
Ensure the quality of all equipment to be used in every project					
Be familiar with the usage of all equipment					
Utilize scaffolding and formwork that can be reused many times (e.g., metal, plastic, etc.)					
Utilize BIM for the project and be familiar with its application					
Utilize other related information technologies for the project and be familiar with their application					
vi) Construction method and process					
Adequate site space and the site layout are cleared for materials movement					

Attributes	Agreement				
	1	2	3	4	5
Adopt prefabricated structural elements					
Adopt preassembled components such as bathroom and kitchen pods					
Efficient use of materials and minimizing the uneconomical cutting shapes and length					
Minimizing waste from application processes (e.g., overpreparation of mortar)					
Minimizing rework at the construction site					
Bins are installed on every floor					
Set up separated bins according to the waste type and sort out waste at the site					
Store waste in easily accessible areas					
vii) Documentation					
Effective document control of CWM (amounts, kinds, etc.)					
Detailed study and thorough understanding of specifications and drawings					
Professional quality management and certification (e.g., ISO, GREEN, etc.)					
Lessons learned repository on CWM					
Preventing shop drawing detailing errors					
Minimizing design changes during construction					
Minimizing variation orders (VO)					
Other related attributes: Apart from the above attributes, could you please suggest other appropriate attributes (if any)?					

Thank you very much for your valuable time in answering this questionnaire!

AUN/SEED-Net

កម្រងសំណួរសម្រាប់អ្នកជំនាញបញ្ជាក់ ប៉ារ៉ាម៉ែត្រសម្រាប់ក្រុមហ៊ុនម៉ៅការសំណង់ (Contractor) ដើម្បីវាស់ស្ទង់ឬវាយតម្លៃលើ ប្រសិទ្ធភាពនៃការគ្រប់គ្រងសំណល់សំណង់នៅការដ្ឋានសាងសង់

សូមគោរពជម្រាបសួរ លោក លោកស្រី!

ក្រុមការងារស្រាវជ្រាវយើងខ្ញុំសូមគោរពអនុញ្ញាតលោក លោកស្រីមេត្តាជួយឆ្លើយនូវកម្រងសំណួរដែលជាផ្នែកមួយនៃការស្រាវជ្រាវថ្នាក់បណ្ឌិត (Double Ph.D. degree) ដើម្បីបង្កើតម៉ូដែលសម្រាប់វាស់ស្ទង់ឬវាយតម្លៃទៅលើប្រសិទ្ធភាពនៃការគ្រប់គ្រងសំណល់សំណង់របស់ក្រុមហ៊ុនម៉ៅការសាសង់ (contractor)។ គម្រោងស្រាវជ្រាវថ្នាក់បណ្ឌិតនេះគាំទ្រដោយគម្រោងសហប្រតិបត្តិការបេច្ចេកទេសរបស់អង្គការទីភ្នាក់ងារសហប្រតិបត្តិការអន្តរជាតិជប៉ុនសម្រាប់បណ្តាញសាកលវិទ្យាល័យអាស៊ាន/បណ្ដាញអភិវឌ្ឍ ការអប់រំវិស្វកម្មអាស៊ីភាគអាគ្នេយ៍ (AUN/SEED-Net Collaborative Education Program) ដែលមានសាស្ត្រាចារ្យណែនាំ Assoc. Prof. Dr. Kriengsak PANUWATWANICH មកពីវិទ្យាស្ថាន Sirindhorn International Institute of Technology (SIIT) នៃសាកលវិទ្យាល័យធម្មសាត (Thammasat University) ប្រទេសថៃ និង លោកសាស្ត្រាចារ្យ Assoc. Prof. Dr. Koji MATSUMOTO មកពីសាកលវិទ្យល័យហុកកៃដូ (Hokkaido University) ប្រទេសជប៉ុន ។

អំពីការស្ទង់មតិនេះ

ការស្ទង់មតិនេះជាផ្នែកមួយនៃដំណើរការបង្កើតម៉ូដែលដើម្បីវាស់ស្ទង់ឬវាយតម្លៃលើប្រសិទ្ធភាពនៃការគ្រប់គ្រងសំណល់សំណង់ ដែលពេលនេះយើងកំពុងកំណត់នូវប៉ារ៉ាម៉ែត្រដើម្បីបង្កើតម៉ូដែលសម្រាប់វាស់ស្ទង់ឬវាយតម្លៃ។ លោក លោកស្រីត្រូវបានក្រុមការងារជ្រើសរើសជាអ្នកជំនាញក្នុងវិស័យសំណង់ដែលមានចំណេះដឹងនិងបទពិសោធន៍លើការគ្រប់គ្រងសំណល់សំណង់ដែលអាចជួយបញ្ជាក់នូវប៉ារ៉ាម៉ែត្រទាំងនេះបាន។

ការសម្ងាត់

ព័ត៌មានទាំងនេះនឹងត្រូវប្រើសម្រាប់គោលបំណងសិក្សាស្រាវជ្រាវតែប៉ុណ្ណោះ។ ចម្លើយរបស់អ្នកនឹងត្រូវរក្សាជាការសម្ងាត់បំផុត និង មិនត្រូវបានបង្ហាញអត្តសញ្ញាណឡើយក្នុងការសិក្សាស្រាវជ្រាវនេះ។

រចនាសម្ព័ន្ធនៃកម្រងសំណួរ

កម្រងសំណួរនេះ មានចំនួន៣ ទំព័រ ដែលក្នុងនោះមាន២ ផ្នែកសំខាន់ៗ គឺ ផ្នែកទី១៖ សាវតាររបស់អ្នក និងក្រុមហ៊ុនរបស់អ្នក, ផ្នែកទី២៖ ការបញ្ជាក់នូវប៉ារ៉ាម៉ែត្រនីមួយៗសម្រាប់វាស់ស្ទង់ ឬវាយតម្លៃលើប្រសិទ្ធភាពនៃការគ្រប់គ្រងសំណល់សំណង់។

រយៈពេលនៃការស្ទង់មតិ

ការស្ទង់មតិនេះនឹងត្រូវចំណាយពេលវេលាប្រមាណ ១៥ នាទី ដើម្បីបញ្ចប់។ សូមមេត្តាឆ្លើយតបត្រឹមថ្ងៃទី ១១ ខែ មីនា ឆ្នាំ ២០២៣នេះ។

យើងខ្ញុំសូមថ្លែងអំណរគុណទុកជាមុន សម្រាប់ការចំណាយពេលវេលា ការយោគយល់ និងចិត្តសប្បុរស

របស់អ្នក ក្នុងការចូលរួមចំណែកដល់ការស្រាវជ្រាវដ៏មានសារៈសំខាន់នេះ!

ក្នុងករណីមានចម្ងល់ ឬអ្វីបន្ថែម សូមទាក់ទងលោក មីន វុទ្ធា (បេក្ខជនបណ្ឌិត) តាមរយៈ Email: minvuhea@gmail.com ឬទូរស័ព្ទលេខ +៦៦-៩០៥៩០៩០៧៨ ។

ដោយក្ដីគោរពពីក្រុមស្រាវជ្រាវ

ថ្ងៃទី ០៩ ខែ មីនា ឆ្នាំ ២០២៣

បេក្ខជនបណ្ឌិត	សាស្ត្រាចារ្យណែនាំ	សាស្ត្រាចារ្យណែនាំ
មីន វុទ្ធា	Assoc. Prof. Dr. Kriengsak PANUWATWANICH	Assoc. Prof. Dr. Koji MATSUMOTO
SIIT, Thammasat University, Thailand, and Hokkaido University, Japan	SIIT, Thammasat University, Thailand	Hokkaido University, Japan

កម្រងសំណួរសម្រាប់អ្នកជំនាញបញ្ជាក់

ផ្នែកទី១ ៖ ព័ត៌មានមូលដ្ឋាន/សាមតារ

តើមុខតំណែង ឬមុខងារការងាររបស់អ្នកជាអ្វី?(ឧទាហរណ៍៖ ប្រធានគ្រប់គ្រងគម្រោង; សាស្ត្រាចារ្យបង្រៀនផ្នែកការគ្រប់គ្រងគម្រោងសាងសង់ ។ល។)

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តើអ្នកមានកម្រិតអប់រំខ្ពស់បំផុតដល់កម្រិតណា?

☐ បរិញ្ញាបត្រ ☐ បរិញ្ញាបត្រជាន់ខ្ពស់

☐ បណ្ឌិត ☐ ផ្សេងទៀត(សូមបញ្ជាក់)_____________

តើអ្នកមានបទពិសោធន៍ប៉ុន្មានឆ្នាំនៅក្នុងឧស្សាហកម្មសំណង់?

☐ 0-៥ ☐ ៦-១០ ☐១១-២០ ☐ ២១-៣០ ☐ លើសពី ៣០

តើអ្នកមានបទពិសោធន៍សរុបប៉ុន្មានឆ្នាំក្នុងការធ្វើការងារនៅក្នុងក្រុមហ៊ុនម៉ៅការសំណង់(Contractors)?

☐ 0-៥ ☐ ៦-១០ ☐១១-២០ ☐ ២១-៣០ ☐ លើសពី ៣០

តើអ្នកមានបទពិសោធន៍សរុបប៉ុន្មានឆ្នាំក្នុងការធ្វើការងារទាក់ទងនឹងការគ្រប់គ្រងសំណល់សំណង់?

☐ 0-៥ ☐ ៦-១០ ☐១១-២០ ☐ ២១-៣០ ☐ លើសពី ៣០

សូមបញ្ជាក់នូវមុខជំនាញវិជ្ជាជីវៈរបស់អ្នក (អាចគូសធីកលើសពីមួយបាន)

☐ គ្រប់គ្រងគម្រោងសាងសង់ ☐ គ្រប់គ្រងបរិស្ថាន

☐ បង្រៀន ឬស្រាវជ្រាវផ្នែកគ្រប់គ្រងគម្រោងសាងសង់ ☐ បង្រៀន ឬស្រាវជ្រាវផ្នែកគ្រប់គ្រងបរិស្ថាន

☐ ផ្សេងទៀត (សូមបញ្ជាក់) ______________

សូមបញ្ជាក់នូវវិញ្ញាបនបត្រអាជីពរបស់អ្នកប្រសិនបើមាន?(ឧទាហរណ៍៖ វិស្វករអាជីព, PMP, សមាជិកគណវិស្វករ ។ល។)

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តើស្ថាប័នអ្នកកំពុងធ្វើការបច្ចុប្បន្នស្ថិតនៅក្នុងប្រភេទណា?

☐ ក្រុមហ៊ុនម៉ៅការសាងសង់(Contractor) ☐ សាកលវិទ្យាល័យ

☐ ក្រុមហ៊ុនប្រឹក្សាសំណង់ (Consultant) ☐ ផ្សេងទៀត (សូមបញ្ជាក់) ______________

ផ្នែកទី២ ៖ ការបញ្ជាក់នូវប៉ារ៉ាម៉ែត្រនីមួយៗសម្រាប់វាស់ស្ទង់ ឬវាយតម្លៃលើប្រសិទ្ធភាពនៃការគ្រប់គ្រងសំណល់សំណង់

ខាងក្រោមនេះជាបញ្ជីប៉ារ៉ាម៉ែត្រសម្រាប់វាស់ស្ទង់ឬវាយតម្លៃប្រសិទ្ធភាពនៃការគ្រប់គ្រងសំណល់សំណង់របស់ក្រុមហ៊ុនសាងសង់(Contractor)សម្រាប់គម្រោងសាងសង់អគារដែលបានមកពីការសិក្សាផ្សេងៗពីមុនមក (Literature review)។

ដោយយោងទៅលើចំណេះដឹង និងបទពិសោធន៍របស់អ្នក សូមអ្នកកម្រិតនូវការយល់ស្រប ឬមិនយល់ស្រប ចំពោះប៉ារ៉ាម៉ែត្រនីមួយៗសម្រាប់វាស់ស្ទង់ ឬវាយតម្លៃប្រសិទ្ធភាពនៃការគ្រប់គ្រងសំណល់សំណង់ក្នុងគម្រោងសាងសង់អគារខាងក្រោមនេះ ដោយធីក(✓)នូវកម្រិតនៃការយល់ស្រប ឬមិនយល់ស្របក្នុងប្រអប់នីមួយៗខាងក្រោម៖

សំគាល់: **១.** មិនយល់ស្របទាំងស្រុង; **២.** មិនយល់ស្រប; **៣.** អព្យាក្រឹត; **៤.** យល់ស្រប; **៥.** យល់ស្របទាំងស្រុង

ប៉ារ៉ាម៉ែត្រ	កម្រិត មិនស្រប ឬស្រប				
	១	២	៣	៤	៥
i) **គ្រប់គ្រង និងភាពជាអ្នកដឹកនាំ**					
ការយល់ដឹងអំពីផលប៉ះពាល់នៃសំណល់សំណង់លើនិរន្តរភាពសំណង់					
ប្រសិទ្ធភាព និងប្រសិទ្ធផលនៃការគ្រប់គ្រងការដ្ឋានសាងសង់					
ប្រសិទ្ធភាពក្នុងការទំនាក់ទំនង និងសម្របសម្រួលគម្រោងជាមួយភាគីពាក់ព័ន្ធ					
ការតាំងចិត្តក្នុងការងារគ្រប់គ្រងសំណល់សំណង់របស់អ្នកគ្រប់គ្រងការសាងសង់					
ប្រសិទ្ធភាពនៃការធ្វើនិងអនុវត្តតាមរចនាសម្ព័ន្ធនៃការបែងចែកការងារគ្រប់គ្រងសំណល់សំណង់					
ការគ្រប់គ្រងសំណល់សំណង់ជាមួយនឹងភាពច្បាស់លាស់នៃការណែនាំចាត់ចែង					
ការអនុវត្តន៍ផែនការគ្រប់គ្រងសំណល់សំណង់ប្រកបដោយប្រសិទ្ធភាព					
សកម្មភាពកាត់បន្ថយសំណល់សំណង់					
សកម្មភាពប្រើប្រាស់ឡើងវិញនូវសំណល់សំណង់					
បទពិសោធន៍នៃការគ្រប់គ្រងសំណល់សំណង់ និងវប្បធម៌នៃការសន្សំសំចៃរបស់ក្រុមហ៊ុនក្នុងការប្រើប្រាស់សម្ភារៈ					
ការត្រួតពិនិត្យ និងធ្វើសវនកម្មប្រព័ន្ធគ្រប់គ្រងសំណល់សំណង់ជាទៀងទាត់					
ការធានាការចូលរួមរបស់ភាគីពាក់ព័ន្ធទាំងអស់នៅក្នុងសកម្មភាពគ្រប់គ្រងសំណល់សំណង់					
សមត្ថភាពក្នុងការច្របាច់បញ្ចូលការគ្រប់គ្រងសំណល់សំណង់ទៅក្នុងការវាយតម្លៃប្រសិទ្ធភាព					
ii) **ធនធានមនុស្ស ឬកម្លាំងពលកម្ម**					
ប្រសិទ្ធភាពនៃការបណ្តុះបណ្តាលការគ្រប់គ្រងកាកសំណល់ដល់វិស្វករនិងកម្មករ					
ការដាក់ភារកិច្ចដាច់ដោយឡែកដល់កម្មករឲ្យមានទំនួលខុសត្រូវក្នុងការកាត់បន្ថយកាកសំណល់សំណង់					
មានបុគ្គលិកកម្មករជំនាញគ្រប់គ្រាន់					
ទឹកដៃឬគុណភាពការងារពលកម្មនីមួយ(Qualify of workmanship)					
iii) **គោលនយោបាយ និងយុទ្ធសាស្ត្រ**					
ការបង្កើតគោលនយោបាយតឹងរឹងលើការគ្រប់គ្រងសំណល់សំណង់នៅក្នុងក្រុមហ៊ុន(រួមទាំងប្រព័ន្ធគ្រប់គ្រងសំណល់សំណង់)					

ប៉ារ៉ាម៉ែត្រ	កម្រិត មិនស្រប ឬស្រប				
	១	២	៣	៤	៥
ការបង្កើតផែនការគ្រប់គ្រងកាកសំណល់សំណង់សមរម្យមុនចាប់ផ្តើមគម្រោងសាងសង់នីមួយៗ					
ការកំណត់គោលដៅកាត់បន្ថយកាកសំណល់សំណង់នៅគ្រប់គម្រោងសាងសង់ដោយការប្រើប្រាស់សម្ភារៈសំណង់សន្សំសំចៃ					
ការកំណត់គោលដៅប្រើប្រាស់សំណល់សំណង់ឡើងវិញនៅគ្រប់គម្រោងសាងសង់ដោយបង្កើន ការប្រើប្រាស់សម្ភារៈដែលនៅសេសសល់ហើយអាចប្រើប្រាស់បាន					
រួមបញ្ចូលតួនាទីក្រុមហ៊ុនម៉ៅការបន្ទាប់(subcontractor)នៅក្នុងកិច្ចសន្យាក្នុងការទទួលខុសត្រូវលើការគ្រប់គ្រងកាកសំណល់សំណង់					
ការផ្តល់រង្វាន់លើកទឹកចិត្តដល់កិច្ចខិតខំប្រឹងប្រែងកាត់បន្ថយកាកសំណល់សំណង់ដល់ក្រុមការងារ					
ស្វែងរកការគាំទ្រពីម្ចាស់គម្រោងលើការគ្រប់គ្រងកាកសំណល់សំណង់					
ទប់ស្កាត់គ្រោះថ្នាក់នៅការដ្ឋានសាងសង់					
iv) សម្ភារៈសំណង់					
ជៀសវាងការបញ្ជាទិញខុស និងត្រូវទិញសម្ភារៈដែលត្រឹមត្រូវទៅតាមខ្នាត ទំហំ និងបរិមាណ					
គណនាបរិមាណសម្ភារៈ(BoQ) ត្រឹមត្រូវ និងទាន់ពេលវេលាសម្រាប់ប្រើប្រាស់					
ប្រើប្រាស់សម្ភារៈសំណង់ដែលមានគុណភាព និងស្តង់ដា					
ទម្លាប់បញ្ចូលសម្ភារៈមកក្នុងការដ្ឋានតាមតម្រូវការប្រើប្រាស់ដោយមិនទុកគរ ឬស្តុកយូរនៅការដ្ឋាន(JIT)					
ប្រុងប្រយ័ត្នខ្ពស់ក្នុងការដឹកជញ្ជូន និងការលើកដាក់សម្ភារៈជៀសវាងការបាក់បែកឬខូចខាត					
មានភាពច្បាស់លាស់ក្នុងការត្រួតពិនិត្យសម្ភារៈនៅការដ្ឋាន (ឧ. ត្រួតពិនិត្យសម្ភារៈនៅពេលដឹកមកដល់ការដ្ឋាន ។ល។)					
កំណត់និងរៀបចំទីតាំងគោល(Central areas)សម្រាប់កាត់និងដាក់សម្ភារៈសំណង់					
ការប្រុងប្រយ័ត្នខ្ពស់ក្នុងការលើកដាក់នៅនឹងកន្លែងរក្សាទុកសម្ភារៈទៅតាមក្រុមឬប្រភេទរបស់វា					
មានសន្តិសុខតឹងរឹងនៅការដ្ឋានសាងសង់ (ការពារការលួច និងការបាត់បង់)					
v) គ្រឿងចក្រ ឬឧបករណ៍					
មានគ្រឿងចក្រ យានយន្ត និងឧបករណ៍គ្រប់គ្រាន់ដើម្បីប្រើប្រាស់នៅគ្រប់គម្រោង					
ធានាបាននូវគុណភាពគ្រឿងចក្រ យានយន្ត និងឧបករណ៍ ដែលត្រូវប្រើប្រាស់នៅគ្រប់គម្រោង					
មានភាពស្ទាត់ជំនាញក្នុងការបញ្ជាឬប្រើប្រាស់នូវគ្រប់គ្រឿងចក្រ យានយន្ត និងឧបករណ៍ ទាំងអស់					
ប្រើប្រាស់ប្រភេទរន្ទានិងជន្ទល់ដែលអាចប្រើប្រាស់បានច្រើនដង(ឧ. ធ្វើពីដែក ផ្លាស្ទិក។ល។)					
ប្រើប្រាស់កម្មវិធី BIM សម្រាប់គម្រោង និងមានភាពស្ទាត់ជំនាញក្នុងកម្មវិធីនេះ					
ប្រើប្រាស់កម្មវិធីបច្ចេកវិទ្យាព័ត៌មានពាក់ព័ន្ធផ្សេងទៀតសម្រាប់គម្រោង និងមានភាពស្ទាត់ជំនាញក្នុងកម្មវិធីនេះ					
vi) វិធីសាស្ត្រ និងដំណើរការសាងសង់					
ទំហំទីតាំងការដ្ឋានធំសមរម្យ និងរៀបចំប្លង់ក្នុងការដ្ឋានយ៉ាងមានប្រសិទ្ធភាពដើម្បីមានភាពងាយស្រួលក្នុងការបំលាស់ទីគ្រឿងចក្រ និងសម្ភារៈ					
ប្រើប្រាស់គ្រឿងបង្គំដែលចាក់ហើយស្រាប់ (ឧ. ប្រើបន្ទះប្លង់សេចាក់ស្រាប់ពីរោងចក្រ)					
ប្រើប្រាស់គ្រឿងសង្ហារិមដែលផ្គុំហើយស្រាប់ពីរោងចក្រឬរោងជាង តួយ៉ាងដូចជាបន្ទប់ទឹកឬផ្នែកខ្លះនៃចង្ក្រានបាយ					
វាស់ និងកាត់សម្ភារៈមានការប្រុងប្រយ័ត្នខ្ពស់ និងសន្សំសំចៃ					
កាត់បន្ថយកាកសំណល់ពីដំណើរការសកម្មភាពការងារនីមួយៗនៅក្នុងការសាងសង់ (ឧ. ការលាយបាយអលើសតម្រូវការប្រើប្រាស់ច្រើន)					
កាត់បន្ថយការវាយចោល និងធ្វើឡើងវិញនូវផ្នែកផ្សេងៗនៃអគារ (ឧ. ចាក់ជណ្តើរខុស រួចវាយចោល និងធ្វើឡើងវិញ)					
ដាក់ធុងសម្រាមគ្រប់ជាន់ក្នុងអគារដែលកំពុងសាងសង់					

ប៉ារ៉ាម៉ែត្រ	កម្រិត មិនស្រប ឬស្រប				
	១	២	៣	៤	៥
បែងចែកធុងសម្រាមទៅតាមប្រភេទនៃសម្រាមនៅការដ្ឋាន					
ដាក់សម្រាមនៅទីតាំងដែលងាយស្រួលដាក់ និងដឹកជញ្ជូន					
vii) ឯកសារសំណង់					
ការគ្រប់គ្រងឯកសារពាក់ព័ន្ធនឹងសំណល់សំណង់ប្រកបដោយប្រសិទ្ធភាព (ឧ. បរិមាណសម្រាម ប្រភេទសម្រាម ។ល។)					
ការសិក្សាលម្អិត និងហ្មត់ចត់អំពីប្លង់ និងSpec					
ទទួលបាននូវវិញ្ញាបនបត្រស្តង់ដាគុណភាពផ្សេងៗ (ឧ. ISO, GREEN, etc.)					
មានការទុកដាក់ និងសិក្សានូវឯកសារដែលជាបទពិសោធន៍ធ្លាប់អនុវត្តកន្លងមកទាក់ទង និងការគ្រប់គ្រងសំណល់សំណង់					
ជៀសវាងការធ្វើប្លង់សម្អិត shop drawing ខុស					
កាត់បន្ថយការកែប្លង់ឌីស្សាញពេលកំពុងសាងសង់					
កាត់បន្ថយការផ្លាស់ប្តូរឬកែកុនការងារសាងសង់ដែលត្រូវប្រើប្រាស់ថវិកាបន្ថែម(VO)					
ក្រៅពីប៉ារ៉ាម៉ែត្រដែលបានរៀបរាប់ខាងលើ តើអ្នកគិតថានៅមានប៉ារ៉ាម៉ែត្រអ្វីផ្សេងទៀតទេ? សូមបញ្ជាក់ខាងក្រោម៖					

ក្រុមការងារសូមថ្លែងអំណរគុណយ៉ាងជ្រាលជ្រៅចំពោះពេលវេលាដ៏មានតម្លៃរបស់អ្នកក្នុងការឆ្លើយសំណួរនេះ!

AUN/SEED-Net

แบบสอบถามการทวนสอบความเชี่ยวชาญ
คุณสมบัติของผู้รับเหมาที่มีส่วนช่วยในการจัดการของเสียจากการก่อสร้างในโครงการก่อสร้างอาคารอย่างมีประสิทธิภาพ

เรียนท่านผู้ที่เกี่ยวข้อง

ทางทีมนักวิจัยต้องการขอความคิดเห็นของท่าน ในการทำแบบสำรวจซึ่งเป็นส่วนหนึ่งของงานวิจัยหลักสูตรปริญญาสองประเทศระดับปริญญาเอก (Double Ph.D. degree) ซึ่งเป็นงานวิจัยเกี่ยวกับการประเมินการการจัดการของเสียจากการก่อสร้างอย่างมีประสิทธิภาพ (Effective Construction Waste Management หรือ CWM) งานวิจัยนี้ได้รับการสนับสนุนจากโครงการ AUN/SEED-Net Collaborative Education Program หรือ CEP ภายใต้การดูแลของ รองศาสตราจารย์ ดร.เกรียงศักดิ์ ภานุวัฒน์วนิชย์ จากสถาบันเทคโนโลยีนานาชาติสิรินธร (SIIT) จากมหาวิทยาลัยธรรมศาสตร์ (Thammasat University) และ Prof. Dr. Koji MATSUMOTO จากมหาวิทยาลัยฮอกไกโด (Hokkaido University)

เกี่ยวกับแบบสำรวจ

งานสำรวจนี้เป็นขั้นตอนแรกของกระบวนการพัฒนารูปแบบการประเมิน โดยมีวัตถุประสงค์เพื่อการตรวจสอบเบื้องต้นของชุดคุณลักษณะที่มีส่วนเกี่ยวข้องในการจัดการของเสียจากการก่อสร้างในโครงการก่อสร้างอย่างมีประสิทธิภาพ (CWM) โดยท่านเป็นผู้ที่ถูกระบุเป็นผู้ที่มีความเกี่ยวข้องในการจัดการของเสียจากการก่อสร้าง (CWM) ซึ่งเหมาะสมแก่การทบทวนความเหมาะสมของแบบสอบถามนี้

การรักษาความลับ

ข้อมูลทั้งหมดจะถูกใช้เพื่อวัตถุประสงค์ทางการศึกษาเท่านั้น ข้อมูลที่ถูกจัดเก็บจะมีการรักษาความปลอดภัย โดยจะไม่มีการระบุตัวตนของผู้ตอบแบบสอบถามในการวิจัยนี้

โครงสร้างของแบบสอบถาม

แบบสอบถามนี้มีทั้งหมด 5 หน้า ประกอบไปด้วย 2 ส่วนหลักได้แก่ ส่วนที่ 1: ข้อมูลพื้นฐานของผู้ตอบแบบสอบถามและบริษัทปัจจุบันของผู้ตอบแบบสอบถาม และส่วนที่ 2: การกำหนดคุณลักษณะสำหรับการประเมินการจัดการของเสียจากการก่อสร้างในโครงการก่อสร้างอย่างมีประสิทธิภาพ

ระยะเวลาการตอบแบบสอบถาม

การทำแบบสอบถามจนเสร็จสมบูรณ์จะใช้เวลาประมาณ 15 นาที หวังเป็นอย่างยิ่งว่าจะได้รับความอนุเคราะห์จาก ผู้ตอบแบบสอบถาม ในการดำเนินการตอบแบบสอบถามให้เสร็จสมบูรณ์ สามารถดำเนินการส่งให้แก่ผู้วิจัยผ่านทางอีเมล์ ได้จนถึงวันที่ 12 มีนาคม 2566

ทีมวิจัยขอขอบพระคุณเป็นอย่างยิ่งที่ท่านสละเวลาและพิจารณามีส่วนร่วมในการวิจัยนี้

หากมีคำถามหรือข้อสงสัยในรายละเอียดงานวิจัยนี้ โปรดติดต่อ:

Mr. Vuthea MIN (Doctoral Researcher), อีเมล: minvuhea@gmail.com, เบอร์โทรศัพท์: +66-905909078

คณะผู้นักวิจัย

ลงวันที่ 8 มีนาคม 2566

Vuthea MIN	รองศาสตราจารย์ ดร.เกรียงศักดิ์ ภานุวัฒน์วนิชย์	Assoc. Prof. Dr. Koji MATSUMOTO
สถาบันเทคโนโลยีนานาชาติสิรินธร (SIIT) มหาวิทยาลัยธรรมศาสตร์ และ มหาวิทยาลัยฮอกไกโด (Hokkaido University)	สถาบันเทคโนโลยีนานาชาติสิรินธร (SIIT) มหาวิทยาลัยธรรมศาสตร์	มหาวิทยาลัยฮอกไกโด (Hokkaido University)

แบบสอบถามสำหรับการตรวจสอบโดยผู้เชี่ยวชาญ

ส่วนที่ 1: ประวัติส่วนตัว

ตำแหน่งปัจจุบันของท่านในองค์กร (อาทิ ผู้จัดการโครงการ อาจารย์สาขาวิชาการจัดการงานก่อสร้าง เป็นต้น)

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วุฒิการศึกษาระดับสูงสุดของท่าน

☐ ปริญญาตรี ☐ ปริญญาโท

☐ ปริญญาเอก ☐ อื่นๆ (โปรดระบุ): _____________

ท่านมีประสบการณ์ในอุตสาหกรรมการก่อสร้างกี่ปี

☐ 0-5 ☐ 6-10 ☐ 11-20 ☐ 21-30 ☐ มากว่า 30

ท่านมีประสบการณ์การทำงานเป็นผู้รับเหมากี่ปี

☐ 0-5 ☐ 6-10 ☐ 11-20 ☐ 21-30 ☐ Over 30

ท่านมีประสบการณ์การทำงานที่เกี่ยวข้องกับการจัดการของเสียจากการก่อสร้างในโครงการก่อสร้างกี่ปี

☐ 0-5 ☐ 6-10 ☐ 11-20 ☐ 21-30 ☐ Over 30

โปรดระบุสาขาที่ท่านเชี่ยวชาญ (สามารถระบุได้มากกว่า 1 ตัวเลือก)

☐ วิชาชีพบริหารงานก่อสร้าง ☐ การจัดการสิ่งแวดล้อมเชิงวิชาการ

☐ การบริหารงานก่อสร้างเชิงวิชาการ ☐ อื่นๆ (โปรดระบุ): ______________

☐ วิชาชีพการจัดการสิ่งแวดล้อม

โปรดระบุคุณสมบัติทางวิชาชีพ/สังกัดของท่าน (เช่น วิศวกรมืออาชีพ หรือ PE, PMP, สมาชิกสภาวิศวกร และอื่นๆ)

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ตัวเลือกใดต่อไปนี้อธิบายลักษณะองค์กรของท่านได้ดีที่สุด

☐ ผู้รับเหมา ☐ มหาวิทยาลัย/สถาบันการศึกษา

☐ ที่ปรึกษา (บริหารโครงการ) ☐ อื่นๆ (โปรดระบุ): ______________

ส่วนที่ 2: การกำหนดคุณลักษณะสำหรับการประเมินการจัดการของเสียจากการก่อสร้างในโครงการก่อสร้างอย่างมีประสิทธิภาพ

ด้านล่างนี้คือรายการคุณสมบัติที่ถูกคัดแยกและวิเคราะห์จากงานวิจัยที่เกี่ยวข้อง คุณสมบัติเหล่านี้ถือเป็น **คุณสมบัติของผู้รับเหมาที่มีส่วนช่วยในการจัดการของเสียจากการก่อสร้าง (CWM) ในโครงการก่อสร้างอย่างมีประสิทธิภาพ**

จากความรู้และประสบการณ์ของท่าน ท่านเห็นด้วยหรือไม่เห็นด้วยมากน้อยเพียงใด ที่รายการแต่ละข้อดังต่อไปนี้มีความเกี่ยวข้องกับ**การจัดการของเสียจากการก่อสร้าง (CWM) ในโครงการก่อสร้างอย่างมีประสิทธิภาพ** โปรดทำเครื่องหมาย (✔) ตามระดับความเห็นของท่านต่อข้อความดังกล่าว

หมายเหตุ: 1: *ไม่เห็นด้วยอย่างยิ่ง;* ***2:*** *ไม่เห็นด้วย;* ***3:*** *ปานกลาง;* ***4:*** *เห็นด้วย;* ***5:*** *เห็นด้วยอย่างยิ่ง*

คุณสมบัติ	ระดับความเห็น				
	1	2	3	4	5
๑) การบริหารจัดการและความเป็นผู้นำ					
ความตระหนักถึงผลกระทบจากของเสียจากการก่อสร้างที่ส่งผลต่อการก่อสร้างอย่างยั่งยืน					
การจัดการสถานที่ก่อสร้างที่มีประสิทธิภาพและประสิทธิผล					
การประสานงานและการสื่อสารที่มีประสิทธิภาพกับผู้มีส่วนได้เสียในโครงการ (Stakeholders)					
ความมุ่งมั่นของผู้บริหารระดับสูงในการดำเนินการตามแนวทางปฏิบัติด้านการจัดการของเสีย					
การจัดโครงสร้างองค์กรที่มีประสิทธิภาพในการจัดการของเสีย					
การกำกับดูแลขั้นตอนการจัดการของเสียพร้อมคู่มือการปฏิบัติงานที่มีความชัดเจนและคำสั่งที่ชัดเจน					
การดำเนินการตามแผนการจัดของเสียอย่างมีประสิทธิภาพ					
มีการดำเนินการเพื่อลดการเกิดของเสียจากการก่อสร้าง					
มีการใช้ซ้ำเพื่อลดของเสียจากการก่อสร้าง					
มีประสบการณ์การทำงานเกี่ยวกับการจัดการของเสียจากการก่อสร้าง และวัฒนธรรมองค์กรที่มีการลดการสร้างของเสีย					
ติดตามและตรวจสอบระบบการจัดการของเสียอย่างสม่ำเสมอ					
ตรวจสอบความเกี่ยวข้องของผู้มีส่วนได้ส่วนเสียทั้งหมดในกิจกรรมการจัดการของเสีย					
ความสามารถในการปรับใช้การจัดการของเสียจากการก่อสร้างเพื่อการประเมิน					
๒) กำลังแรงงาน					
การฝึกอบรมที่มีประสิทธิภาพสำหรับวิศวกรและแรงงานในด้านการจัดการของเสีย					
มอบหมายงานให้พนักงานมีความรับผิดชอบเป็นพิเศษในการลดของเสียที่เกิดขึ้นจากกิจกรรมการก่อสร้างให้เหลือน้อยที่สุด					
มีจำนวนแรงงานฝีมือที่เพียงพอ					
คุณภาพของแรงงานฝีมือ					

คุณสมบัติ	ระดับความเห็น				
	1	2	3	4	5
๓) นโยบายและกลยุทธ์					
กำหนดนโยบายที่เข้มงวดในการจัดการของเสียจากการก่อสร้างภายในองค์กร (รวมถึงระบบการจัดการของเสียจากการจากการก่อสร้าง)					
จัดทำแผนการจัดการของเสียที่เหมาะสมในช่วงเริ่มต้นของการก่อสร้างแต่ละขั้นตอน					
กำหนดเป้าหมายการลดของเสียในทุกโครงการ โดยลดการใช้วัสดุให้ได้มากที่สุด					
กำหนดเป้าหมายการนำของเสียกลับมาใช้ใหม่ (Waste Resuse) ในทุกโครงการ โดยเพิ่มการนำวัสดุกลับมาใช้ใหม่ (Reuse of Material) ให้ได้มากที่สุด					
เพิ่มความรับผิดชอบให้แก่ผู้รับเหมาช่วง (subcontract) สำหรับเป้าหมายในการจัดการของเสียในเอกสารสัญญา					
มีข้อเสนอสิ่งจูงใจให้เกิดความพยายามในการลดของเสียให้กับทีมงานในโครงการ					
ได้รับการคัดเลือกและการสนับสนุนจากเจ้าของโครงการ สำหรับการจัดการของเสียจากงานก่อสร้าง					
การหลีกเลี่ยงอุบัติเหตุในพื้นที่ก่อสร้าง					
๔) วัสดุ					
การหลีกเลี่ยงจากคำสั่งซื้อที่ผิดพลาดและการสั่งซื้อวัสดุที่มีปริมาณและขนาดที่เพียงพอ					
การจัดด้านการถอดปริมาณวัสดุและ/หรือใบเสร็จที่มีความแม่นยำและตรงตามกำหนดเวลา					
การใช้วัสดุที่มีคุณภาพ ทนทาน และได้มาตรฐาน					
การเลือกใช้ระบบการผลิตแบบทันเวลาพอดี (Just in Time delivery หรือ JIT)					
มีการป้องกันที่เพียงพอในขั้นตอนการขนส่งและลำเลียง (ทั้งแบบ Loading และ Unloading)					
มีการควบคุมวัสดุในสถานที่อย่างแม่นยำ (เช่น การตรวจสอบวัสดุเมื่อมาถึง เป็นต้น)					
มีพื้นที่ส่วนกลางสำหรับงานตัดแต่งและจัดเก็บวัสดุ					
มีการป้องกันวัสดุแต่ละประเภท อย่างเหมาะสมระหว่างการจัดเก็บและการกองเก็บวัสดุ					
มีการรักษาความปลอดภัยอย่างเข้มงวดในบริเวณโครงการ (เช่น การป้องกันการโจรกรรมและการสูญหายของวัสดุ)					
๕) อุปกรณ์หรือเครื่องมือ					
ความมั่นใจด้านความพร้อมของอุปกรณ์ที่จำเป็นในการใช้งานสำหรับทุกโครงการ (เช่น เครื่องมือเครื่องจักร และยานพาหนะ)					
ความมั่นใจด้านคุณภาพของอุปกรณ์ทั้งหมดที่จะถูกใช้ในทุกโครงการ					
มีความคุ้นเคยและมีความชำนาญในการใช้อุปกรณ์ทั้งหมด					
การใช้งานนั่งร้านและแบบหล่อที่สามารถใช้ซ้ำได้หลายครั้ง (เช่น โลหะ พลาสติก ฯลฯ)					
การประยุกต์ใช้ Building Information Modeling หรือ BIM สำหรับโครงการเพื่อทำความคุ้นเคยกับการใช้งาน					
การประยุกต์ใช้เทคโนโลยีสารสนเทศอื่นๆ ที่เกี่ยวข้องสำหรับโครงการและทำความคุ้นเคยกับการใช้งาน					

คุณสมบัติ	ระดับความเห็น				
	1	2	3	4	5
๖) วิธีการและขั้นตอนการก่อสร้าง					
มีพื้นที่ภายในโครงการที่เพียงพอ และผังบริเวณที่มีการจัดการสำหรับการเคลื่อนย้ายวัสดุ					
มีการใช้องค์ประกอบโครงสร้างสำเร็จรูป หรือ Prefabricated Structural Elements					
ใช้ส่วนประกอบที่ประกอบไว้ล่วงหน้า หรือ Preassembled Components เช่น ห้องน้ำและชุดครัวแบบโมดูลาร์					
การใช้วัสดุอย่างมีประสิทธิภาพและลดรูปทรงและความยาวการตัดที่สิ้นเปลืองให้น้อยที่สุด					
ลดของเสียจากกระบวนการก่อสร้างให้เหลือน้อยที่สุด (เช่น การเตรียมปูนมากเกินกว่าการใช้งาน)					
ลดการทำงานซ้ำซ้อนที่บริเวณก่อสร้าง					
มีการติดตั้งถังสำหรับใส่ของเสียทุกชั้นในอาคาร					
มีการแยกประเภทถังสำหรับใส่ของเสียตามประเภทของของเสียและมีการคัดแยกของเสียที่หน้างาน					
มีการจัดเก็บของเสียในพื้นที่ที่สามารถเข้าถึงได้ง่าย					
๗) เอกสารในโครงการ					
การควบคุมจัดการเอกสารให้มีประสิทธิภาพในการจัดการของเสียจากการก่อสร้าง (จำนวน ชนิด ฯลฯ)					
มีการศึกษารายละเอียดและมีความเข้าใจอย่างถ่องแท้เกี่ยวกับข้อกำหนดและแบบรายละเอียด					
การจัดการคุณภาพระดับมืออาชีพและการรับรอง (เช่น ISO, GREEN เป็นต้น)					
เก็บบันทึกบทเรียนจากการเรียนรู้เกี่ยวกับการจัดการของเสียจากการก่อสร้าง					
การป้องกันข้อผิดพลาดในการจัดทำรายละเอียดของงานก่อสร้าง					
ลดการเปลี่ยนแปลงแก้ไขการออกแบบระหว่างการก่อสร้าง					
ลดการใช้คำสั่งเปลี่ยนแปลงงาน Variation Order หรือ VO (ใบลดงาน หรือใบเพิ่มงาน)					
คุณสมบัติอื่น ๆ : นอกเหนือจากคุณสมบัติที่กำหนดให้ ท่านสามารถแนะนำคุณสมบัติอื่นๆที่เกี่ยวข้องได้ (ถ้ามี)					

ขอบพระคุณสำหรับการสละเวลาของท่านในการทำแบบสอบถามนี้

APPENDIX 2

QUESTIONNAIRE FOR DATA COLLECTION EFA AND CFA IN ENGLISH, KHMER, AND THAI

AUN/SEED-Net

QUESTIONNAIRE

Attributes Contributing to Better Construction Waste Management in Building Construction

Dear Sir/ Madam,

I would like to seek your input in completing a survey that is part of double Ph.D. degree research that seeks to improve construction waste management (CWM). This double Ph.D. degree research is sponsored by the AUN/SEED-Net Collaborative Education Program (CEP) under the supervision of Assoc. Prof. Dr. Kriengsak PANUWATWANICH (at Sirindhorn International Institute of Technology, Thammasat University) and Assoc. Prof. Dr. Koji MATSUMOTO (at Hokkaido University).

About this survey

The aim of this survey is to assess the significant of attributes contributing to the better performance of CWM. The survey is the phase of the development process of the assessment model for CWM. You have been identified as an expert who can provide valuable input to this survey.

Confidentiality

The information will be used for academic purposes only. All information collected will be stored securely, and you will not be identified at any point in this research. Any reporting or summaries derived from the data will be presented in an aggregated form, without any individual identification or specific answers.

Questionnaire structure

This questionnaire contains three pages and consists of two main parts. Part I: Background of you and your company. Part II: Rating the effect level of attributes on the better performance of construction waste management.

Duration of the survey

The survey takes approximately 15 minutes to complete, and it would be very much appreciated if you could kindly finish it on or before **31st August 2023**.

The research team would be most grateful for your time and consideration in contributing to this research.

Please direct any inquiries about this research to:

Mr. Vuthea MIN (Doctoral Researcher), Email: minvuthea@gmail.com, Cell No.: +66-905909078

Thanks, and regards,

16th August 2023

Vuthea MIN	**Assoc. Prof. Dr. Kriengsak PANUWATWANICH**	**Assoc. Prof. Dr. Koji MATSUMOTO**
SIIT, Thammasat University, Thailand, and Hokkaido University, Japan	SIIT, Thammasat University, Thailand	Hokkaido University, Japan

QUESTIONNAIRE

Part I: Background Information

Note: Respondents are expected to have a minimum of approximately 1 year experience as a contractor (this experience could be at any point in your entire career)

Please provide the necessary information.

1.1) Country where your company located:

☐ Cambodia ☐ Thailand

1.2) Your current position within your company: (Please tick only one option that best describes your position.)

☐ Owner/ Executive
☐ Project Manager (PM)
☐ Senior staff
☐ Staff
☐ Other (please specify): _______________

1.3) Your current professional role within your company:

☐ Engineer
☐ Architect
☐ Other (please specify): _______________

1.4) Your highest level of education:

☐ Vocational training/diploma or lower
☐ Bachelor's degree
☐ Master's degree or higher
☐ Other (please specify): _______________

1.5) Your years of experience in the construction industry:

☐ Below 5 ☐ 5-10 ☐ 11-20 ☐ 21-30 ☐ Over 30

1.6) Your years of experience working as contractor(s): (Note: Contractor means main contractor/ general contractor/ contractor, but exclude sub-contractor)

☐ Below 5 ☐ 5-10 ☐ 11-20 ☐ 21-30 ☐ Over 30

1.7) Your years of experience working in building construction project(s):

☐ Below 5 ☐ 5-10 ☐ 11-20 ☐ 21-30 ☐ Over 30

1.8) To what extent have you been involved in construction waste management (CWM) throughout your experience in building construction projects? (e.g., participated in CWM activities at the project site, discussed CWM in meetings, taken steps to minimize material usage, etc.)

☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always

1.9) Your professional qualification(s): (Tick as appropriate, multiple options are applicable):

☐ Professional Engineer (PE)
☐ ACPE/ APEC Engineer
☐ Professional Architect
☐ Project Management Professional (PMP)
☐ TREES/ LEED
☐ None
☐ Other (please specify): _______________

Part II: Rating the Effect Level of Attributes on the Better Performance of Construction Waste Management

To the best of your knowledge and experience, please rate (✓) the level of effect that each of the following ***attributes has on improving the performance of construction waste management (CWM) in building construction.***

Note: **1:** No effect; **2:** Minor effect; **3:** Moderate effect; **4:** Significant effect; **5:** Very significant effect.

Attributes	Effect level				
	1	2	3	4	5
A) Management and leadership					
A1: Effective site management					
A2: Effective communication with all stakeholders					
A3: Senior management's commitment to implementing waste management (WM) practices					
A4: Implementing an effective organizational structure for WM					
A5: Supervision of WM activities with clear instructions					
A6: Properly following a WM plan					
A7: Monitoring and auditing waste management systems periodically (e.g., every 3 months)					
B) Manpower					
B1: Having enough skilled workers in every project					
C) Policy and strategy					
C1: Establishment of a strict CWM policy within the company (including the CWM system)					
C2: Establishment of an appropriate WM plan in the earlier stage of each construction project					
C3: Setting a “Waste Reduction Target” for every project by maximizing the reduction of materials usage (e.g., reducing wastage from 15% to 10% of all materials usage)					
C4: Including subcontractor responsibilities for WM targets in the contract					
C5: Offering incentives for waste minimization efforts to the project team (e.g., money, certificate)					
C6: Preventing site accidents (e.g., fires and deaths causing material waste and project delays)					
D) Materials					
D1: Precise material purchasing (i.e., preventing order errors, right sizes and quantities)					
D2: On-time and accurate quantification of materials/bills of quantities					
D3: Using quality, durable, and standardized materials (i.e., according to specification)					
D4: Adopting Just in Time delivery (JIT) system					
D5: Adequate protection of material transportation and handling (loading and unloading)					
D6: Precise on-site material control (e.g., inspecting the materials when they arrive, etc.)					
D7: Adequate protection of different categories of materials during storing and stacking					
D8: High level of security at the project site (i.e., prevent theft and loss of materials)					
E) Equipment or tools					
E1: Ensuring the availability of equipment required for every project (i.e., tools, machines, and vehicles)					
E2: Ensuring the quality of all equipment to be used in every project					
E3: Be familiar with the usage of all equipment (i.e., persons in charge)					
E4: Utilizing scaffolding and formwork that can be reused many times (e.g., metal, plastic, etc.)					
E5: Utilizing Building Information Modeling (BIM) for the project and be familiar with its application					
E6: Utilizing other related information technologies for the project and be familiar with their application					
F) Construction method and process					
F1: Adequate site space and the site layout are cleared for materials movement					

Attributes	Effect level				
	1	2	3	4	5
F2: Adopting preassembled components such as bathroom and kitchen pods					
F3: Efficient use of materials and minimizing the uneconomical cutting shapes and length					
F4: Implementing proper method statement for each activity, including minimizing waste from application processes					
F5: Minimizing rework at the construction site					
F6: Bins are installed on every floor					
F7: Setting up separated bins according to the waste type and sort out waste at the site					
F8: Storing construction waste in easily accessible areas					
G) Documentation					
G1: Effective document control of CWM, including tracking the amounts and kinds of CW generated					
G2: Detailed study and thorough understanding of specifications and drawings					
G3: Professional quality management and certification (e.g., ISO, GREEN, etc.)					
G4: Keeping lessons learned repository about CWM					
G5: Preventing shop drawing detailing errors (i.e., implementing a proper process check)					
G6: Minimizing design changes during construction					
G7: Minimizing variation orders (VO)					

In case you have any comment or question, please add bellow:

Thank you very much for your valuable time in answering this questionnaire!

AUN/SEED-Net

កម្រងសំណួរ
ប៉ារ៉ាម៉ែត្រ/កត្តាសម្រាប់វាស់ស្ទង់ឬវាយតម្លៃលើប្រសិទ្ធភាពនៃការគ្រប់គ្រងសំណល់សំណង់នៅការដ្ឋានសាងសង់

សូមគោរពជម្រាបសួរ លោក លោកស្រី!

ខ្ញុំបាទសូមគោរពអនុញ្ញាតលោក លោកស្រីមេត្តាជួយឆ្លើយនូវកម្រងសំណួរដែលជាផ្នែកមួយនៃការស្រាវជ្រាវថ្នាក់បណ្ឌិត(Double Ph.D. degree) ដែលជាផ្នែកមួយដើម្បីធ្វើឲ្យប្រសើរឡើងក្នុងការគ្រប់គ្រងសំណល់សំណង់។ គម្រោងស្រាវជ្រាវថ្នាក់បណ្ឌិតនេះគាំទ្រដោយគម្រោងសហប្រតិបត្តិការបច្ចេកទេសរបស់អង្គការទីភ្នាក់ងារសហប្រតិបត្តិការអន្តរជាតិជប៉ុនសម្រាប់បណ្តាញសាកលវិទ្យាល័យអាស៊ាន/បណ្តាញអភិវឌ្ឍ ការអប់រំវិស្វកម្មអាស៊ីភាគអាគ្នេយ៍ (AUN/SEED-Net Collaborative Education Program) ដែលមានសាស្ត្រាចារ្យណែនាំ Assoc. Prof. Dr. Kriengsak PANUWATWANICH មកពីវិទ្យាស្ថាន Sirindhorn International Institute of Technology(SIIT) នៃសាកលវិទ្យាល័យធម្មសាត(Thammasat University) ប្រទេសថៃ និង លោកសាស្ត្រាចារ្យ Assoc. Prof. Dr. Koji MATSUMOTO មកពីសាកលវិទ្យាល័យហុកកៃដូ(Hokkaido University)ប្រទេសជប៉ុន ។

អំពីការស្ទង់មតិនេះ

គោលបំណងនៃការស្ទង់មតិនេះគឺដើម្បីវាយតម្លៃលើប៉ារ៉ាម៉ែត្រឬកត្តានីមួយៗដែលមានឥទ្ធិពលលើប្រសិទ្ធភាពនៃការគ្រប់គ្រងសំណល់សំណង់ ដែលនេះជាផ្នែកមួយដើម្បីបង្កើតម៉ូដែលសម្រាប់វាស់ស្ទង់ឬវាយតម្លៃលើប្រសិទ្ធភាពនៃការគ្រប់គ្រងសំណល់សំណង់។ លោក លោកស្រីត្រូវបានក្រុមការងារជ្រើសរើសជាអ្នកជំនាញដើម្បីផ្តល់ព័ត៌មានសម្រាប់ការស្រាវជ្រាវនេះ ។

ការសម្ងាត់

ព័ត៌មានទាំងនេះនឹងត្រូវប្រើសម្រាប់គោលបំណងសិក្សាស្រាវជ្រាវតែប៉ុណ្ណោះ។ ចម្លើយរបស់អ្នកនឹងត្រូវរក្សាជាការសម្ងាត់បំផុត និង មិនត្រូវបានបង្ហាញអត្តសញ្ញាណឡើយក្នុងការសិក្សាស្រាវជ្រាវនេះ។

រចនាសម្ព័ន្ធនៃកម្រងសំណួរ

កម្រងសំណួរនេះ មានចំនួន៣ទំព័រ ដែលក្នុងនោះមាន២ ផ្នែកសំខាន់ៗ គឺ ផ្នែកទី១៖ ព័ត៌មានមូលដ្ឋាន/សាវតាររបស់អ្នក និងក្រុមហ៊ុនរបស់អ្នក, ផ្នែកទី២៖ ការធ្វើចំណាត់ថ្នាក់ឥទ្ធិពលរបស់ប៉ារ៉ាម៉ែត្រនីមួយៗលើប្រសិទ្ធភាពនៃការគ្រប់គ្រងសំណល់សំណង់។

រយៈពេលនៃការស្ទង់មតិ

ការស្ទង់មតិនេះនឹងត្រូវចំណាយពេលវេលាប្រមាណ ១៥នាទី ដើម្បីបញ្ចប់។ សូមមេត្តាឆ្លើយតបត្រឹមថ្ងៃទី៣១ ខែសីហា ឆ្នាំ២០២៣ នេះ។

យើងខ្ញុំសូមថ្លែងអំណរគុណទុកជាមុន សម្រាប់ការចំណាយពេលវេលា ការយោគយល់ និងចិត្តសប្បុរសរបស់អ្នក ក្នុងការចូលរួមចំណែកដល់ការស្រាវជ្រាវដ៏មានសារៈសំខាន់នេះ!

ក្នុងករណីមានចម្ងល់ ឬអ្វីបន្ថែម សូមទាក់ទងលោក មីន វុទ្ធា (បេក្ខជនបណ្ឌិត) តាមរយៈ Email: minvuthea@gmail.com ឬទូរស័ព្ទលេខ +៦៦-៩០៥៩០៩០៧៨ ។

ដោយក្តីគោរពពីខ្ញុំបាទ

ថ្ងៃទី១៦ ខែសីហា ឆ្នាំ២០២៣

បេក្ខជនបណ្ឌិត	សាស្ត្រាចារ្យណែនាំ	សាស្ត្រាចារ្យណែនាំ
មីន វុទ្ធា	Assoc. Prof. Dr. Kriengsak PANUWATWANICH	Assoc. Prof. Dr. Koji MATSUMOTO
SIIT, Thammasat University, Thailand, and Hokkaido University, Japan	SIIT, Thammasat University, Thailand	Hokkaido University, Japan

កម្រងសំណួរ

ផ្នែកទី១ ៖ ព័ត៌មានមូលដ្ឋាន/សាមីតារ

សំគាល់៖ អ្នកឆ្លើយសំណួរត្រូវបានរំពឹងថាមានបទពិសោធន៍ការងារយ៉ាងតិច១ឆ្នាំនៅក្នុងក្រុមហ៊ុនសាងសង់ (Contractor)ដោយបទពិសោធន៍នេះអាចនៅក្នុងកំឡុងពេលណាមួយនៃអាជីពការងាររបស់របស់អ្នក។

សូមមេត្តាផ្តល់នូវព័ត៌មានដូចខាងក្រោម៖

1.1. ទីតាំងក្រុមហ៊ុនដែលអ្នកកំពុងធ្វើការ៖

☐ ប្រទេសកម្ពុជា ☐ ប្រទេសថៃ

1.2. តួនាទីរបស់អ្នកនៅក្នុងក្រុមហ៊ុន (សូមគូសធីកលើជម្រើសមួយដែលសំខាន់បំផុតអំពីអ្នក)

☐ អគ្គនាយកក្រុមហ៊ុន ឬគណៈគ្រប់គ្រង ☐ បុគ្គលិកទូទៅ

☐ ប្រធានគម្រោង ☐ ផ្សេងទៀត(សូមបញ្ជាក់)________________

☐ បុគ្គលិកជាន់ខ្ពស់/ រៀមច្បង(Senior staff)

1.3. សូមបញ្ជាក់នូវមុខជំនាញវិជ្ជាជីវៈរបស់អ្នក៖

☐ វិស្វករ ☐ ផ្សេងទៀត(សូមបញ្ជាក់)________________

☐ ស្ថាបត្យករ

1.4. កម្រិតអប់រំ/កម្រិតវប្បធម៌របស់អ្នក៖

☐ បរិញ្ញាបត្ររង ឬទាបជាងនេះ ☐ អនុបណ្ឌិត ឬបណ្ឌិត

☐ បរិញ្ញាបត្រ ☐ ផ្សេងទៀត(សូមបញ្ជាក់)________________

1.5. បទពិសោធន៍របស់អ្នកនៅក្នុងឧស្សាហកម្មសំណង់គិតជាឆ្នាំ៖

☐ តិចជាង៥ ☐ ៥-១០ ☐១១-២០ ☐ ២១-៣០ ☐ លើសពី ៣០

1.6. បទពិសោធន៍របស់អ្នកនៅក្នុងក្រុមហ៊ុនម៉ៅការសំណង់(Contractors)គិតជាឆ្នាំ៖

☐ តិចជាង៥ ☐ ៥-១០ ☐១១-២០ ☐ ២១-៣០ ☐ លើសពី ៣០

1.7. បទពិសោធន៍របស់អ្នកនៅក្នុងគម្រោងសាងសង់អគារគិតជាឆ្នាំ៖

☐ តិចជាង៥ ☐ ៥-១០ ☐១១-២០ ☐ ២១-៣០ ☐ លើសពី ៣០

1.8. តើអ្នករួមចំណែកកម្រិតណាក្នុងការងារទាក់ទងនឹងការគ្រប់គ្រងសំណល់សំណង់ក្នុងគម្រោងសាងសង់អគារ? (ឧទាហរណ៍៖ ការរួមចំណែកក្នុងការគ្រប់គ្រងសំណល់សំណង់នៅការដ្ឋាន ឬចូលរួមការប្រជុំដែលពាក់ព័ន្ធនឹងការគ្រប់គ្រងសំណល់សំណង់ ឬការចូលរួមសន្សំសំចៃការប្រើប្រាស់សម្ភារៈសំណង់ ។ល។)

☐មិនដែលសោះ ☐ កម្រណាស់ ☐ម្តងម្កាល ☐ ញឹកញាប់ ☐ ជាប្រចាំ

1.9. សូមបញ្ជាក់នូវវិញ្ញាបនបត្រជំនាញវិជ្ជាជីវៈរបស់អ្នក៖ (អាចគូសធីកលើសពីមួយបាន)

☐ វិស្វករអាជីព(PE)

☐ វិស្វករអាស៊ានឆ្នើម(ACPE) ឬវិស្វករ APEC

☐ ស្ថាបត្យករអាជីព

☐ Project Management Professional (PMP)

☐ TREES/ LEED

☐ គ្មាន

☐ ផ្សេងទៀត (សូមបញ្ជាក់) _______________

ផ្នែកទី២ ៖ ការធ្វើចំណាត់ថ្នាក់ឥទ្ធិពលរបស់ប៉ារ៉ាម៉ែត្រនីមួយៗ លើប្រសិទ្ធភាពនៃការគ្រប់គ្រងសំណល់សំណង់

ដោយយោងទៅតាមបទពិសោធន៍និងចំណេះដឹងរបស់អ្នក សូមវាយតម្លៃដោយគូស(✓)លើកម្រិតនៃឥទ្ធិពលឬភាពសំខាន់នៃប៉ារ៉ាម៉ែត្រ(កត្តា)នីមួយៗទៅលើប្រសិទ្ធភាពនៃការគ្រប់គ្រងសំណល់សំណង់ក្នុងគម្រោងសាងសង់អគារៈ

សំគាល់: ១. គ្មានឥទ្ធិពលសោះ; **២.** មានឥទ្ធិពលតិចតួច; **៣.** មានឥទ្ធិពលមធ្យម; **៤.** មានឥទ្ធិពលខ្លាំង; **៥.** មានឥទ្ធិពលខ្លាំងណាស់

ប៉ារ៉ាម៉ែត្រ/ កត្តា	កម្រិតនៃឥទ្ធិពល				
	១	២	៣	៤	៥
A) គ្រប់គ្រង និងភាពជាអ្នកដឹកនាំ					
A1: ប្រសិទ្ធភាពនៃការគ្រប់គ្រងការដ្ឋានសាងសង់					
A2: ប្រសិទ្ធភាពក្នុងការទំនាក់ទំនងឬសម្របសម្រួលគម្រោងជាមួយភាគីពាក់ព័ន្ធ					
A3: ការតាំងចិត្តក្នុងការងារគ្រប់គ្រងសំណល់សំណង់របស់អ្នកគ្រប់គ្រងការសាងសង់					
A4: ប្រសិទ្ធភាពនៃការធ្វើនិងអនុវត្តតាមរចនាសម្ព័ន្ធនៃការបែងចែកការងារគ្រប់គ្រងសំណល់សំណង់					
A5: ការគ្រប់គ្រងសំណល់សំណង់ជាមួយនឹងភាពច្បាស់លាស់នៃការណែនាំចាត់ចែង					
A6: ការអនុវត្តនូវផែនការគ្រប់គ្រងសំណល់សំណង់យ៉ាងត្រឹមត្រូវ					
A7: ការត្រួតពិនិត្យ និងធ្វើសវនកម្មប្រព័ន្ធគ្រប់គ្រងសំណល់សំណង់ជាទៀងទាត់ (ឧ. រៀងរាល់បីខែម្តង)					
B) ធនធានមនុស្ស ឬកម្លាំងពលកម្ម					
B1: មានបុគ្គលិកកម្មករជំនាញគ្រប់គ្រាន់គ្រប់គម្រោងសាងសង់					
C) គោលនយោបាយ និងយុទ្ធសាស្ត្រ					
C1: ការបង្កើតគោលនយោបាយតឹងរ៉ឹងលើការគ្រប់គ្រងសំណល់សំណង់នៅក្នុងក្រុមហ៊ុន(រួមទាំងប្រព័ន្ធគ្រប់គ្រងសំណល់សំណង់)					
C2: ការបង្កើតផែនការគ្រប់គ្រងកាកសំណល់សំណង់ច្បាស់លាស់មុនចាប់ផ្តើមគម្រោងសាងសង់នីមួយៗ					
C3: ការកំណត់គោលដៅកាត់បន្ថយកាកសំណល់សំណង់នៅគ្រប់គម្រោងសាងសង់ដោយការប្រើប្រាស់សម្ភារៈសំណង់សន្សំសំចៃ (ឧ. កាត់បន្ថយសំណល់សំណង់ពី១៥%មកត្រឹម១០%សម្រាប់គ្រប់សម្ភារៈប្រើប្រាស់)					
C4: ការរួមបញ្ចូលតួនាទីក្រុមហ៊ុនម៉ៅការបន្ទាប់(subcontractor)នៅក្នុងកិច្ចសន្យាក្នុងការទទួលខុសត្រូវលើការគ្រប់គ្រងកាកសំណល់សំណង់					
C5: ការផ្តល់រង្វាន់លើកទឹកចិត្តដល់កិច្ចខិតខំប្រឹងប្រែងកាត់បន្ថយកាកសំណល់សំណង់ដល់ក្រុមការងារគម្រោង					
C6: ការទប់ស្កាត់គ្រោះថ្នាក់នៅការដ្ឋានសាងសង់ (ឧ. អគ្គិភ័យបង្កឲ្យឆេះឬខូចខាតសម្ភារៈ គ្រោះថ្នាក់ស្លាប់បង្កឲ្យមានការពន្យារពេលឬបិទការដ្ឋាន ដែលជាហេតុធ្វើឲ្យសម្ភារៈដែលបញ្ជាទិញហើយខូចខាតឬខ្ជះខ្ជាយ)					
D) សម្ភារៈសំណង់					
D1: ការបញ្ជាទិញសម្ភារៈឲ្យបានត្រឹមត្រូវ (ឧ. ជៀសវាងការបញ្ជាទិញខុស និងត្រូវទិញសម្ភារៈដែលត្រឹមត្រូវទៅតាមខ្នាត ទំហំ និងបរិមាណ)					
D2: ការគណនាបរិមាណសម្ភារៈ (BoQ) ត្រឹមត្រូវ និងទាន់ពេលវេលាសម្រាប់ប្រើប្រាស់					
D3: ការប្រើប្រាស់សម្ភារៈសំណង់ដែលមានគុណភាព និងស្តង់ដា (ដោយយោងទៅតាម Spec)					
D4: ទម្លាប់បញ្ចូលសម្ភារៈមកក្នុងការដ្ឋានតាមតម្រូវការប្រើប្រាស់ដោយមិនទុកគរ ឬស្តុកយូរនៅការដ្ឋាន (JIT)					
D5: ប្រុងប្រយ័ត្នខ្ពស់ក្នុងការដឹកជញ្ជូន និងការលើកដាក់សម្ភារៈជៀសវាងការបាក់បែកឬខូចខាត					
D6: ច្បាស់លាស់ក្នុងការត្រួតពិនិត្យសម្ភារៈនៅការដ្ឋាន (ឧ. ត្រួតពិនិត្យសម្ភារៈនៅពេលដឹកមកដល់ការដ្ឋាន ។ល។)					

ប៉ារ៉ាម៉ែត្រ/ កត្តា	កម្រិតនៃឥទ្ធិពល				
	១	២	៣	៤	៥
D7: ប្រុងប្រយ័ត្នខ្ពស់ក្នុងការលើកដាក់នៅនឹងកន្លែងរក្សាទុកសម្ភារៈនិងទុកដាក់ទៅតាមក្រុមឬប្រភេទរបស់វា					
D8: មានសន្តិសុខតឹងរ៉ឹងនៅការដ្ឋានសាងសង់ (ការពារការលួច និងការបាត់បង់សម្ភារៈ)					
E) គ្រឿងចក្រ ឬឧបករណ៍					
E1: មានគ្រឿងចក្រ យានយន្ត និងឧបករណ៍គ្រប់គ្រាន់ដើម្បីប្រើប្រាស់នៅគ្រប់គម្រោង					
E2: ធានាបាននូវគុណភាពគ្រឿងចក្រ យានយន្ត និងឧបករណ៍ ដែលត្រូវប្រើប្រាស់នៅគ្រប់គម្រោង					
E3: មានភាពស្ទាត់ជំនាញក្នុងការបញ្ជាឬប្រើប្រាស់នូវគ្រប់គ្រឿងចក្រ យានយន្ត និងឧបករណ៍ទាំងអស់					
E4: ប្រើប្រាស់ប្រភេទរន្ទានិងជន្ទល់ដែលអាចប្រើប្រាស់បានច្រើនដង (ឧ. ធ្វើពីដែក ផ្លាស្ទិក។ល។)					
E5: ប្រើប្រាស់កម្មវិធី Building Information Modeling (BIM) សម្រាប់គម្រោង និងមានភាពស្ទាត់ជំនាញក្នុងកម្មវិធីនេះ					
E6: ប្រើប្រាស់កម្មវិធីបច្ចេកវិទ្យាព័ត៌មានពាក់ព័ន្ធផ្សេងទៀតសម្រាប់គម្រោងនិងមានភាពស្ទាត់ជំនាញក្នុងកម្មវិធីទាំងនេះ					
F) វិធីសាស្ត្រ និងដំណើរការសាងសង់					
F1: ទំហំទីតាំងការដ្ឋានធំសមរម្យ និងរៀបចំប្លង់ក្នុងការដ្ឋាន (site layout) ច្បាស់លាស់ដើម្បីមានភាពងាយស្រួលក្នុងការបំលាស់ទីគ្រឿងចក្រ ស្តូចឬលើកដាក់សម្ភារៈ					
F2: ប្រើប្រាស់គ្រឿងសង្ហារិមឬគ្រឿងបង្គុំដែលផ្គុំឬចាក់ហើយស្រាប់ពីរោងចក្រឬរោងជាង តួយ៉ាងដូចជាបន្ទប់ទឹកឬផ្នែកខ្លះនៃចង្ក្រានបាយ					
F3: វាស់ និងកាត់សម្ភារៈមានការប្រុងប្រយ័ត្នខ្ពស់ និងសន្សំសំចៃ					
F4: ភាពច្បាស់លាស់ក្នុងការអនុវត្តការងារនីមួយៗនៅក្នុងការសាងសង់ដោយយោងទៅតាមផែនការលម្អិត (method statement) ដោយព្យាយាមកាត់បន្ថយសំណល់ពីដំណើរការសកម្មភាពការងារទាំងនេះ					
F5: កាត់បន្ថយការវាយចោលនិងធ្វើឡើងវិញនូវផ្នែកផ្សេងៗនៃអគារ ឧ.ចាក់ជណ្តើរខុសរួចវាយចោលនិងធ្វើឡើងវិញ)					
F6: ដាក់ធុងសំរាមគ្រប់ជាន់ក្នុងអគារដែលកំពុងសាងសង់					
F7: បែងចែកធុងសំរាមទៅតាមប្រភេទនៃសំរាមនៅការដ្ឋាន (ដោយបែងចែកសម្រាប់សំណល់សំណង់ផងដែរ)					
F8: ដាក់សំណល់សំណង់នៅទីតាំងដែលងាយស្រួលដាក់ និងដឹកជញ្ជូន					
G)ឯកសារសំណង់					
G1: ការគ្រប់គ្រងឯកសារពាក់ព័ន្ធនឹងសំណល់សំណង់ប្រកបដោយប្រសិទ្ធភាព តួយ៉ាងបច្ចុប្បន្នភាពនៃបរិមាណសំណល់ ប្រភេទសសំណល់ជាដើម					
G2: ការសិក្សាលម្អិត និងហ្មត់ចត់អំពីប្លង់ និងSpec					
G3: ទទួលបាននូវវិញ្ញាបនបត្រស្តង់ដារគុណភាពផ្សេងៗ (ឧ. ISO, GREEN, etc.)					
G4: មានការទុកដាក់និងសិក្សានូវឯកសារដែលជាបទពិសោធន៍ធ្លាប់អនុវត្តកន្លងមកទាក់ទងនឹងការគ្រប់គ្រងសំណល់សំណង់					
G5: ជៀសវាងកំហុសក្នុងការធ្វើប្លង់លម្អិត shop drawing (មានការត្រួតពិនិត្យត្រឹមត្រូវ)					
G6: កាត់បន្ថយការកែប្លង់ឌីស្សាញ (Design drawing) ពេលកំពុងសាងសង់					
G7: កាត់បន្ថយការផ្លាស់ប្តូរឬកែកុនការងារសាងសង់ដែលត្រូវប្រើប្រាស់ថវិកាបន្ថែម (VO)					

ប្រសិនបើអ្នកមានមតិយោបល់ ឬសំណួរបន្ថែម សូមបញ្ជាក់ខាងក្រោម៖

ក្រុមការងារសូមថ្លែងអំណរគុណយ៉ាងជ្រាលជ្រៅចំពោះពេលវេលាដ៏មានតម្លៃរបស់អ្នកក្នុងការឆ្លើយសំណួរនេះ!

ផ្នែកទី២ ៖ ការធ្វើចំណាត់ថ្នាក់ឥទ្ធិពលរបស់ប៉ារ៉ាម៉ែត្រនីមួយៗ លើប្រសិទ្ធភាពនៃការគ្រប់គ្រងសំណល់សំណង់

ដោយយោងទៅតាមបទពិសោធន៍និងចំណេះដឹងរបស់អ្នក សូមវាយតម្លៃដោយគូស(✓)លើកម្រិតនៃឥទ្ធិពលឬភាពសំខាន់នៃប៉ារ៉ាម៉ែត្រ(កត្តា)នីមួយៗទៅលើប្រសិទ្ធភាពនៃការគ្រប់គ្រងសំណល់សំណង់ក្នុងគម្រោងសាងសង់អគារៈ

សំគាល់: **១.** គ្មានឥទ្ធិពលសោះ; **២.** មានឥទ្ធិពលតិចតួច; **៣.** មានឥទ្ធិពលមធ្យម; **៤.** មានឥទ្ធិពលខ្លាំង; **៥.** មានឥទ្ធិពលខ្លាំងណាស់

ប៉ារ៉ាម៉ែត្រ/ កត្តា	កម្រិតនៃឥទ្ធិពល				
	១	២	៣	៤	៥
A) គ្រប់គ្រង និងភាពជាអ្នកដឹកនាំ					
A1: ប្រសិទ្ធភាពនៃការគ្រប់គ្រងការដ្ឋានសាងសង់					
A2: ប្រសិទ្ធភាពក្នុងការទំនាក់ទំនងឬសម្របសម្រួលគម្រោងជាមួយភាគីពាក់ព័ន្ធ					
A3: ការតាំងចិត្តក្នុងការងារគ្រប់គ្រងសំណល់សំណង់របស់អ្នកគ្រប់គ្រងការសាងសង់					
A4: ប្រសិទ្ធភាពនៃការធ្វើនិងអនុវត្តតាមរចនាសម្ព័ន្ធនៃការបែងចែកការងារគ្រប់គ្រងសំណល់សំណង់					
A5: ការគ្រប់គ្រងសំណល់សំណង់ជាមួយនឹងភាពច្បាស់លាស់នៃការណែនាំចាត់ចែង					
A6: ការអនុវត្តនូវផែនការគ្រប់គ្រងសំណល់សំណង់យ៉ាងត្រឹមត្រូវ					
A7: ការត្រួតពិនិត្យ និងធ្វើសវនកម្មប្រព័ន្ធគ្រប់គ្រងសំណល់សំណង់ជាទៀងទាត់ (ឧ. រៀងរាល់បីខែម្តង)					
B) ធនធានមនុស្ស ឬកម្លាំងពលកម្ម					
B1: មានបុគ្គលិកកម្មករជំនាញគ្រប់គ្រាន់គ្រប់គម្រោងសាងសង់					
C) គោលនយោបាយ និងយុទ្ធសាស្ត្រ					
C1: ការបង្កើតគោលនយោបាយតឹងរ៉ឹងលើការគ្រប់គ្រងសំណល់សំណង់នៅក្នុងក្រុមហ៊ុន(រួមទាំងប្រព័ន្ធគ្រប់គ្រងសំណល់សំណង់)					
C2: ការបង្កើតផែនការគ្រប់គ្រងកាកសំណល់សំណង់ច្បាស់លាស់មុនចាប់ផ្តើមគម្រោងសាងសង់នីមួយៗ					
C3: ការកំណត់គោលដៅកាត់បន្ថយកាកសំណល់សំណង់នៅគ្រប់គម្រោងសាងសង់ដោយការប្រើប្រាស់សម្ភារៈសំណង់សន្សំសំចៃ (ឧ. កាត់បន្ថយសំណល់សំណង់ពី១៥%មកត្រឹម១០%សម្រាប់គ្រប់សម្ភារៈប្រើប្រាស់)					
C4: ការរួមបញ្ចូលតួនាទីក្រុមហ៊ុនម៉ៅការបន្ទាប់(subcontractor)នៅក្នុងកិច្ចសន្យាក្នុងការទទួលខុសត្រូវលើការគ្រប់គ្រងកាកសំណល់សំណង់					
C5: ការផ្តល់រង្វាន់លើកទឹកចិត្តដល់កិច្ចខិតខំប្រឹងប្រែងកាត់បន្ថយកាកសំណល់សំណង់ដល់ក្រុមការងារគម្រោង					
C6: ការទប់ស្កាត់គ្រោះថ្នាក់នៅការដ្ឋានសាងសង់ (ឧ. អគ្គិសភ័យបង្កឲ្យឆេះឬខូចខាតសម្ភារៈ គ្រោះថ្នាក់ស្លាប់បង្កឲ្យមានការពន្យារពេលឬបិទការដ្ឋាន ដែលជាហេតុធ្វើឲ្យសម្ភារៈដែលបញ្ជាទិញហើយខូចខាតឬខ្ជះខ្ជាយ)					
D) សម្ភារៈសំណង់					
D1: ការបញ្ជាទិញសម្ភារៈឲ្យបានត្រឹមត្រូវ (ឧ. ជៀសវាងការបញ្ជាទិញខុស និងត្រូវទិញសម្ភារៈដែលត្រឹមត្រូវទៅតាមខ្នាត ទំហំ និងបរិមាណ)					
D2: ការគណនាបរិមាណសម្ភារៈ (BoQ) ត្រឹមត្រូវ និងទាន់ពេលវេលាសម្រាប់ប្រើប្រាស់					
D3: ការប្រើប្រាស់សម្ភារៈសំណង់ដែលមានគុណភាព និងស្តង់ដា (ដោយយោងទៅតាម Spec)					
D4: ទម្លាប់បញ្ចូលសម្ភារៈមកក្នុងការដ្ឋានតាមតម្រូវការប្រើប្រាស់ដោយមិនទុកគរ ឬស្តុកយូរនៅការដ្ឋាន (JIT)					
D5: ប្រុងប្រយ័ត្នខ្ពស់ក្នុងការដឹកជញ្ជូន និងការលើកដាក់សម្ភារៈជៀសវាងការបាក់បែកឬខូចខាត					
D6: ច្បាស់លាស់ក្នុងការត្រួតពិនិត្យសម្ភារៈនៅការដ្ឋាន (ឧ. ត្រួតពិនិត្យសម្ភារៈនៅពេលដឹកមកដល់ការដ្ឋាន ។ល។)					

ប៉ារ៉ាម៉ែត្រ/ កត្តា	កម្រិតនៃឥទ្ធិពល				
	១	២	៣	៤	៥
D7: ប្រុងប្រយ័ត្នខ្ពស់ក្នុងការលើកដាក់នៅនឹងកន្លែងរក្សាទុកសម្ភារៈនិងទុកដាក់ទៅតាមក្រុមឬប្រភេទរបស់វា					
D8: មានសន្តិសុខតឹងរ៉ឹងនៅការដ្ឋានសាងសង់ (ការពារការលួច និងការបាត់បង់សម្ភារៈ)					
E) គ្រឿងចក្រ ឬឧបករណ៍					
E1: មានគ្រឿងចក្រ យានយន្ត និងឧបករណ៍គ្រប់គ្រាន់ដើម្បីប្រើប្រាស់នៅគ្រប់គម្រោង					
E2: ធានាបាននូវគុណភាពគ្រឿងចក្រ យានយន្ត និងឧបករណ៍ ដែលត្រូវប្រើប្រាស់នៅគ្រប់គម្រោង					
E3: មានភាពស្ទាត់ជំនាញក្នុងការបញ្ជាឬប្រើប្រាស់នូវគ្រប់គ្រឿងចក្រ យានយន្ត និងឧបករណ៍ទាំងអស់					
E4: ប្រើប្រាស់ប្រភេទរន្ទានិងជន្ទល់ដែលអាចប្រើប្រាស់បានច្រើនដង (ឧ. ធ្វើពីដែក ផ្លាស្ទិក។ល។)					
E5: ប្រើប្រាស់កម្មវិធី Building Information Modeling (BIM) សម្រាប់គម្រោង និងមានភាពស្ទាត់ជំនាញក្នុងកម្មវិធីនេះ					
E6: ប្រើប្រាស់កម្មវិធីបច្ចេកវិទ្យាព័ត៌មានពាក់ព័ន្ធផ្សេងទៀតសម្រាប់គម្រោងនិងមានភាពស្ទាត់ជំនាញក្នុងកម្មវិធីទាំងនេះ					
F) វិធីសាស្ត្រ និងដំណើរការសាងសង់					
F1: ទំហំទីតាំងការដ្ឋានធំសមរម្យ និងរៀបចំប្លង់ក្នុងការដ្ឋាន (site layout) ច្បាស់លាស់ដើម្បីមានភាពងាយស្រួលក្នុងការបំលាស់ទីគ្រឿងចក្រ ស្ទួចឬលើកដាក់សម្ភារៈ					
F2: ប្រើប្រាស់គ្រឿងសង្ហារិមឬគ្រឿងបង្គុំដែលផ្គុំឬចាក់ហើយស្រាប់ពីរោងចក្រឬរោងជាង តួយ៉ាងដូចជាបន្ទប់ទឹកឬផ្នែកខ្លះនៃចង្ក្រានបាយ					
F3: វាស់ និងកាត់សម្ភារៈមានការប្រុងប្រយ័ត្នខ្ពស់ និងសន្សំសំចៃ					
F4: ភាពច្បាស់លាស់ក្នុងការអនុវត្តការងារនីមួយៗនៅក្នុងការសាងសង់ដោយយោងទៅតាមផែនការលម្អិត (method statement) ដោយព្យាយាមកាត់បន្ថយសំណល់ពីដំណើរការសកម្មភាពការងារទាំងនេះ					
F5: កាត់បន្ថយការវាយចោលនិងធ្វើឡើងវិញនូវផ្នែកផ្សេងៗនៃអគារ ឧ.ចាក់ជណ្តើរខុសរួចវាយចោលនិងធ្វើឡើងវិញ)					
F6: ដាក់ធុងសំរាមគ្រប់ជាន់ក្នុងអគារដែលកំពុងសាងសង់					
F7: បែងចែកធុងសំរាមទៅតាមប្រភេទនៃសំរាមនៅការដ្ឋាន (ដោយបែងចែកសម្រាប់សំណល់សំណង់ផងដែរ)					
F8: ដាក់សំណល់សំណង់នៅទីតាំងដែលងាយស្រួលដាក់ និងដឹកជញ្ជូន					
G)ឯកសារសំណង់					
G1: ការគ្រប់គ្រងឯកសារពាក់ព័ន្ធនឹងសំណល់សំណង់ប្រកបដោយប្រសិទ្ធភាព តួយ៉ាងបច្ចុប្បន្នភាពនៃបរិមាណសំណល់ ប្រភេទសសំណល់ជាដើម					
G2: ការសិក្សាលម្អិត និងហ្មត់ចត់អំពីប្លង់ និងSpec					
G3: ទទួលបាននូវវិញ្ញាបនបត្រស្តង់ដារគុណភាពផ្សេងៗ (ឧ. ISO, GREEN, etc.)					
G4: មានការទុកដាក់និងសិក្សានូវឯកសារដែលជាបទពិសោធន៍ធ្លាប់អនុវត្តកន្លងមកទាក់ទងនឹងការគ្រប់គ្រងសំណល់សំណង់					
G5: ជៀសវាងកំហុសក្នុងការធ្វើប្លង់លម្អិត shop drawing (មានការត្រួតពិនិត្យត្រឹមត្រូវ)					
G6: កាត់បន្ថយការកែប្លង់ឌីស្សាញ (Design drawing) ពេលកំពុងសាងសង់					
G7: កាត់បន្ថយការផ្លាស់ប្តូរឬកែកុនការងារសាងសង់ដែលត្រូវប្រើប្រាស់ថវិកាបន្ថែម (VO)					

ប្រសិនបើអ្នកមានមតិយោបល់ ឬសំណួរបន្ថែម សូមបញ្ជាក់ខាងក្រោម៖

ក្រុមការងារសូមថ្លែងអំណរគុណយ៉ាងជ្រាលជ្រៅចំពោះពេលវេលាដ៏មានតម្លៃរបស់អ្នកក្នុងការឆ្លើយសំណួរនេះ!

AUN/SEED-Net

แบบสอบถาม

ปัจจัยที่ส่งผลต่อการเพิ่มประสิทธิภาพ การจัดการของเสียจากการก่อสร้างในงานก่อสร้างอาคาร

เรียน ท่านผู้ตอบแบบสอบถาม

กระผม นาย Vuthea MIN นักศึกษาปริญญาเอก จากสถาบันเทคโนโลยีนานาชาติสิรินธร มหาวิทยาลัยธรรมศาสตร์ มีความประสงค์ที่จะขอความอนุเคราะห์จากท่านในการกรอกแบบสอบถามเกี่ยวกับปัจจัยที่ส่งผลต่อการเพิ่มประสิทธิภาพการจัดการของเสียจากการก่อสร้าง โดยแบบสอบถามนี้เป็นส่วนหนึ่งของงานวิจัยในหลักสูตรปริญญาเอกที่ได้รับการสนับสนุนจากโครงการความร่วมมือภายใต้เครือข่ายพัฒนาการศึกษาด้านวิศวกรรมศาสตร์ในเอเชียตะวันออกเฉียงใต้ (AUN/SEED-Net Collaborative Education Program) โดยมีอาจารย์ที่ปรึกษาโครงการวิจัยคือ รศ. ดร.เกรียงศักดิ์ ภานุวัฒน์วนิชย์ (สถาบันเทคโนโลยีนานาชาติสิรินธร มหาวิทยาลัยธรรมศาสตร์) และ รศ. ดร.โคจิ มัตสึโมโตะ (มหาวิทยาลัยฮอกไกโด)

เกี่ยวกับแบบสำรวจนี้
แบบสอบถามนี้มีจุดมุ่งหมายเพื่อประเมินความสำคัญของปัจจัยต่าง ๆ ที่ส่งผลต่อการเพิ่มประสิทธิภาพการจัดการของเสียจากการก่อสร้างในงานก่อสร้างอาคาร โดยผลจากการสำรวจนี้จะถูกนำไปวิเคราะห์เพื่อพัฒนาระบบประเมินการจัดการของเสียจากการก่อสร้าง โดยกระผมเห็นว่าท่านมีความเชี่ยวชาญที่สามารถให้ข้อมูลที่เป็นประโยชน์ต่อโครงการวิจัยนี้ได้

การรักษาความลับ
ข้อมูลจากท่านจะถูกใช้เพื่อวัตถุประสงค์ทางวิชาการเท่านั้น โดยข้อมูลทั้งหมดที่รวบรวมได้จะถูกเก็บไว้อย่างเป็นความลับและจะไม่มีกล่าวอ้างถึงตัวตนของท่าน ไม่ว่าในกรณีใด ๆ การรายงานหรือการสรุปผลการศึกษา โดยใช้ข้อมูลเหล่านี้จะถูกนำเสนอในแบบภาพรวม และจะไม่มีการระบุตัวบุคคลหรือคำตอบที่เฉพาะเจาะจงจากผู้ตอบแบบสอบถาม

ข้อมูลแบบสอบถาม
แบบสอบถามนี้มีด้วยกันสามหน้าและประกอบด้วยสองส่วนหลัก ส่วนที่ 1 คือ ข้อมูลภูมิหลังทั่วไปของท่านและบริษัท ส่วนที่ 2 คือ การให้คะแนนปัจจัยที่ส่งผลต่อการจัดการของเสียจากการก่อสร้าง

ระยะเวลาในการทำแบบสอบถาม
แบบสอบถามนี้ใช้เวลาประมาณ 15 นาทีในการตอบคำถาม และจะเป็นพระคุณอย่างยิ่งหากท่านสามารถตอบแบบสอบถามให้แล้วเสร็จได้ภายในวันที่ **31 สิงหาคม 2566**

กระผมขอขอบคุณท่านเป็นอย่างยิ่งที่สละเวลาและการมีส่วนร่วมในการวิจัยนี้ หากท่านมีข้อสงสัยหรือต้องการข้อมูเพิ่มเติม

เกี่ยวกับการวิจัยนี้ สามารถติดต่อกระผมได้ที่:

นาย Vuthea MIN อีเมล: minvuthea@gmail.com เบอร์โทร: +66-905909078

16 สิงหาคม 2566

Vuthea MIN
สถาบันเทคโนโลยีนานาชาติสิรินธร
มหาวิทยาลัยธรรมศาสตร์
ประเทศไทย
และ
มหาวิทยาลัยฮอกไกโด
ประเทศญี่ปุ่น

รศ. ดร.เกรียงศักดิ์ ภานุวัฒน์วานิช
สถาบันเทคโนโลยีนานาชาติสิรินธร
มหาวิทยาลัยธรรมศาสตร์ ประเทศไทย

รศ. ดร.โคจิ มัตสึโมโตะ
มหาวิทยาลัยฮอกไกโด
ประเทศญี่ปุ่น

แบบสอบถาม

ส่วนที่ 1: ข้อมูลทั่วไป

หมายเหตุ: ผู้ตอบแบบสอบถามควรมีประสบการณ์ทำงานในบริษัทผู้รับเหมา (ผู้รับเหมาก่อสร้าง ผู้รับเหมางานสถาปัตยกรรม และ/หรือผู้รับเหมางานระบบ) อย่างน้อยประมาณ 1 ปี (อาจเป็นช่วงเวลาใดก็ได้ในการทำงานของท่าน)

โปรดตอบคำถามต่อไปนี้

1.1) ประเทศที่ตั้งบริษัทของคุณ:
☐ กัมพูชา ☐ ไทย

1.2) ตำแหน่งงานปัจจุบันของท่านในบริษัท: (โปรดทำเครื่องหมายถูกในช่องที่อธิบายถึงตำแหน่งของคุณได้ดีที่สุดเพียงช่องเดียว)
☐ เจ้าของ/ผู้บริหาร
☐ ผู้จัดการโครงการ (PM)
☐ พนักงานอาวุโส
☐ พนักงาน
☐ อื่น ๆ (โปรดระบุ): _______________

1.3) สายงานอาชีพปัจจุบันของท่านภายในบริษัท:
☐ วิศวกร
☐ สถาปนิก
☐ อื่น ๆ (โปรดระบุ): _______________

1.4) ระดับการศึกษาของท่าน:
☐ ปวช./ปวส. หรือต่ำกว่า
☐ ปริญญาตรี
☐ ปริญญาโท หรือสูงกว่า
☐ อื่น ๆ (โปรดระบุ): _______________

1.5) ประสบการณ์ของท่านในอุตสาหกรรมการก่อสร้าง:
☐ ต่ำกว่า 5 ปี ☐ 5-10 ปี ☐ 11-20 ปี ☐ 21-30 ปี ☐ มากกว่า 30 ปี

1.6) ประสบการณ์ของท่านในการทำงานเป็นผู้รับเหมาหรือทำงานในบริษัทผู้รับเหมา: (หมายเหตุ: ผู้รับเหมาในที่นี้หมายถึง ผู้รับเหมาหลัก/ผู้รับเหมาทั่วไป ในงานก่อสร้าง งานสถาปัตยกรรม หรืองานระบบ แต่ไม่รวมถึงผู้รับเหมาช่วง)
☐ ต่ำกว่า 5 ปี ☐ 5-10 ปี ☐ 11-20 ปี ☐ 21-30 ปี ☐ มากกว่า 30 ปี

1.7) ประสบการณ์ของท่านในการทำงานในโครงการก่อสร้างอาคาร:
☐ ต่ำกว่า 5 ปี ☐ 5-10 ปี ☐ 11-20 ปี ☐ 21-30 ปี ☐ มากกว่า 30 ปี

1.8) ตลอดประสบการณ์ของท่านในโครงการก่อสร้าง ท่านมีส่วนร่วมในการจัดการขยะจากการก่อสร้างมากน้อยเพียงใด (เช่น เข้าร่วมในกิจกรรมการจัดการของเสียจากการก่อสร้างในพื้นที่โครงการ หารือเกี่ยวกับการจัดการของเสียจากการก่อสร้างในการประชุม ดำเนินการเพื่อลดการใช้วัสดุ ฯลฯ)
☐ ไม่เคย ☐ น้อยครั้ง ☐ บางครั้ง ☐ บ่อยครั้ง ☐ ประจำ

1.9) คุณวุฒิวิชาชีพของท่าน: (ทำเครื่องหมายถูกได้หลายตัวเลือกตามความเหมาะสม)
☐วิศวกรผู้ได้รับใบอนุญาตประกอบวิชาชีพวิศวกรรมควบคุม (ภาคีวิศวกร สามัญวิศวกร หรือวุฒิวิศวกร)
☐ วิศวกร ACPE/ APEC
☐ สถาปนิกมืออาชีพ
☐ผู้ได้รับใบรับรองการเป็นผู้บริหารโครงการมืออาชีพ (PMP)
☐ TREES/ LEED
☐ ไม่มี
☐ อื่น ๆ (โปรดระบุ): _______________

ส่วนที่ 2: ให้คะแนนต่อปัจจัยที่ส่งผลต่อการปรับปรุงประสิทธิภาพในการจัดการของเสียจากการก่อสร้างในงานก่อสร้างอาคาร

โปรดให้คะแนนโดยทำเครื่องหมาย (✓) เพื่อระบุระดับของปัจจัย**ที่ส่งผลต่อการปรับปรุงประสิทธิภาพในการจัดการของเสียจากการก่อสร้าง (CWM) ในงานก่อสร้างอาคาร** ตามความรู้และประสบการณ์ของท่านที่ผ่านมา

หมายเหตุ: **1:** ไม่ส่งผล; **2:** ส่งผลเล็กน้อย; **3:** ส่งผลปานกลาง; **4:** ส่งผลมาก; **5:** ส่งผลมากที่สุด

คุณลักษณะ	ระดับ				
	1	2	3	4	5
A) การจัดการและความเป็นผู้นำ					
A1: การจัดการพื้นที่โครงการอย่างมีประสิทธิภาพ					
A2: การสื่อสารกับผู้มีส่วนได้ส่วนเสียทั้งหมดอย่างมีประสิทธิภาพ					
A3: ผู้บริหารระดับสูง มีความมุ่งมั่นในการนำแนวปฏิบัติด้านการจัดการของเสียไปใช้					
A4: การนำโครงสร้างองค์กรที่มีประสิทธิภาพมาประยุกต์ใช้กับการจัดการของเสีย					
A5: การกำกับดูแลกิจกรรมการจัดการของเสียพร้อมคำแนะนำที่ชัดเจน					
A6: การทำตามแผนการจัดการของเสียอย่างถูกต้อง					
A7: การติดตามและตรวจสอบระบบการจัดการของเสียเป็นระยะ (เช่น ทุก 3 เดือน)					
B) กำลังคน					
B1: การมีแรงงานฝีมือเพียงพอในทุกโครงการ					
C) นโยบายและกลยุทธ์					
C1: การกำหนดนโยบายการจัดการของเสียจากการก่อสร้างที่เข้มงวดภายในบริษัท (รวมถึงระบบการจัดการของเสียจากงานก่อสร้าง)					
C2: การจัดทำแผนการจัดการของเสียที่เหมาะสมตั้งแต่ขั้นตอนแรก ๆ ของโครงการก่อสร้าง					
C3: การตั้งเป้าหมายการลดของเสียสำหรับทุกโครงการ โดยการลดการใช้วัสดุให้มากที่สุด (เช่น ลดการสูญเสียจาก 15% เป็น 10% ของการใช้วัสดุทั้งหมด)					
C4: ความรับผิดชอบในการจัดการของเสียของผู้รับเหมาช่วงถูกรวมอยู่ในสัญญาก่อสร้าง					
C5: การเสนอสิ่งจูงใจให้แก่ทีมงานในโครงการ เพื่อสร้างความพยายามในการลดของเสียให้เหลือน้อยที่สุด					
C6: การป้องกันอุบัติเหตุในพื้นที่โครงการ					
D) วัสดุ					
D1: การจัดซื้อวัสดุที่ถูกต้อง (เช่น การป้องกันข้อผิดพลาดในการสั่งซื้อ ขนาด และปริมาณที่เหมาะสม)					
D2: การตรวจสอบปริมาณวัสดุ/รายการปริมาณที่ถูกต้องและตรงเวลาสำหรับงานก่อสร้างนั้นๆ					
D3: การใช้วัสดุที่มีคุณภาพ คงทน และได้มาตรฐาน					
D4: การนำ "ระบบทันเวลาพอดี" (Just in Time) มาปรับใช้					
D5: การขนส่งและการขนถ่ายวัสดุอย่างเหมาะสม					
D6: การควบคุมวัสดุในสถานที่ทำงานอย่างถูกต้อง (เช่น การตรวจรับวัสดุเมื่อมาถึง เป็นต้น)					
D7: การป้องกันที่เหมาะสม สำหรับการจัดเก็บและการวางซ้อนวัสดุประเภทต่าง ๆ					
D8: การรักษาความปลอดภัยระดับสูงในพื้นที่โครงการ (เช่น ป้องกันการโจรกรรมและการสูญหายของวัสดุ)					
E) อุปกรณ์หรือเครื่องมือ					
E1: การตรวจสอบความพร้อมของอุปกรณ์ที่จำเป็นสำหรับทุกโครงการ					
E2: การตรวจสอบคุณภาพของอุปกรณ์ทั้งหมดให้มั่นใจก่อนที่จะใช้ในทุกโครงการ					
E3: ผู้ปฏิบัติงานมีความคุ้นเคยกับการใช้อุปกรณ์ที่เกี่ยวข้อง					
E4: การใช้นั่งร้านและแบบหล่อที่สามารถนำกลับมาใช้ใหม่ได้หลายครั้ง (เช่น โลหะ พลาสติก เป็นต้น)					
E5: การใช้เทคโนโลยีแบบจำลองสารสนเทศอาคาร (BIM) และทำความคุ้นเคยกับการใช้งาน					
E6: การใช้เทคโนโลยีสารสนเทศอื่น ๆ ที่เกี่ยวข้องสำหรับโครงการและทำความคุ้นเคยกับการใช้งาน					
F) วิธีการและขั้นตอนการก่อสร้าง					
F1: การมีพื้นที่โครงการที่เพียงพอและแผนผังโครงการที่เหมาะสมต่อการเคลื่อนย้ายวัสดุ					
F2: การใช้ระบบก่อสร้างแบบสำเร็จรูป หรือแบบประกอบสำเร็จ					
F3: การใช้วัสดุอย่างคุ้มค่า รวมถึงวิธีการตัดวัสดุเพื่อลดการสูญเสีย					
F4: การปฏิบัติตามวิธีการก่อสร้างที่เป็นมาตรฐาน					
F5: การลดการทำงานซ้ำในพื้นที่ก่อสร้างให้เหลือน้อยที่สุด					
F6: การติดตั้งถังขยะในทุกชั้น					
F7: การตั้งถังขยะแบบแยกประเภทและการคัดแยกขยะในพื้นที่โครงการ					
F8: การจัดเก็บของเสียจากการก่อสร้างในพื้นที่ที่เข้าถึงได้ง่าย					
G) เอกสาร					

คุณลักษณะ	ระดับ				
	1	2	3	4	5
G1: การมีเอกสารควบคุมการจัดการของเสียจากการก่อสร้างอย่างมีประสิทธิภาพ รวมถึงการติดตามจำนวนและชนิดของของเสียจากการก่อสร้างที่เกิดขึ้น					
G2: การศึกษารายละเอียดและมีความเข้าใจอย่างถ่องแท้เกี่ยวกับข้อกำหนดและแบบแปลน					
G3: การจัดการคุณภาพในระดับมืออาชีพและการได้รับการรับรอง (เช่น มาตรฐาน ISO)					
G4: การจัดเก็บเอกสารการจัดการของเสียจากการก่อสร้างเพื่อใช้เป็นบทเรียนในอนาคต					
G5: การป้องกันข้อผิดพลาดในการจัดทำแบบก่อสร้าง					
G6: การลดการแก้ไขการออกแบบระหว่างการก่อสร้าง					
G7: การลดคำสั่งเปลี่ยนแปลงงาน (Variation Order)					

หากท่านมีความคิดเห็นหรือคำถามใด ๆ โปรดระบุไว้ด้านล่าง:

____

ขอบคุณอย่างยิ่งที่ท่านสละเวลาอันมีค่าในการตอบแบบสอบถามนี้

APPENDIX 3

INPUT DATA FROM EXPERT VERIFICATION PROCESS (32 SETS)

Sets/ Q	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	2.10	2.11	2.12	2.13	2.14	2.15	2.16	2.17	2.18	2.19	2.20	2.21	2.22	2.23	2.24	2.25
1	1	1	2	2	2	2	1	1	1	5	4	4	5	5	4	4	5	4	5	5	5	4	5	3	4	2	5	5	5	5	4	4	4	4
2	1	1	3	2	2	1	1	2	1	5	4	5	4	4	5	5	4	4	5	5	5	4	4	5	4	4	5	5	5	4	5	5	4	5
3	2	3	2	1	1	1	1	1	2	5	4	5	5	4	5	5	3	4	3	5	5	3	5	4	5	4	5	5	3	4	3	4	5	4
4	1	1	3	1	1	1	1	2	1	4	5	5	5	5	5	5	5	4	5	5	5	4	5	4	5	5	5	5	4	4	5	4	4	5
5	2	4	3	3	2	1	2	1	3	5	5	5	5	5	5	5	3	3	4	5	4	5	5	5	4	5	5	5	5	5	5	4	5	5
6	2	2	2	3	3	1	2	5	1	5	4	3	3	3	3	3	4	3	4	4	3	3	4	4	3	4	3	3	4	5	4	4	4	3
7	2	6	2	2	1	1	1	2	4	3	3	4	4	4	4	4	5	3	3	4	3	4	4	4	3	3	5	5	4	4	4	5	4	5
8	2	4	2	2	2	1	1	1	3	4	5	4	3	4	4	3	3	4	3	4	4	4	3	3	3	3	5	4	5	4	4	4	4	4
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13	2	1	2	3	3	1	1	1	2	5	5	4	5	4	5	5	5	5	5	5	4	4	5	5	4	4	5	5	4	4	5	4	4	5
14	1	8	1	2	2	1	5	2	4	2	4	5	3	4	4	4	5	4	5	4	5	3	5	5	5	5	4	4	3	4	4	4	3	2
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31	1	1	2	5	3	3	1	1	4	5	5	4	4	4	4	4	4	4	4	5	5	4	4	4	4	3	5	5	4	4	5	5	4	4
32	2	6	2	2	1	1	5	1	2	4	3	5	5	3	4	4	3	5	5	5	5	3	5	5	3	3	5	5	5	5	3	5	3	5

Sets/ Q	2.26	2.27	2.28	2.29	2.30	2.31	2.32	2.33	2.34	2.35	2.36	2.37	2.38	2.39	2.40	2.41	2.42	2.43	2.44	2.45	2.46	2.47	2.48	2.49	2.50	2.51	2.52	2.53	2.54	2.55	2.56
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2	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4	5	5	5	5	5	5	4	5	5	5	5	5	5
3	4	3	3	4	4	5	5	3	4	3	5	3	3	5	3	3	3	2	2	1	2	3	5	3	5	3	5	3	3	1	1
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11	3	3	5	3	5	5	4	4	5	4	4	4	4	3	5	5	4	4	3	3	3	3	4	3	4	4	5	4	3	3	3
12	5	5	5	4	4	5	5	4	5	5	4	5	4	5	4	5	4	4	5	5	5	4	5	5	4	5	5	4	4	5	5
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14	5	5	3	4	4	3	5	4	3	4	3	4	4	4	4	2	3	3	5	5	5	1	4	1	4	5	2	4	5	5	2
15	3	3	4	4	3	4	3	3	4	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
16	5	5	5	4	5	5	5	5	5	5	5	5	5	4	4	4	4	4	4	5	5	5	5	5	5	5	4	5	5	4	3
17	5	5	3	4	5	3	1	4	3	5	5	5	5	4	4	3	4	4	5	5	5	5	5	5	5	5	5	5	5	5	3
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19	4	3	3	3	4	4	4	4	3	4	3	4	4	4	5	3	5	5	5	4	5	4	4	3	5	4	4	4	3	4	4
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21	3	3	3	5	3	3	3	3	3	5	3	4	4	5	4	3	5	5	5	4	4	4	5	4	4	3	5	3	4	4	4
22	3	3	4	3	4	3	3	4	3	2	2	3	4	4	3	3	4	4	4	5	5	2	4	4	3	2	3	3	3	2	2
23	4	4	4	4	3	4	3	4	4	4	4	4	3	4	4	4	4	3	4	5	5	4	4	4	4	4	3	4	4	5	4
24	5	4	5	5	5	5	5	5	4	5	4	5	5	5	5	4	4	5	5	5	5	5	4	5	4	5	4	5	5	5	4
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26	5	5	5	4	3	3	4	4	3	3	3	3	5	2	2	3	4	3	4	4	5	3	5	5	4	4	4	5	5	5	4
27	5	5	5	4	5	5	4	5	4	4	4	4	4	3	3	4	3	4	4	4	4	4	3	4	3	4	4	4	4	4	4
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29	5	5	4	4	4	4	4	4	4	4	4	4	3	3	4	4	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4
30	4	5	4	2	4	4	3	4	4	4	4	4	5	3	3	4	4	4	4	4	5	5	5	4	4	4	4	4	4	3	3
31	4	4	4	4	4	3	3	3	3	4	4	4	4	3	3	4	4	4	3	4	4	4	4	4	4	4	4	4	4	4	4
32	5	5	3	4	4	4	5	4	3	4	4	5	5	5	5	4	2	2	5	5	5	2	3	4	4	5	3	3	5	4	4

APPENDIX 4

INPUT DATA FROM RESPONDENTS FOR EFA AND CFA (304 SETS)

Sets/ Q	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	A1	A2	A3	A4	A5	A6	A7	B1	C1	C2	C3	C4	C5	C6	D1	D2	D3	D4	D5	D6	D7	D8	E1	E2	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	F7	F8	G1	G2	G3	G4	G5	G6	G7
1	1	3	1	3	1	1	1	4	6	4	3	4	4	4	4	4	4	4	3	4	4	4	4	2	2	3	4	3	2	2	2	2	4	2	2	1	2	3	3	2	4	4	3	3	4	2	2	3	3	2	3	2
2	1	1	1	2	1	1	1	5	5	5	4	4	4	4	4	3	5	4	3	4	4	3	4	4	4	4	4	5	4	4	4	4	5	5	5	4	4	4	4	4	4	5	4	3	5	4	4	4	3	4	5	4
3	1	2	1	2	2	2	2	5	1	5	4	4	4	4	4	5	4	4	4	4	3	4	4	5	5	4	2	4	3	3	3	3	3	4	4	3	4	4	3	4	4	4	3	3	4	3	3	3	3	4	4	2
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5	1	2	1	3	2	2	1	4	4	4	4	5	3	2	3	3	2	4	4	3	2	1	4	4	3	3	3	4	3	3	4	3	3	4	4	4	4	3	3	3	3	5	3	3	3	3	3	3	3	4	4	2
6	1	3	1	3	2	2	2	4	6	5	5	5	5	5	5	5	5	4	3	5	5	5	5	5	5	5	5	5	5	5	3	5	5	5	5	5	5	4	4	4	4	5	5	4	4	4	4	4	3	3	3	3
7	1	4	1	3	1	1	1	2	6	4	3	4	3	4	4	5	3	4	4	3	4	4	4	3	4	4	3	4	4	4	4	4	3	4	4	4	3	4	3	4	4	4	3	3	3	4	4	4	4	3	3	3
8	1	3	1	2	4	3	2	3	1	4	4	5	4	4	4	4	4	5	5	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4	5	5	4	4	4	4	4	4	4	5	1	1
9	1	3	1	3	1	1	1	2	6	4	3	2	3	2	4	4	4	4	3	3	3	3	3	4	5	4	3	4	3	3	3	3	3	4	4	4	4	4	3	3	4	4	4	4	3	3	4	3	4	4	5	4
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12	1	1	1	2	3	2	3	2	1	3	4	4	4	3	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5
13	1	4	1	2	1	1	1	3	6	3	4	3	3	3	3	2	4	3	3	3	3	3	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	3	3	4	4	4	3	3	3	4	3	3	3	3	4	3
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247	2	4	1	2	5	3	3	3	1	5	5	5	5	5	4	4	5	5	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
248	2	4	1	2	1	1	1	1	1	4	4	5	4	4	4	4	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
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251	2	4	1	2	1	1	1	4	1	4	3	3	3	3	3	3	3	3	2	2	1	1	5	5	4	3	2	3	5	4	5	5	5	5	5	3	5	3	3	3	5	3	1	3	3	3	3	2	3	3	5	5
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258	2	1	1	3	2	2	2	3	1	5	5	5	4	5	5	5	5	5	5	5	5	5	3	3	4	5	3	4	4	5	3	5	4	5	5	3	3	4	5	5	4	4	5	5	5	4	4	4	5	5	5	5
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261	2	4	3	2	1	1	1	1	6	4	3	3	4	4	4	3	4	3	3	4	5	3	5	4	3	4	4	4	3	4	4	4	3	3	4	4	3	3	4	4	3	2	4	2	3	3	3	5	4	4	2	4
262	2	1	1	3	5	2	5	4	1	4	3	4	3	4	3	3	3	4	4	5	4	4	4	4	4	4	3	4	4	3	4	4	4	4	4	3	3	4	4	5	5	4	4	4	4	4	5	4	4	4	4	3
263	2	1	1	3	5	4	5	4	1	5	5	3	3	3	3	3	3	3	3	2	2	2	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
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265	2	4	3	3	1	1	1	1	1	5	5	5	5	5	5	5	3	5	5	3	5	3	5	5	5	5	5	5	5	5	3	5	5	5	3	5	5	5	3	4	5	5	5	5	5	5	5	3	5	5	5	5
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269	2	4	1	3	3	1	1	2	1	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
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Sets/Q	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	A1	A2	A3	A4	A5	A6	A7	B1	C1	C2	C3	C4	C5	C6	D1	D2	D3	D4	D5	D6	D7	D8	E1	E2	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	F7	F8	G1	G2	G3	G4	G5	G6	G7
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APPENDIX 5

Z-SCORE TEST

Z-Score test: Pecentage of |Z| score >3.29

Sets	A1	A2	A3	A4	A5	A6	A7	B1	C1	C2	C3	C4	C5	C6	D1	D2	D3	D4	D5	D6	D7	D8	E1	E2	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	F7	F8	G1	G2	G3	G4	G5	G6	G7
1	0.1	1.3	0.0	0.2	0.0	0.0	0.3	0.1	0.2	0.9	0.4	0.2	0.3	0.0	2.6	2.3	1.2	0.2	1.1	2.1	2.3	1.9	2.3	0.3	2.1	2.6	2.3	1.7	1.4	0.6	2.5	0.0	0.0	0.7	0.6	0.1	1.9	2.4	0.6	0.8	2.1	0.9	1.8
2	1.1	0.0	0.0	0.2	0.0	0.0	0.7	1.3	0.2	0.9	0.4	0.2	0.6	0.0	0.1	0.1	0.0	0.2	1.3	0.1	0.1	0.2	0.1	1.5	1.4	1.2	0.4	0.5	0.1	0.4	0.0	0.0	1.2	0.4	0.6	1.3	0.4	0.0	0.4	0.8	0.1	1.3	0.3
3	1.1	0.0	0.0	0.2	0.0	0.0	1.3	0.1	0.2	0.2	0.4	0.9	0.3	0.0	1.1	1.0	0.0	2.0	0.1	1.0	1.1	0.9	1.1	0.9	0.2	0.1	0.5	0.5	0.1	0.6	0.0	0.0	0.0	0.7	0.6	0.1	0.8	1.2	0.6	0.8	0.1	0.2	1.8
4	0.1	0.0	0.0	0.2	0.0	0.0	0.3	0.1	0.2	0.2	0.4	0.2	0.3	0.0	0.1	0.1	0.0	0.9	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.5	0.6	1.4	0.6	0.0	0.0	0.0	0.7	0.6	1.1	0.8	0.0	0.6	0.8	0.1	0.2	0.3
5	0.1	0.0	1.2	1.0	2.2	1.1	0.7	2.3	0.2	0.2	0.8	2.0	2.6	0.0	0.1	1.2	1.2	0.9	0.1	1.0	1.1	0.2	1.1	0.9	0.2	0.1	0.4	0.5	1.4	0.6	1.3	1.2	1.2	0.7	0.6	1.1	0.8	1.2	0.6	0.8	0.1	0.2	1.8
6	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	0.2	0.9	1.5	1.2	1.3	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	0.9	1.3	1.5	1.4	1.2	1.3	1.6	0.1	0.4	0.0	0.0	1.2	1.5	0.4	0.1	0.4	0.0	0.4	0.8	1.0	0.9	0.8
7	0.1	1.3	0.0	1.0	0.0	0.0	1.3	1.1	0.2	0.2	0.8	0.2	0.3	0.0	1.4	0.1	0.0	0.9	0.1	0.1	0.1	0.2	0.1	0.9	0.2	0.1	0.4	0.6	0.1	0.6	0.0	0.0	0.0	0.7	0.6	1.1	0.4	0.0	0.4	0.4	1.0	0.9	0.8
8	0.1	0.0	1.2	0.2	0.0	0.0	0.3	0.1	1.3	1.3	0.4	1.2	1.3	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	1.3	1.6	1.3	0.4	0.0	1.3	1.2	0.4	0.4	0.1	0.4	0.0	0.4	0.4	1.2	3.0	2.8
9	0.1	1.3	2.2	1.0	2.2	0.0	0.3	0.1	0.2	0.9	0.8	0.9	0.6	1.1	0.1	1.0	0.0	0.9	0.1	1.0	1.1	0.9	1.1	0.9	0.2	0.1	0.4	0.5	0.1	0.6	1.3	0.0	0.0	0.4	0.4	1.1	0.8	0.0	0.6	0.4	0.1	1.3	0.3
10	1.1	0.0	1.1	2.2	2.2	2.3	1.7	2.3	2.1	2.1	0.8	0.9	0.3	0.0	0.1	1.0	1.2	0.2	1.3	0.1	0.1	0.2	0.1	0.3	0.9	0.1	1.4	0.5	0.1	1.6	0.0	0.0	0.0	0.4	1.5	0.1	0.8	0.0	0.6	1.9	0.1	0.9	0.3
11	1.3	1.3	2.2	2.2	2.2	2.3	0.7	1.1	0.9	0.9	0.4	2.0	1.6	0.0	0.1	3.4	0.0	0.9	0.1	0.1	0.1	0.9	1.1	0.9	2.1	1.3	2.3	1.7	2.8	0.6	0.0	0.0	1.2	0.7	0.6	0.1	0.4	1.2	0.6	0.8	0.1	0.9	0.8
12	1.3	0.0	0.0	0.2	1.1	0.0	0.7	0.1	0.2	0.2	0.4	0.2	0.3	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.4	0.0	0.4	0.4	0.1	1.3	1.3
13	1.3	0.0	1.1	1.0	1.1	1.1	1.7	0.1	0.9	0.9	0.8	0.9	0.6	1.1	1.4	1.2	1.2	0.9	1.1	1.0	0.1	0.9	1.1	0.9	0.9	1.3	0.5	0.6	1.4	0.6	0.0	0.0	0.0	0.7	0.6	1.1	0.4	1.2	0.6	0.8	1.0	0.2	0.8
14	1.1	1.2	1.2	1.3	1.1	1.1	1.3	0.1	1.3	1.3	0.4	1.2	0.3	1.1	1.1	1.0	1.2	1.4	0.1	1.2	0.1	1.2	1.3	1.5	1.4	1.2	1.3	1.6	0.1	1.5	1.3	0.0	0.0	0.4	0.4	1.3	1.5	1.2	0.4	0.4	0.1	1.3	0.3
15	0.1	1.2	0.0	0.2	1.1	0.0	0.3	0.1	0.2	0.2	0.4	0.9	0.6	1.1	0.1	0.1	1.2	0.2	0.1	0.1	0.1	0.2	1.3	0.9	0.2	1.3	0.4	0.5	0.1	1.6	1.3	1.2	0.0	0.7	0.6	0.1	0.4	1.2	0.4	0.4	0.1	0.9	0.8
16	1.3	1.3	1.1	2.2	2.2	1.1	1.7	1.1	0.9	0.9	0.8	0.9	1.6	1.1	1.4	1.2	1.2	0.9	1.1	1.0	1.1	0.2	0.1	0.3	0.9	0.1	1.4	0.6	0.1	1.6	1.3	1.2	1.2	0.4	0.6	1.1	1.9	1.2	2.6	0.8	0.1	0.9	0.8
17	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	1.3	1.3	1.5	1.2	1.3	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	1.3	1.6	1.3	1.5	1.3	1.3	1.2	1.5	1.4	1.3	1.5	1.2	1.4	1.5	1.2	1.3	1.3
18	0.1	1.2	1.2	1.3	1.1	1.1	1.7	1.1	1.3	1.3	0.4	0.2	1.3	1.1	1.1	1.0	1.2	0.2	1.1	1.0	1.1	0.9	1.1	0.9	0.9	0.1	0.5	0.6	1.4	0.4	0.0	0.0	1.2	1.5	1.4	1.3	1.5	0.0	0.6	1.5	1.2	0.2	1.3
19	0.1	0.0	1.2	0.2	1.1	0.0	0.7	1.3	0.9	0.2	0.8	1.2	0.6	1.1	2.6	2.3	1.2	0.9	3.5	1.0	2.3	0.2	0.1	0.9	0.2	1.3	1.4	1.7	0.1	1.6	2.5	1.2	0.0	0.4	0.6	1.1	1.9	1.2	0.6	0.8	0.1	0.2	0.8
20	1.3	1.3	1.1	2.2	1.1	2.3	1.7	2.3	0.9	0.9	0.8	2.0	0.6	2.2	2.6	2.3	1.2	2.0	2.3	2.1	2.3	0.9	1.1	2.1	0.9	2.6	1.4	0.6	2.8	0.6	2.5	2.5	2.4	1.8	1.5	2.3	0.8	1.2	0.6	0.8	1.0	0.9	0.8
21	1.1	0.0	0.0	0.2	0.0	0.0	0.7	1.3	0.2	0.9	0.8	0.2	0.3	1.1	0.1	0.1	0.0	0.9	0.1	0.1	0.1	0.9	0.1	0.9	0.2	0.1	0.5	0.5	0.1	0.6	0.0	0.0	1.2	0.4	0.4	1.3	0.4	1.2	1.4	0.4	1.0	0.2	0.3
22	0.1	0.0	0.0	0.2	0.0	0.0	0.3	0.1	0.2	0.2	0.4	0.2	0.3	0.0	0.1	1.0	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	1.3	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3
23	0.1	0.0	1.1	0.2	0.0	0.0	0.3	1.1	0.9	0.2	0.4	0.2	0.3	1.1	1.4	1.2	0.0	0.2	1.1	2.1	2.3	1.9	1.1	0.9	2.1	0.1	1.4	1.7	1.4	0.6	0.0	0.0	0.0	0.4	0.4	0.1	0.8	1.2	0.4	0.8	1.0	0.2	0.3
24	0.1	0.0	0.0	0.2	0.0	0.0	0.7	1.1	0.9	0.9	0.8	0.9	0.6	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.9	1.1	0.9	0.9	1.3	2.3	2.8	1.4	0.6	1.3	1.2	1.2	0.7	0.6	1.1	1.9	1.2	2.6	3.0	2.1	0.9	0.8
25	1.1	0.0	1.2	1.3	1.1	1.1	1.3	0.1	1.3	1.3	0.4	1.2	1.3	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	1.3	1.6	0.1	1.5	0.0	1.3	1.2	1.5	1.4	1.3	1.5	1.2	1.4	1.5	1.2	1.3	1.3
26	0.1	0.0	0.0	1.0	1.1	1.1	1.7	1.1	0.2	1.3	0.4	0.2	0.6	1.1	1.1	1.0	1.2	0.2	0.1	0.1	0.1	1.2	1.3	1.5	1.4	1.2	0.4	1.6	0.1	0.4	0.0	0.0	2.4	1.8	0.4	0.1	0.4	0.0	0.4	0.4	1.2	0.2	0.3
27	1.1	1.2	0.0	0.2	1.1	1.1	0.3	1.3	0.2	0.2	0.4	0.2	0.3	0.0	1.1	1.0	0.0	0.2	0.1	1.2	1.3	1.2	1.3	1.5	0.2	0.1	0.4	0.5	0.1	0.4	0.0	0.0	1.2	0.4	0.6	1.1	0.4	1.2	0.4	0.8	0.1	0.2	0.3
28	1.1	0.0	0.0	1.3	1.1	1.1	0.3	1.3	0.2	0.2	0.4	0.2	0.3	0.0	1.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.5	0.6	1.4	0.4	1.3	0.0	0.0	0.7	0.6	1.3	0.4	1.2	0.6	0.4	1.0	1.9	1.8
29	0.1	0.0	0.0	0.2	1.1	1.1	0.7	0.1	0.9	0.2	0.8	0.2	0.6	0.0	0.1	1.2	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	1.3	0.4	0.5	0.1	0.6	0.0	0.0	0.0	0.7	0.6	0.1	0.8	0.0	0.6	0.4	0.1	0.2	0.3
30	1.3	0.0	1.2	1.3	1.1	1.1	1.3	0.1	1.3	1.3	1.5	1.2	1.3	0.0	0.1	0.1	1.2	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.9	1.2	0.4	0.5	0.1	0.4	0.0	0.0	1.2	1.5	1.4	1.3	0.4	1.2	0.6	1.5	0.1	0.9	0.8
31	0.1	1.3	1.1	0.2	0.0	1.1	1.7	1.1	0.2	0.9	1.5	0.2	1.6	1.1	0.1	1.2	1.2	0.2	1.3	1.2	0.1	0.2	1.1	0.9	0.9	0.1	2.3	0.6	0.1	1.6	0.0	1.2	0.0	0.7	0.6	0.1	0.4	0.0	0.6	0.8	0.1	0.9	1.8
32	0.1	0.0	0.0	0.2	0.0	0.0	0.7	0.1	0.2	0.2	2.0	0.9	0.3	0.0	0.1	0.1	0.0	0.2	0.1	1.0	1.1	0.2	0.1	0.3	0.2	3.9	0.4	0.6	0.1	0.4	0.0	1.2	2.4	1.8	0.6	0.1	1.5	0.0	1.4	1.9	0.1	0.2	0.8
33	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	1.3	1.3	0.4	1.2	0.3	0.0	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	0.4	0.5	1.3	0.6	1.3	1.3	1.2	0.4	1.4	1.3	1.5	1.2	1.4	1.5	1.2	0.2	0.3
34	1.3	0.0	1.1	0.2	0.0	1.1	0.7	1.1	0.9	0.2	2.0	0.2	1.6	0.0	0.1	1.2	1.2	0.2	0.1	0.1	0.1	1.2	1.3	0.9	0.9	0.1	1.3	0.6	1.3	0.6	1.3	1.2	1.2	1.5	1.4	1.1	0.4	0.0	1.6	0.4	0.1	1.9	0.3
35	0.1	1.3	1.1	1.0	0.0	1.1	0.3	0.1	1.3	0.2	0.4	0.9	0.6	0.0	1.4	1.2	1.2	0.2	0.1	1.0	1.1	1.9	2.3	0.9	2.1	1.3	1.4	1.7	1.4	1.6	1.3	0.0	0.0	0.4	0.4	0.1	0.8	1.2	0.6	1.9	1.0	0.9	0.8
36	0.1	1.3	0.0	0.2	0.0	0.0	0.3	1.3	0.2	0.2	1.5	1.2	1.3	1.1	1.1	1.0	1.2	0.2	0.1	1.2	1.3	1.2	0.1	0.3	0.2	1.2	1.3	0.5	1.3	0.4	1.3	1.3	1.2	0.4	0.4	0.1	0.4	0.0	0.4	0.4	1.2	1.3	1.3
37	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	0.2	0.9	0.8	0.2	1.6	1.1	1.4	0.1	1.2	0.2	1.1	1.0	1.1	0.9	0.1	0.9	0.2	1.3	1.4	0.5	1.3	1.6	1.3	0.0	1.2	1.8	1.5	1.1	0.8	1.2	1.6	0.8	1.0	0.2	1.3
38	0.1	0.0	0.0	0.2	0.0	0.0	0.7	0.1	0.9	0.9	0.4	0.9	0.6	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	1.3	0.5	0.6	0.1	0.6	0.0	0.0	0.0	0.7	0.6	1.1	0.8	0.0	0.6	0.8	0.1	0.2	0.3
39	0.1	1.3	0.0	0.2	1.1	1.1	0.7	1.1	0.9	1.3	0.8	0.9	0.6	1.1	1.4	0.1	1.2	0.2	1.1	1.0	1.1	0.9	0.1	0.9	0.9	0.1	0.4	0.5	0.1	0.4	0.0	1.2	0.0	0.4	0.6	0.1	0.8	0.0	0.4	0.4	1.0	0.2	0.3
40	1.1	0.0	1.1	0.2	0.0	0.0	1.3	1.3	0.2	0.2	0.8	1.2	0.3	1.1	0.1	0.1	1.2	1.4	2.3	0.1	1.3	1.2	1.3	1.5	1.4	1.3	0.5	1.6	1.3	0.6	0.0	1.2	0.0	0.7	0.6	0.1	0.8	1.2	0.6	0.8	1.2	1.3	1.3
41	1.3	0.0	0.0	1.3	0.0	0.0	0.7	1.1	0.9	0.9	0.8	0.2	0.3	1.1	0.1	0.1	0.0	0.2	0.1	1.2	0.1	0.2	0.1	0.3	2.1	1.2	0.5	0.6	0.1	0.6	1.3	0.0	0.0	0.4	0.4	0.1	0.8	0.0	1.4	0.4	1.0	0.9	0.8
42	1.3	1.3	1.1	1.0	1.1	1.1	0.7	1.1	0.9	0.9	0.8	0.9	1.6	0.0	0.1	0.1	1.2	0.9	0.1	0.1	1.1	0.9	1.1	0.9	0.2	0.1	0.5	0.6	0.1	0.6	0.0	0.0	1.2	0.4	0.6	1.1	0.8	0.0	0.6	0.8	0.1	0.2	0.3
43	1.1	1.2	0.0	1.3	1.1	0.0	0.3	0.1	1.3	1.3	0.4	1.2	1.3	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	0.2	1.3	1.5	1.4	1.2	0.4	0.5	1.3	0.6	0.0	1.3	1.2	1.5	1.4	1.3	0.4	1.2	0.4	0.8	1.2	1.3	1.3
44	1.3	1.3	0.0	1.0	0.0	1.1	0.7	0.1	0.2	0.9	0.4	0.9	0.3	0.0	0.1	0.1	1.2	0.9	1.1	0.1	0.1	0.2	0.1	0.9	0.9	1.3	0.4	0.5	0.1	0.4	1.3	1.2	0.0	0.4	0.4	0.1	0.4	0.0	0.4	0.8	0.1	0.2	0.3
45	0.1	0.0	1.2	1.0	1.1	1.1	0.7	1.3	1.3	1.3	0.8	1.2	1.6	1.1	2.6	2.3	2.4	0.9	1.1	1.0	1.1	0.9	1.1	0.9	0.9	2.6	1.3	0.5	0.1	1.6	1.3	0.0	0.0	1.8	0.6	1.1	0.8	1.2	0.6	0.8	1.0	0.9	0.8

Z-Score test: Pecentage of |Z| score >3.29

Sets	A1	A2	A3	A4	A5	A6	A7	B1	C1	C2	C3	C4	C5	C6	D1	D2	D3	D4	D5	D6	D7	D8	E1	E2	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	F7	F8	G1	G2	G3	G4	G5	G6	G7
46	0.1	0.0	1.1	1.0	1.1	1.1	1.7	0.1	0.9	0.9	2.0	2.0	1.6	1.1	0.1	0.1	1.2	0.2	0.1	0.1	1.1	0.2	0.1	0.9	0.2	1.3	1.4	0.6	0.1	0.6	0.0	1.2	0.0	1.8	1.5	2.3	1.9	0.0	2.6	1.9	1.0	0.2	0.3
47	0.1	1.2	1.1	1.0	1.1	1.1	0.7	1.3	0.9	0.9	0.4	0.9	0.6	1.1	1.1	1.0	0.0	0.2	1.3	1.2	1.3	1.2	1.3	1.5	1.4	0.1	1.3	1.6	0.1	0.4	1.3	1.3	1.2	0.4	0.6	1.1	1.5	1.2	0.4	0.4	0.1	0.2	0.3
48	1.1	1.2	0.0	0.2	1.1	1.1	1.3	1.1	0.2	0.9	0.8	0.2	0.6	1.1	1.1	1.0	0.0	1.4	0.1	1.0	0.1	0.9	1.1	0.9	0.2	1.2	0.5	0.6	0.1	0.4	1.3	1.3	1.2	0.7	0.6	1.1	1.5	1.2	0.6	0.4	1.2	1.3	0.3
49	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	1.3	1.3	1.5	1.2	1.3	1.1	1.1	1.0	1.2	1.4	1.3	0.1	1.3	1.2	1.3	1.5	1.4	1.2	1.3	1.6	1.3	1.5	1.3	1.3	1.2	0.7	1.4	1.3	1.5	1.2	1.4	1.5	1.2	1.3	1.3
50	0.1	0.0	0.0	0.2	1.1	1.1	0.7	1.1	0.9	0.2	0.4	0.9	0.3	1.1	0.1	0.1	0.0	0.2	1.1	0.1	1.1	0.2	0.1	0.9	0.2	0.1	0.5	0.5	1.4	0.4	1.3	0.0	0.0	0.4	0.4	0.1	0.4	1.2	0.4	0.4	1.0	0.9	0.3
51	1.1	1.2	0.0	1.3	0.0	1.1	1.3	1.3	1.3	0.2	0.4	0.2	1.3	1.1	0.1	1.0	1.2	1.4	0.1	0.1	0.1	0.9	0.1	0.3	0.2	1.2	0.4	0.5	1.4	0.6	0.0	0.0	1.2	0.4	0.4	0.1	0.4	0.0	1.4	1.5	0.1	0.2	0.8
52	0.1	2.5	0.0	1.0	1.1	1.1	0.3	0.1	0.9	0.2	0.8	0.2	1.6	1.1	1.1	1.0	1.2	0.9	2.3	1.2	1.1	0.2	2.3	2.1	2.1	1.3	0.5	0.6	1.4	1.6	0.0	0.0	1.2	0.7	0.6	1.1	0.4	1.2	0.6	0.4	1.2	3.0	2.8
53	0.1	0.0	0.0	0.2	1.1	0.0	0.3	0.1	0.2	0.2	0.4	0.2	0.3	1.1	1.1	1.0	1.2	0.2	0.1	0.1	1.3	0.2	0.1	0.3	1.4	1.2	1.3	0.5	0.1	0.6	0.0	0.0	1.2	0.4	0.6	1.1	0.4	0.0	1.4	1.5	0.1	0.2	1.3
54	0.1	2.5	1.1	0.2	0.0	0.0	0.3	0.1	0.2	0.2	0.4	0.9	0.3	1.1	0.1	0.1	1.2	0.2	1.1	0.1	1.1	0.9	2.3	2.1	2.1	0.1	1.4	0.6	1.4	0.4	0.0	0.0	0.0	0.7	0.4	1.1	0.4	0.0	0.6	0.4	0.1	0.2	0.3
55	0.1	1.3	1.2	1.0	1.1	0.0	0.3	1.1	1.3	0.9	2.0	0.9	0.6	1.1	0.1	1.2	1.2	0.2	1.1	1.0	0.1	1.9	1.1	2.1	0.9	1.2	0.5	0.6	1.3	0.4	0.0	1.2	1.2	1.5	0.4	0.1	0.8	1.2	0.4	0.4	1.0	0.2	0.3
56	1.3	0.0	1.1	1.0	1.1	0.0	0.7	2.3	0.2	0.2	0.4	0.2	0.3	0.0	0.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	0.1	0.3	0.2	0.1	1.3	0.5	0.1	0.4	0.0	1.3	1.2	0.4	0.4	0.1	0.4	0.0	0.4	0.4	1.2	1.3	1.3
57	1.1	1.2	1.1	0.2	0.0	1.1	1.7	1.1	1.3	0.9	3.1	2.0	0.6	1.1	1.4	1.2	3.5	2.0	3.5	3.2	0.1	0.9	1.1	2.1	0.9	0.1	0.5	0.6	1.3	1.5	1.3	0.0	2.4	0.4	2.5	0.1	1.9	2.4	1.4	0.8	2.1	0.9	2.8
58	0.1	0.0	1.1	1.0	1.1	1.1	0.7	0.1	0.9	0.9	0.4	0.9	0.6	0.0	0.1	0.1	0.0	1.4	0.1	0.1	0.1	0.9	1.1	0.9	0.2	1.2	2.3	1.7	0.1	0.6	0.0	0.0	0.0	0.7	0.6	1.1	0.4	0.0	2.6	1.9	0.1	0.9	0.8
59	0.1	0.0	1.1	0.2	0.0	1.1	0.3	0.1	1.3	0.2	0.4	0.2	0.3	0.0	0.1	1.0	0.0	0.2	1.1	1.0	1.1	0.2	0.1	0.3	0.9	1.3	1.3	0.5	0.1	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.8	1.2	0.4	0.4	1.0	0.9	0.8
60	0.1	0.0	0.0	0.2	0.0	1.1	0.7	1.3	0.2	0.9	0.8	0.9	0.6	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	0.4	1.6	1.3	1.5	1.3	1.3	1.2	1.5	1.4	1.3	0.4	1.2	1.4	0.4	1.2	1.3	1.3
61	1.1	1.2	1.2	0.2	0.0	1.1	0.7	0.1	0.2	0.2	0.4	1.2	0.6	0.0	0.1	1.0	0.0	0.9	1.1	1.0	1.1	0.9	0.1	0.3	0.2	0.1	0.5	0.6	1.4	0.6	0.0	0.0	0.0	0.7	1.5	1.1	0.4	0.0	0.4	0.4	0.1	0.9	0.8
62	0.1	1.2	1.1	0.2	0.0	1.1	0.7	1.3	0.9	0.2	1.5	0.2	0.3	1.1	1.1	1.0	0.0	0.9	0.1	0.1	0.1	1.2	1.3	0.3	0.2	1.3	0.5	0.6	0.1	1.6	1.3	0.0	1.2	0.4	0.6	0.1	0.8	1.2	0.6	0.8	0.1	0.9	0.8
63	1.3	0.0	0.0	0.2	0.0	0.0	0.3	0.1	0.2	0.2	0.4	0.2	0.3	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3
64	0.1	0.0	0.0	0.2	1.1	0.0	0.7	0.1	0.2	0.2	0.8	0.2	0.3	0.0	0.1	1.2	1.2	0.9	0.1	1.0	1.1	0.9	0.1	0.3	0.2	0.1	0.4	0.6	0.1	0.6	0.0	0.0	0.0	0.4	0.4	0.1	0.8	1.2	0.6	0.8	1.0	0.9	0.8
65	1.3	1.3	1.2	0.2	0.0	1.1	0.7	1.1	0.9	0.9	0.4	0.9	0.3	0.0	1.1	1.0	1.2	1.4	1.3	1.2	1.3	0.9	0.1	0.9	0.9	0.1	0.5	0.6	0.1	1.5	1.3	1.3	1.2	0.7	0.6	1.3	0.4	0.0	0.4	0.4	1.0	1.3	0.8
66	0.1	0.0	0.0	0.2	0.0	0.0	0.7	0.1	0.2	0.2	0.8	0.9	0.6	1.1	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.5	0.6	1.4	0.6	1.3	0.0	0.0	0.7	0.6	0.1	0.4	1.2	0.6	0.4	0.1	0.2	0.3
67	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	1.3	1.3	0.8	1.2	1.6	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	0.9	1.3	1.5	1.4	1.2	1.3	1.6	1.3	1.6	1.3	1.3	1.2	1.8	1.4	1.3	1.5	1.2	1.4	1.5	1.2	1.3	1.3
68	1.3	1.3	1.1	1.0	1.1	1.1	0.7	1.1	0.9	0.9	0.8	0.9	0.6	1.1	1.4	1.2	1.2	0.9	1.1	1.0	1.1	0.9	1.1	0.9	0.9	1.3	0.5	0.6	1.4	0.6	1.3	1.2	1.2	0.7	0.6	1.1	0.8	1.2	0.6	0.8	1.0	0.9	0.8
69	1.1	1.2	0.0	1.3	1.1	1.1	0.3	1.3	0.2	0.9	0.4	1.2	0.6	0.0	1.1	1.0	1.2	0.2	1.1	1.2	0.1	1.2	0.1	0.9	0.9	1.2	1.3	1.6	1.3	0.4	0.0	1.2	1.2	0.4	0.6	1.1	1.5	1.2	1.4	1.5	1.2	0.9	0.8
70	1.1	1.2	0.0	0.2	0.0	0.0	0.3	1.3	1.3	0.9	0.4	1.2	0.3	1.1	1.1	0.1	1.2	1.4	1.3	0.1	1.1	1.2	1.3	0.3	0.9	1.2	0.5	0.6	1.3	0.6	0.0	0.0	1.2	0.4	1.4	0.1	0.8	1.2	0.4	1.5	1.2	1.3	1.3
71	0.1	0.0	1.1	1.0	1.1	1.1	0.3	0.1	0.2	0.9	0.4	0.2	1.3	0.0	0.1	1.2	1.2	0.9	2.3	1.0	1.1	0.2	1.1	0.3	0.2	1.2	1.4	1.7	0.1	0.4	1.3	0.0	1.2	0.7	1.5	0.1	1.9	1.2	0.6	1.9	0.1	0.9	1.8
72	2.6	2.5	1.1	1.0	1.1	1.1	0.7	2.3	2.1	0.9	2.0	2.0	2.6	2.2	3.8	3.4	0.0	3.2	1.1	3.2	3.5	2.9	2.3	2.1	3.2	2.6	0.5	0.6	0.1	2.7	2.5	1.3	1.2	1.5	0.4	1.1	0.8	1.2	2.6	1.9	1.0	0.9	2.8
73	1.3	1.3	1.1	1.0	1.1	1.1	0.7	1.1	0.9	2.1	2.0	2.0	1.6	1.1	1.4	1.2	1.2	0.2	0.1	0.1	0.1	0.2	1.1	0.9	0.9	1.3	1.4	1.7	1.4	0.6	1.3	1.2	1.2	0.7	0.6	1.1	1.9	1.2	2.6	3.0	1.0	0.9	0.8
74	0.1	1.3	0.0	0.2	0.0	1.1	1.3	0.1	1.3	0.2	0.4	1.2	1.3	0.0	1.1	1.0	1.2	0.2	0.1	1.0	0.1	0.2	1.3	0.3	0.2	1.2	1.3	0.5	1.4	0.6	1.3	0.0	0.0	0.4	0.4	0.1	1.5	0.0	1.4	0.8	1.0	0.2	0.3
75	1.1	1.2	0.0	0.2	0.0	0.0	0.3	1.3	0.2	0.2	0.8	0.2	0.6	0.0	0.1	1.0	0.0	1.4	0.1	1.2	0.1	1.2	0.1	0.9	0.2	0.1	0.5	0.6	1.4	0.6	0.0	0.0	0.0	0.4	0.6	0.1	0.8	1.2	0.4	0.4	1.2	0.2	1.3
76	0.1	1.2	0.0	1.3	1.1	0.0	0.3	0.1	0.2	0.2	0.4	0.2	0.3	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3
77	0.1	1.2	0.0	0.2	0.0	1.1	0.7	0.1	0.9	0.2	0.8	0.9	0.6	1.1	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3
78	0.1	0.0	1.1	1.0	1.1	1.1	0.7	0.1	0.9	0.9	0.4	0.9	0.3	1.1	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.9	1.1	0.9	0.2	0.1	0.5	0.5	1.4	0.6	0.0	0.0	0.0	0.7	0.6	1.1	0.8	0.0	1.6	0.8	0.1	0.2	0.3
79	0.1	0.0	1.2	1.0	0.0	0.0	1.3	0.1	0.2	0.2	1.5	1.2	0.3	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	0.2	0.1	0.5	0.6	1.3	0.6	1.3	1.3	1.2	0.4	0.6	0.1	0.8	0.0	2.6	0.4	1.2	1.3	1.3
80	0.1	0.0	0.0	1.0	1.1	0.0	0.3	1.3	0.2	0.2	0.8	0.2	0.3	2.2	1.1	0.1	0.0	0.2	1.1	1.2	1.1	1.2	0.1	0.3	1.4	0.1	0.4	0.6	0.1	0.6	0.0	0.0	0.0	0.4	0.4	1.3	0.4	0.0	0.4	0.4	0.1	0.9	0.8
81	0.1	1.2	1.2	0.2	0.0	0.0	0.7	0.1	0.2	0.9	0.8	0.9	0.6	1.1	0.1	0.1	0.0	0.9	1.1	1.0	1.1	0.9	0.1	0.3	0.2	1.3	0.4	0.6	1.4	0.6	1.3	0.0	1.2	1.8	1.5	2.3	0.8	0.0	0.6	0.4	0.1	0.2	0.3
82	0.1	0.0	0.0	1.3	1.1	1.1	1.3	1.3	0.9	0.9	0.4	0.2	1.3	1.1	0.1	1.2	1.2	2.0	1.1	1.0	1.1	0.2	0.1	0.9	1.4	1.2	0.4	0.6	1.3	0.4	0.0	0.0	0.0	0.4	0.6	0.1	0.4	1.2	0.4	0.8	1.2	0.2	0.8
83	0.1	0.0	2.2	2.2	2.2	3.4	1.7	0.1	2.1	2.1	2.0	2.0	1.6	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	1.1	0.9	0.9	0.1	2.3	2.8	1.3	1.6	0.0	2.5	0.0	0.4	1.5	0.1	0.8	0.0	0.6	0.8	1.0	0.9	0.8
84	1.3	1.3	1.1	1.0	1.1	1.1	0.7	1.1	0.9	0.9	0.8	0.9	0.6	1.1	1.4	1.2	0.0	2.0	0.1	1.0	0.1	1.9	1.1	0.9	0.9	1.3	1.4	1.7	1.4	1.6	1.3	2.5	2.4	0.4	1.5	1.1	0.8	1.2	0.6	0.8	1.0	0.9	0.8
85	1.3	1.3	1.2	0.2	1.1	1.1	1.3	1.1	0.9	1.3	1.5	0.2	1.3	1.1	0.1	0.1	1.2	1.4	0.1	0.1	0.1	0.2	0.1	0.9	0.2	1.2	1.3	1.6	1.3	1.5	1.3	1.3	1.2	1.5	2.5	1.3	1.5	0.0	1.4	0.4	1.2	1.3	0.3
86	1.1	1.2	0.0	0.2	1.1	1.1	0.7	2.3	0.9	0.9	0.8	0.9	1.6	0.0	1.4	1.2	1.2	2.0	2.3	3.2	2.3	2.9	2.3	0.9	2.1	1.3	0.5	0.6	0.1	0.6	1.3	1.2	1.2	0.7	0.4	1.1	0.4	1.2	0.6	0.4	0.1	0.2	0.3
87	1.1	0.0	1.1	0.2	2.2	0.0	0.3	0.1	0.9	0.2	0.4	0.2	0.3	0.0	0.1	0.1	1.2	0.2	1.1	1.0	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.4	1.2	0.4	0.4	1.0	0.2	0.3
88	1.3	2.5	1.1	2.2	1.1	1.1	1.7	1.1	2.1	0.9	2.0	0.9	1.6	1.1	1.4	0.1	1.2	0.9	1.1	2.1	1.1	0.9	0.1	0.9	2.1	1.3	0.4	0.6	2.8	0.6	1.3	2.5	2.4	0.7	1.5	1.1	0.8	2.4	0.6	0.4	1.0	1.9	0.8
89	0.1	0.0	1.2	0.2	0.0	0.0	0.3	1.3	1.3	0.2	0.8	0.9	0.6	0.0	1.4	1.2	1.2	0.2	0.1	0.1	0.1	1.9	0.1	0.3	0.2	0.1	2.3	0.6	1.4	0.6	0.0	1.2	1.2	1.8	2.5	2.3	1.9	0.0	0.6	0.8	1.0	0.9	0.3
90	1.1	1.2	1.2	1.3	1.1	1.1	2.7	1.3	0.9	1.3	0.8	0.9	0.3	1.1	1.1	1.0	1.2	3.2	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	2.3	1.7	1.3	1.5	1.3	1.3	1.2	0.7	2.5	1.3	1.5	1.2	2.6	1.5	1.2	1.3	1.3

Z-Score test: Pecentage of |Z| score >3.29

Sets	A1	A2	A3	A4	A5	A6	A7	B1	C1	C2	C3	C4	C5	C6	D1	D2	D3	D4	D5	D6	D7	D8	E1	E2	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	F7	F8	G1	G2	G3	G4	G5	G6	G7
91	1.3	1.3	1.1	1.0	1.1	1.1	1.7	0.1	0.9	0.9	0.4	0.9	0.6	0.0	0.1	0.1	1.2	1.4	1.3	1.2	1.3	0.2	0.1	0.3	0.2	0.1	2.3	0.5	0.1	0.4	0.0	0.0	1.2	1.5	1.4	1.3	1.9	0.0	2.6	3.0	0.1	0.9	0.3
92	2.6	1.3	1.1	2.2	2.2	1.1	0.7	0.1	2.1	2.1	0.8	0.9	0.6	0.0	0.1	0.1	1.2	0.2	0.1	0.1	0.1	0.2	1.1	0.9	0.9	1.3	0.5	0.6	1.4	0.4	0.0	0.0	1.2	0.4	1.5	1.1	0.4	0.0	1.6	0.8	0.1	0.2	0.3
93	0.1	0.0	1.2	1.0	1.1	0.0	2.7	1.3	3.2	2.1	0.4	0.2	2.6	3.3	1.4	0.1	1.2	0.9	1.1	2.1	3.5	2.9	2.3	2.1	0.9	1.3	1.4	0.6	1.4	0.6	1.3	1.2	1.2	0.7	0.6	1.1	0.8	0.0	0.6	0.8	2.1	1.9	0.8
94	1.1	0.0	0.0	0.2	0.0	0.0	0.3	0.1	0.9	0.9	0.4	0.9	0.6	0.0	0.1	0.1	1.2	0.2	2.3	1.0	1.1	0.2	1.1	2.1	0.9	0.1	0.4	0.5	0.1	0.4	0.0	0.0	1.2	0.7	0.4	1.1	0.8	0.0	0.4	0.4	0.1	0.2	0.8
95	1.1	0.0	1.1	0.2	0.0	1.1	0.3	0.1	1.3	0.9	1.5	0.2	0.3	0.0	0.1	1.0	0.0	0.2	1.1	0.1	1.1	0.9	0.1	0.9	0.9	0.1	1.3	0.5	0.1	0.4	0.0	1.3	0.0	0.7	0.6	1.1	0.4	0.0	0.4	0.8	0.1	1.3	0.3
96	1.3	1.3	0.0	0.2	0.0	1.1	0.3	0.1	0.2	0.2	1.5	0.2	1.3	1.1	1.4	0.1	1.2	1.4	0.1	0.1	1.3	1.2	0.1	0.3	1.4	1.2	1.3	1.6	0.1	0.6	0.0	0.0	0.0	1.5	1.4	1.3	1.5	1.2	0.4	0.4	0.1	0.9	0.8
97	0.1	0.0	1.1	0.2	0.0	0.0	0.3	0.1	0.2	0.9	1.5	0.2	0.3	1.1	1.1	0.1	1.2	0.2	0.1	1.2	0.1	0.2	0.1	0.3	0.2	0.1	0.5	0.5	0.1	0.4	0.0	1.3	0.0	0.4	0.4	0.1	0.4	1.2	0.6	0.8	0.1	0.2	0.3
98	1.3	0.0	0.0	0.2	0.0	0.0	0.3	1.1	0.2	0.2	0.4	0.2	0.3	1.1	0.1	1.0	0.0	1.4	0.1	0.1	0.1	1.2	0.1	0.3	1.4	0.1	0.4	0.5	0.1	1.5	1.3	0.0	0.0	0.4	1.4	1.3	0.4	1.2	0.4	1.5	1.0	0.2	0.3
99	1.3	1.3	1.2	0.2	0.0	0.0	0.7	1.1	0.9	0.9	0.4	0.9	0.6	1.1	1.1	0.1	1.2	1.4	1.3	1.2	1.3	1.2	0.1	0.3	0.9	0.1	0.5	0.6	1.3	0.6	0.0	0.0	1.2	0.7	1.5	0.1	0.8	0.0	0.6	1.5	0.1	0.2	0.8
100	1.3	1.3	0.0	0.2	1.1	1.1	0.3	1.3	0.2	0.2	0.4	1.2	1.3	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	0.1	0.3	0.2	0.1	0.4	0.5	1.3	0.4	1.3	1.3	1.2	1.5	1.4	1.3	0.4	1.2	0.4	0.4	1.2	0.2	0.3
101	1.3	0.0	1.2	1.3	0.0	0.0	0.3	0.1	1.3	1.3	0.4	0.2	1.3	1.1	0.1	1.0	1.2	1.4	0.1	0.1	0.1	0.2	1.3	0.3	0.2	1.3	0.4	0.5	1.3	0.4	0.0	0.0	1.2	0.4	1.4	1.3	0.4	1.2	1.4	0.4	0.1	0.2	0.3
102	1.3	1.3	1.1	1.0	1.1	1.1	0.7	1.1	0.9	0.9	0.8	0.9	0.6	1.1	1.4	3.4	3.5	0.9	1.1	1.0	1.1	0.2	0.1	0.3	0.9	1.3	0.5	0.6	1.3	0.4	1.3	0.0	1.2	0.4	0.6	0.1	0.4	1.2	0.6	0.8	1.0	0.9	0.8
103	0.1	0.0	2.2	1.3	1.1	1.1	1.3	1.3	0.9	0.9	2.0	0.2	1.3	1.1	2.6	2.3	2.4	0.9	1.1	1.2	0.1	1.9	2.3	2.1	2.1	1.2	0.4	0.5	1.3	1.5	0.0	0.0	1.2	1.5	1.4	0.1	0.8	1.2	0.6	1.9	2.1	1.9	1.3
104	0.1	0.0	0.0	0.2	0.0	0.0	0.3	0.1	0.2	0.2	0.4	0.2	0.3	0.0	1.1	1.0	1.2	1.4	1.3	1.2	0.1	0.9	0.1	0.9	1.4	0.1	0.5	0.6	0.1	1.6	1.3	1.2	0.0	0.4	0.6	1.1	0.8	0.0	0.6	0.8	0.1	0.2	0.8
105	0.1	0.0	1.1	0.2	0.0	1.1	0.3	1.1	0.2	1.3	0.8	0.9	0.6	1.1	1.1	0.1	1.2	0.2	0.1	0.1	0.1	0.9	2.3	0.9	0.9	0.1	0.4	0.6	0.1	0.6	0.0	1.3	1.2	0.7	0.6	1.1	0.8	1.2	0.6	0.8	1.2	0.2	0.3
106	0.1	0.0	2.2	1.0	1.1	0.0	0.7	0.1	0.9	0.9	0.4	0.2	1.3	0.0	0.1	0.1	0.0	0.2	1.3	0.1	0.1	1.2	0.1	0.9	0.2	0.1	1.4	0.5	0.1	1.6	0.0	0.0	0.0	0.7	0.6	0.1	0.4	1.2	0.4	0.4	0.1	1.3	0.3
107	1.3	1.3	0.0	0.2	0.0	0.0	0.3	0.1	0.9	0.9	0.4	0.9	0.3	0.0	0.1	1.2	0.0	0.9	1.1	1.0	1.1	0.2	1.1	0.9	0.9	0.1	0.5	0.6	0.1	0.6	1.3	1.2	0.0	0.7	0.6	1.1	0.4	0.0	0.4	0.8	1.0	0.9	0.8
108	0.1	0.0	0.0	0.2	0.0	0.0	0.7	1.1	0.9	0.9	0.8	0.9	0.6	0.0	0.1	0.1	0.0	0.9	1.1	0.1	0.1	0.2	1.1	0.9	0.9	1.3	0.5	0.6	0.1	0.4	0.0	0.0	0.0	0.7	0.6	0.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3
109	1.3	1.3	2.2	3.3	2.2	2.3	2.7	1.1	2.1	2.1	2.0	3.1	0.6	1.1	0.1	0.1	1.2	0.9	1.3	1.2	1.1	0.2	1.1	0.3	0.2	0.1	1.4	1.7	0.1	0.4	1.3	1.3	0.0	1.8	1.5	1.1	0.8	0.0	0.6	0.8	0.1	1.3	1.3
110	1.1	0.0	1.2	0.2	0.0	0.0	0.3	0.1	0.2	0.9	0.4	0.2	0.6	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	1.3	1.4	0.6	0.1	0.6	0.0	0.0	0.0	0.7	0.6	0.1	0.8	0.0	0.6	1.9	1.0	0.2	0.3
111	1.1	0.0	1.2	0.2	1.1	1.1	1.3	1.3	0.2	0.2	1.5	0.9	0.3	0.0	1.1	1.0	0.0	0.9	1.3	1.2	1.3	1.2	1.1	0.9	2.1	1.3	0.4	0.5	1.4	1.5	1.3	1.3	1.2	0.4	0.4	1.3	1.5	1.2	0.6	0.4	1.2	1.3	1.3
112	0.1	0.0	0.0	0.2	0.0	0.0	0.3	0.1	0.9	0.9	0.8	0.2	0.6	0.0	1.1	1.0	1.2	0.9	1.1	1.2	1.3	1.2	1.1	0.9	0.2	1.2	0.5	0.6	1.4	0.4	1.3	1.3	1.2	0.4	0.4	0.1	1.5	1.2	0.6	0.8	1.2	1.3	1.3
113	1.3	1.2	1.2	1.0	1.1	0.0	1.7	1.1	0.9	2.1	0.8	0.2	1.6	1.1	0.1	1.0	0.0	0.2	1.3	1.2	1.3	0.9	1.1	0.9	0.9	1.2	1.4	1.7	1.4	0.6	1.3	1.2	1.2	0.7	1.5	0.1	1.9	1.2	0.6	0.8	0.1	0.2	0.3
114	1.3	0.0	1.1	1.0	2.2	1.1	1.7	2.3	2.1	2.1	2.0	2.0	2.6	1.1	0.1	1.2	2.4	0.2	0.1	1.0	1.1	0.2	0.1	0.9	0.9	0.1	1.4	0.6	1.4	1.6	1.3	2.5	0.0	1.8	2.5	1.1	1.9	1.2	2.6	1.9	1.0	0.9	1.8
115	1.3	0.0	0.0	0.2	0.0	0.0	0.3	0.1	0.2	0.9	0.8	0.2	0.3	0.0	1.4	1.2	1.2	0.9	1.1	0.1	0.1	0.9	1.1	0.9	0.9	0.1	0.4	0.5	0.1	0.6	0.0	0.0	0.0	0.4	0.4	0.1	0.4	1.2	0.6	0.8	1.0	0.9	0.8
116	0.1	0.0	0.0	1.0	0.0	0.0	0.3	0.1	0.9	0.2	0.4	0.2	0.3	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	2.3	0.5	0.1	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.4	0.0	0.6	0.4	0.1	0.2	0.8
117	0.1	0.0	0.0	0.2	1.1	1.1	0.7	0.1	0.9	0.9	0.8	0.9	0.6	0.0	0.1	0.1	0.0	0.2	0.1	1.0	1.1	0.2	0.1	1.5	1.4	1.2	1.4	1.7	1.3	2.7	1.3	0.0	0.0	0.4	0.4	1.3	0.8	0.0	0.4	0.8	0.1	0.2	0.3
118	0.1	0.0	1.1	1.3	1.1	0.0	0.7	1.3	1.3	0.2	0.4	1.2	1.3	0.0	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.1	0.9	0.9	1.3	1.4	0.5	1.3	1.5	1.3	1.3	1.2	1.8	0.4	1.1	0.8	1.2	0.6	0.8	0.1	1.3	0.3
119	1.3	1.3	2.2	1.0	2.2	1.1	1.7	1.1	0.9	0.9	0.8	0.2	0.3	1.1	0.1	0.1	1.2	0.9	0.1	1.2	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.6	0.0	0.0	0.0	0.7	0.6	1.1	0.8	1.2	0.4	0.8	0.1	1.3	0.3
120	0.1	0.0	1.2	1.3	1.1	1.1	0.7	1.1	1.3	1.3	1.5	0.2	0.6	0.0	1.1	1.0	1.2	1.4	1.3	1.2	0.1	1.2	0.1	0.9	0.9	1.2	0.5	0.5	0.1	0.6	1.3	1.3	1.2	1.5	0.6	1.3	0.8	1.2	0.6	1.5	1.0	1.3	1.3
121	3.8	3.7	3.4	3.3	3.3	3.4	2.7	2.3	2.1	2.1	2.0	2.0	1.6	2.2	2.6	2.3	2.4	2.0	2.3	2.1	2.3	1.9	2.3	2.1	2.1	3.9	2.3	2.8	2.8	1.6	2.5	2.5	2.4	1.8	1.5	2.3	1.9	2.4	1.6	1.9	2.1	1.9	1.8
122	2.6	2.5	1.1	1.0	1.1	0.0	0.3	1.1	0.2	0.2	0.4	0.2	0.3	0.0	1.4	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.6	1.3	0.0	0.0	0.7	0.6	0.1	0.8	0.0	0.4	0.8	1.0	0.9	0.8
123	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	0.2	0.2	0.4	1.2	0.3	0.0	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	1.3	1.6	1.3	1.6	1.3	1.3	0.0	0.4	0.4	0.1	1.5	1.2	1.4	1.5	1.2	1.3	1.3
124	0.1	1.3	2.2	1.0	1.1	2.3	1.7	1.1	2.1	2.1	2.0	2.0	1.6	2.2	1.4	1.2	1.2	2.0	0.1	1.0	1.1	0.9	1.1	0.9	0.9	1.3	0.5	0.6	1.4	1.6	1.3	1.2	1.2	1.8	1.5	2.3	0.8	1.2	1.6	0.8	1.0	0.9	0.8
125	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	1.3	1.3	1.5	1.2	1.3	1.1	0.1	0.1	1.2	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.4	0.0	1.3	0.0	0.4	1.4	0.1	0.4	1.2	1.4	0.4	1.2	1.3	1.3
126	0.1	0.0	1.1	1.0	1.1	1.1	0.7	0.1	0.2	0.2	0.8	0.2	0.3	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.5	0.6	2.8	1.6	2.5	2.5	2.4	1.8	1.5	2.3	0.8	2.4	1.6	1.9	2.1	1.9	1.8
127	0.1	1.2	0.0	1.3	1.1	0.0	0.7	0.1	1.3	1.3	0.8	0.2	1.3	0.0	0.1	1.0	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	1.4	1.3	0.4	0.5	1.3	0.6	0.0	0.0	1.2	0.7	0.6	0.1	0.4	0.0	0.6	0.8	0.1	0.9	1.3
128	1.3	1.3	0.0	0.2	0.0	1.1	0.7	0.1	0.2	0.9	1.5	1.2	0.3	1.1	1.1	1.0	1.2	0.2	1.3	1.2	0.1	0.2	1.3	0.3	1.4	1.2	0.4	0.5	0.1	0.4	1.3	1.3	1.2	1.5	0.4	0.1	0.4	1.2	0.6	0.4	1.2	0.9	1.3
129	2.6	2.5	0.0	0.2	0.0	0.0	0.3	0.1	0.2	0.2	2.0	0.2	1.6	0.0	0.1	1.0	1.2	1.4	1.3	1.2	0.1	0.2	0.1	0.3	0.2	0.1	1.4	1.7	0.1	1.6	0.0	0.0	0.0	0.4	0.6	1.3	1.9	1.2	1.6	1.9	0.1	0.2	0.8
130	1.1	0.0	1.2	1.3	1.1	1.1	0.3	1.3	0.2	0.2	0.4	0.2	0.3	1.1	1.1	1.0	1.2	0.2	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	1.3	1.6	1.3	0.4	0.0	1.3	1.2	0.4	0.4	1.3	1.5	1.2	0.4	0.4	1.2	0.2	1.3
131	1.1	0.0	0.0	0.2	0.0	0.0	0.3	1.3	0.2	0.9	0.4	0.9	0.6	1.1	1.1	1.0	1.2	0.2	0.1	0.1	0.1	0.2	1.3	0.3	0.2	0.1	0.5	0.6	1.3	0.6	0.0	1.3	1.2	0.4	0.6	0.1	1.9	1.2	0.6	1.9	0.1	1.3	1.3
132	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	0.9	0.2	0.8	1.2	1.3	1.1	0.1	1.0	0.0	1.4	1.3	1.0	1.1	0.2	1.1	0.9	0.2	0.1	0.5	0.6	1.4	2.7	2.5	1.3	1.2	1.8	0.6	1.1	0.8	0.0	0.4	0.4	0.1	0.2	0.8
133	0.1	0.0	0.0	0.2	1.1	1.1	0.3	1.1	0.9	0.9	0.4	0.9	0.6	1.1	0.1	0.1	0.0	0.2	0.1	1.0	1.1	0.9	0.1	0.9	0.9	1.3	0.4	0.5	0.1	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.8	0.0	0.4	0.4	0.1	0.2	0.3
134	2.6	2.5	2.2	2.2	2.2	2.3	1.7	2.3	2.1	2.1	2.0	2.0	1.6	2.2	2.6	2.3	2.4	2.0	2.3	1.0	1.1	0.9	1.1	0.9	0.9	1.3	1.4	1.7	1.4	1.6	2.5	2.5	1.2	0.7	1.5	2.3	1.9	2.4	1.6	1.9	2.1	1.9	1.8
135	1.1	0.0	1.2	1.3	1.1	1.1	0.3	0.1	1.3	1.3	0.4	1.2	0.3	1.1	0.1	1.0	1.2	1.4	1.3	1.2	1.3	0.9	1.1	0.9	0.2	1.2	0.5	0.6	0.1	0.4	0.0	1.3	0.0	0.7	0.4	1.3	0.4	1.2	0.6	0.8	2.1	1.9	1.8

Z-Score test: Pecentage of |Z| score >3.29

Sets	A1	A2	A3	A4	A5	A6	A7	B1	C1	C2	C3	C4	C5	C6	D1	D2	D3	D4	D5	D6	D7	D8	E1	E2	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	F7	F8	G1	G2	G3	G4	G5	G6	G7
136	1.3	1.3	0.0	1.0	0.0	1.1	0.3	0.1	0.2	0.9	0.8	0.9	0.6	1.1	0.1	1.0	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.9	0.1	0.5	0.6	0.1	0.6	0.0	0.0	0.0	0.7	0.6	1.1	0.8	0.0	0.6	0.4	0.1	0.2	0.3
137	1.1	0.0	1.2	0.2	0.0	0.0	1.3	1.1	0.2	0.2	1.5	0.2	0.3	1.1	1.1	1.0	1.2	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	1.3	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3
138	0.1	0.0	0.0	0.2	0.0	0.0	0.7	1.3	0.9	0.2	0.8	0.2	0.6	0.0	0.1	0.1	0.0	0.2	0.1	1.2	0.1	1.2	0.1	0.3	0.2	0.1	0.4	0.6	0.1	0.6	0.0	1.3	0.0	0.4	0.6	0.1	0.4	0.0	0.4	0.8	0.1	0.9	0.8
139	0.1	0.0	1.1	1.3	2.2	2.3	0.7	1.3	2.1	2.1	0.8	1.2	2.6	1.1	0.1	1.2	1.2	0.9	0.1	0.1	0.1	0.2	0.1	0.3	0.2	1.3	2.3	0.6	1.3	0.4	1.3	1.2	0.0	0.7	2.5	1.1	1.9	1.2	0.4	0.8	1.0	0.9	0.3
140	1.3	1.3	1.1	1.0	1.1	1.1	0.7	1.1	0.2	0.9	0.8	0.9	0.6	1.1	1.4	0.1	0.0	0.9	1.1	1.0	1.1	0.9	1.1	0.9	0.9	1.3	0.5	0.6	1.4	0.6	1.3	1.2	1.2	0.7	0.6	1.1	0.8	1.2	0.6	0.8	1.0	0.9	0.8
141	0.1	0.0	1.1	1.0	1.1	0.0	0.3	0.1	0.2	0.9	2.0	0.9	0.3	0.0	1.4	1.2	0.0	0.2	1.1	1.0	0.1	0.2	0.1	0.3	0.2	1.2	1.3	0.5	1.4	1.6	1.3	0.0	0.0	0.4	0.6	1.1	0.8	0.0	0.4	0.4	0.1	0.9	0.8
142	1.1	0.0	0.0	1.3	1.1	0.0	0.3	0.1	1.3	0.2	0.8	1.2	0.3	0.0	1.1	1.0	0.0	0.2	0.1	1.2	1.3	0.2	0.1	0.3	0.2	0.1	0.5	0.5	0.1	0.6	0.0	0.0	0.0	0.4	0.4	0.1	0.8	0.0	0.6	0.4	0.1	0.2	0.3
143	1.1	0.0	1.2	0.2	0.0	1.1	0.7	0.1	0.2	0.2	0.4	0.9	0.6	1.1	1.1	0.1	0.0	1.4	0.1	0.1	0.1	1.2	0.1	0.9	2.1	1.3	0.5	1.7	1.3	0.6	0.0	0.0	1.2	0.4	0.6	1.3	0.8	1.2	0.6	0.8	0.1	1.3	0.3
144	0.1	0.0	0.0	0.2	0.0	0.0	0.3	0.1	1.3	0.2	0.8	0.2	0.3	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.4	0.0	1.3	0.0	1.5	0.4	1.3	0.4	0.0	0.4	0.4	0.1	0.2	0.3
145	1.1	0.0	0.0	0.2	0.0	1.1	0.7	1.3	0.2	0.2	1.5	0.2	1.3	1.1	0.1	0.1	1.2	1.4	0.1	0.1	0.1	1.2	0.1	0.3	0.2	1.3	0.4	0.5	1.4	0.4	1.3	0.0	0.0	0.4	1.4	1.1	1.5	1.2	1.4	0.4	1.2	0.2	0.3
146	0.1	0.0	1.1	1.0	0.0	0.0	0.3	1.1	0.9	0.2	2.0	0.2	1.3	2.2	0.1	0.1	1.2	2.0	1.1	0.1	1.1	1.2	0.1	0.9	0.9	0.1	0.5	0.6	0.1	0.4	0.0	1.2	1.2	0.4	0.6	0.1	0.4	0.0	0.6	0.4	1.0	0.9	0.3
147	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	1.3	1.3	0.4	0.2	1.3	0.0	1.1	0.1	0.0	0.2	0.1	1.2	1.3	1.2	1.1	0.9	0.9	0.1	1.3	0.5	0.1	1.5	0.0	0.0	1.2	0.7	1.5	1.1	0.4	1.2	2.6	0.4	1.2	0.2	0.3
148	1.3	1.3	0.0	1.0	1.1	1.1	1.7	0.1	2.1	2.1	2.0	2.0	2.6	2.2	1.4	0.1	0.0	0.2	0.1	0.1	1.1	0.2	0.1	0.3	0.9	0.1	2.3	1.7	1.4	2.7	1.3	1.2	0.0	2.8	2.5	1.1	1.9	0.0	1.6	1.9	0.1	1.9	1.8
149	0.1	0.0	1.2	0.2	0.0	1.1	1.7	0.1	0.2	0.9	0.8	1.2	1.6	0.0	0.1	0.1	1.2	0.2	1.3	0.1	0.1	0.2	0.1	0.3	1.4	0.1	0.4	0.5	0.1	0.4	0.0	1.3	1.2	0.4	0.4	0.1	1.5	0.0	0.4	1.9	1.2	0.2	0.3
150	0.1	1.2	0.0	0.2	0.0	0.0	0.3	1.3	0.9	0.2	0.4	0.2	0.3	1.1	0.1	1.0	1.2	0.2	0.1	1.2	1.3	0.2	1.3	0.3	0.2	0.1	0.4	0.5	1.3	0.6	0.0	0.0	1.2	0.4	0.4	0.1	0.4	1.2	0.4	0.4	1.2	1.3	0.3
151	1.1	1.2	0.0	0.2	1.1	0.0	1.3	0.1	0.2	1.3	0.4	0.2	0.3	1.1	1.1	0.1	0.0	1.4	0.1	1.2	0.1	0.2	1.3	0.9	0.2	0.1	0.4	0.6	0.1	0.4	1.3	1.2	0.0	0.7	0.4	0.1	0.4	1.2	0.4	0.4	0.1	1.3	1.3
152	1.3	1.3	0.0	0.2	1.1	1.1	0.7	0.1	0.9	0.2	0.4	0.2	0.3	0.0	1.4	0.1	1.2	0.9	0.1	1.0	1.1	0.2	1.1	0.3	0.9	0.1	0.5	0.5	1.4	0.6	1.3	1.2	0.0	0.7	0.6	0.1	0.4	0.0	0.4	0.8	0.1	0.9	0.3
153	0.1	0.0	0.0	0.2	0.0	0.0	0.3	0.1	0.2	0.2	0.4	0.2	0.3	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	1.4	0.6	0.1	1.6	0.0	0.0	0.0	0.4	0.4	0.1	0.4	0.0	0.6	0.8	0.1	0.2	0.3
154	1.1	0.0	1.2	1.3	1.1	1.1	1.3	1.3	0.2	1.3	1.5	0.2	1.3	1.1	1.1	1.0	1.2	1.4	0.1	1.2	1.3	1.2	0.1	1.5	1.4	1.2	0.4	0.5	1.3	0.4	1.3	0.0	1.2	0.4	0.4	0.1	1.5	1.2	1.4	0.4	1.2	1.3	1.3
155	0.1	1.3	0.0	0.2	0.0	0.0	0.3	0.1	0.2	1.3	0.4	0.2	0.3	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	1.1	0.3	0.9	0.1	0.4	0.5	1.4	0.4	1.3	0.0	0.0	0.4	0.4	0.1	0.8	0.0	0.4	0.4	1.0	0.2	0.3
156	0.1	0.0	1.1	0.2	0.0	1.1	0.3	1.1	0.2	0.9	0.4	0.2	0.3	0.0	1.4	0.1	1.2	0.9	1.1	2.1	1.1	0.9	1.1	0.9	2.1	0.1	0.5	0.6	0.1	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.8	1.2	0.6	0.8	1.0	0.9	0.8
157	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	0.2	0.2	0.4	0.2	0.3	0.0	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	0.1	0.3	0.2	0.1	0.4	0.5	1.3	1.5	1.3	1.3	1.2	1.5	1.4	1.3	1.5	1.2	1.4	1.5	1.2	1.3	1.3
158	0.1	0.0	1.1	1.0	0.0	0.0	0.7	0.1	0.2	0.9	0.4	0.2	0.6	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	1.3	0.4	0.5	0.1	0.4	0.0	0.0	0.0	0.4	0.6	0.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3
159	1.3	1.3	2.2	2.2	2.2	2.3	2.7	0.1	2.1	3.2	0.8	3.1	2.6	1.1	0.1	0.1	1.2	0.9	0.1	0.1	0.1	0.9	0.1	0.9	0.9	0.1	0.4	1.7	1.4	1.6	1.3	1.2	0.0	1.8	2.5	1.1	1.9	1.2	2.6	3.0	0.1	0.9	0.3
160	1.1	0.0	0.0	1.0	0.0	1.1	0.7	0.1	0.9	0.2	2.0	2.0	1.3	1.1	0.1	0.1	1.2	0.9	1.1	1.2	1.1	0.9	1.3	0.9	0.2	0.1	0.5	1.7	0.1	2.7	2.5	1.2	2.4	1.8	1.4	1.1	1.5	1.2	0.6	1.5	1.2	3.0	2.8
161	0.1	0.0	0.0	0.2	0.0	0.0	0.7	0.1	0.9	0.2	0.4	0.9	0.3	1.1	0.1	1.0	0.0	0.9	0.1	1.0	0.1	0.9	1.1	0.9	0.9	1.3	0.5	0.6	1.4	0.6	1.3	0.0	0.0	0.7	0.6	1.1	0.8	0.0	0.6	0.4	0.1	0.9	0.8
162	1.1	0.0	0.0	0.2	0.0	0.0	0.3	0.1	0.9	0.2	0.4	0.2	0.3	1.1	0.1	0.1	0.0	0.9	1.1	1.0	0.1	0.9	1.1	0.9	0.9	1.3	0.4	0.5	0.1	0.6	0.0	0.0	0.0	0.4	0.6	1.1	0.4	1.2	1.4	0.4	0.1	1.3	1.3
163	0.1	0.0	0.0	0.2	0.0	0.0	0.3	1.1	0.9	0.9	0.8	0.9	1.6	0.0	0.1	1.2	0.0	0.9	0.1	0.1	0.1	0.9	0.1	0.9	0.9	0.1	1.4	1.7	1.4	0.6	0.0	0.0	0.0	0.7	1.5	1.1	0.8	0.0	0.6	0.4	0.1	0.9	0.8
164	0.1	1.3	0.0	0.2	1.1	1.1	0.7	0.1	0.2	0.2	0.8	0.2	0.6	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	0.1	0.9	0.9	0.1	0.4	0.5	0.1	0.6	0.0	1.3	0.0	0.4	0.4	0.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3
165	1.3	0.0	1.1	0.2	0.0	0.0	0.3	0.1	0.2	0.2	0.4	0.2	0.3	1.1	0.1	0.1	1.2	0.2	0.1	0.1	1.1	0.2	0.1	0.9	0.2	1.3	0.4	0.5	0.1	0.4	0.0	0.0	0.0	0.7	0.6	1.1	0.4	0.0	0.4	1.5	0.1	0.2	0.3
166	1.3	1.3	1.1	1.0	1.1	1.1	0.7	1.1	0.9	0.9	0.8	0.9	0.6	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	1.1	0.9	2.1	0.1	2.3	0.5	0.1	0.6	0.0	0.0	1.2	0.4	0.4	0.1	0.4	0.0	0.6	0.4	1.0	0.2	0.8
167	1.3	1.3	0.0	1.0	0.0	0.0	0.3	0.1	0.9	0.2	0.4	0.2	0.3	0.0	0.1	1.2	1.2	1.4	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.5	0.6	0.1	0.4	0.0	1.2	0.0	0.4	0.4	0.1	0.4	0.0	0.6	0.4	0.1	0.9	0.8
168	0.1	0.0	1.1	1.0	0.0	0.0	0.7	0.1	0.2	0.9	0.4	0.2	0.3	0.0	0.1	0.1	0.0	0.2	1.1	1.0	1.1	0.9	0.1	0.3	0.2	0.1	0.4	0.5	1.3	0.4	1.3	1.3	1.2	0.4	0.4	0.1	0.4	0.0	0.4	0.8	1.2	1.3	0.3
169	0.1	0.0	0.0	0.2	0.0	0.0	0.3	0.1	0.2	0.9	0.4	0.2	0.3	0.0	0.1	1.2	0.0	0.2	1.3	0.1	0.1	0.2	0.1	0.3	0.9	0.1	0.5	0.6	0.1	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.4	1.2	0.6	0.8	0.1	0.9	0.8
170	0.1	0.0	0.0	0.2	0.0	0.0	0.3	1.1	0.2	0.2	0.8	0.2	0.3	1.1	0.1	3.4	0.0	0.9	0.1	0.1	0.1	1.9	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3
171	0.1	0.0	1.1	1.0	1.1	1.1	0.7	1.1	2.1	0.9	0.4	0.9	0.3	0.0	0.1	0.1	0.0	0.2	1.3	0.1	1.3	1.2	0.1	0.3	0.2	1.3	0.5	0.5	0.1	0.6	0.0	0.0	1.2	0.4	0.6	1.3	0.4	0.0	0.4	0.8	1.2	0.2	1.3
172	1.1	1.2	1.2	1.3	1.1	1.1	0.3	0.1	0.2	0.2	0.4	1.2	0.3	1.1	1.1	1.0	0.0	0.2	0.1	0.1	0.1	1.2	0.1	0.3	1.4	1.2	0.4	0.5	0.1	1.5	1.3	1.3	1.2	1.5	0.4	1.3	1.5	0.0	0.4	0.4	1.2	0.2	0.3
173	1.3	0.0	1.1	1.0	0.0	1.1	0.7	1.1	0.9	2.1	0.8	0.2	0.6	0.0	1.4	1.2	1.2	0.9	0.1	0.1	1.1	0.9	0.1	0.9	0.9	0.1	1.4	1.7	1.4	1.6	2.5	1.2	2.4	0.7	1.5	2.3	1.9	1.2	1.6	0.8	0.1	0.2	0.8
174	1.3	0.0	0.0	0.2	1.1	1.1	1.7	0.1	0.9	0.2	0.4	0.2	0.3	0.0	0.1	1.2	1.2	0.2	0.1	0.1	0.1	0.2	0.1	0.9	0.2	0.1	1.4	1.7	1.4	0.6	2.5	2.5	1.2	0.4	0.4	2.3	0.8	2.4	1.6	1.9	2.1	0.9	0.8
175	0.1	0.0	0.0	0.2	0.0	1.1	1.3	1.3	1.3	1.3	0.4	0.2	0.3	1.1	1.1	0.1	0.0	0.2	0.1	0.1	1.1	0.9	0.1	1.5	1.4	1.3	1.3	0.5	1.3	0.4	0.0	0.0	0.0	0.7	0.6	1.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3
176	1.1	1.2	1.2	1.3	1.1	1.1	0.3	1.3	1.3	1.3	0.4	0.2	0.6	1.1	1.1	1.0	1.2	0.9	1.3	1.2	0.1	1.2	1.3	1.5	1.4	0.1	0.4	0.5	0.1	0.6	1.3	1.3	1.2	0.7	0.6	0.1	0.8	1.2	1.4	1.5	1.2	1.3	1.3
177	0.1	1.3	0.0	0.2	1.1	1.1	0.7	1.1	0.9	0.9	0.8	0.9	0.6	1.1	2.6	1.2	1.2	0.9	1.1	0.1	1.3	0.9	2.3	0.9	2.1	1.3	1.4	0.6	0.1	1.6	1.3	1.2	0.0	0.7	0.6	1.1	0.8	0.0	0.6	0.8	1.0	0.9	0.8
178	0.1	1.2	3.4	1.0	2.2	1.1	1.7	1.1	0.9	0.9	2.0	0.2	0.3	0.0	1.1	0.1	1.2	0.2	0.1	0.1	0.1	0.9	1.1	0.9	0.9	1.3	1.4	2.8	1.4	1.6	1.3	0.0	0.0	1.5	0.6	0.1	0.8	0.0	1.6	1.9	0.1	0.2	0.3
179	0.1	1.2	0.0	1.3	1.1	1.1	1.3	1.3	0.2	1.3	0.4	1.2	0.3	1.1	1.1	1.0	1.2	0.2	0.1	1.2	1.3	1.2	0.1	0.3	1.4	0.1	1.3	1.6	1.3	0.6	0.0	0.0	0.0	0.4	0.4	0.1	0.4	1.2	0.4	0.4	1.2	0.2	1.3
180	1.3	0.0	0.0	1.0	0.0	0.0	0.7	0.1	0.9	0.2	0.4	0.2	0.3	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	1.3	0.5	0.5	0.1	0.4	0.0	0.0	0.0	0.7	0.6	0.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3

Z-Score test: Pecentage of |Z| score >3.29

Sets	A1	A2	A3	A4	A5	A6	A7	B1	C1	C2	C3	C4	C5	C6	D1	D2	D3	D4	D5	D6	D7	D8	E1	E2	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	F7	F8	G1	G2	G3	G4	G5	G6	G7
181	1.1	0.0	1.2	0.2	1.1	1.1	1.3	1.3	1.3	1.3	1.5	1.2	0.3	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	0.2	1.3	0.4	0.5	0.1	0.4	1.3	1.3	1.2	1.5	1.4	1.3	1.5	1.2	1.4	1.5	1.2	0.2	0.3
182	1.1	0.0	0.0	1.3	1.1	0.0	0.3	1.3	0.2	0.9	0.4	0.2	0.6	0.0	1.1	1.0	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.6	0.0	0.0	0.0	0.7	0.4	0.1	0.4	0.0	0.4	0.4	0.1	1.3	0.3
183	0.1	1.2	0.0	1.0	1.1	1.1	0.3	1.3	0.2	1.3	1.5	2.0	0.3	1.1	1.1	1.0	1.2	1.4	0.1	0.1	0.1	1.2	1.3	0.3	1.4	0.1	0.4	0.5	1.4	0.6	1.3	1.3	1.2	0.4	1.4	1.3	0.4	1.2	1.4	1.5	1.2	0.2	0.3
184	0.1	0.0	0.0	0.2	0.0	1.1	1.3	0.1	0.2	0.2	0.4	0.9	0.6	1.1	1.1	1.0	0.0	1.4	0.1	0.1	0.1	1.2	0.1	0.3	0.2	0.1	0.4	0.6	1.3	0.4	0.0	0.0	0.0	0.7	0.4	1.3	0.8	1.2	0.4	0.4	0.1	1.9	1.8
185	1.3	0.0	1.1	1.0	1.1	0.0	0.7	0.1	0.2	0.2	0.8	0.2	0.3	0.0	0.1	1.0	0.0	0.2	0.1	0.1	0.1	1.2	0.1	0.3	1.4	0.1	0.5	0.5	0.1	0.6	0.0	0.0	0.0	0.4	0.6	0.1	0.8	0.0	0.6	0.4	1.2	0.2	0.3
186	1.3	1.3	0.0	1.0	1.1	1.1	0.7	1.1	0.2	0.9	0.4	0.2	0.6	0.0	0.1	0.1	0.0	0.9	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.5	0.5	0.1	0.6	0.0	0.0	0.0	0.4	0.4	0.1	0.8	1.2	0.6	0.4	1.0	0.2	1.3
187	1.3	1.3	1.1	2.2	1.1	1.1	0.7	1.1	0.9	0.9	0.8	0.9	0.6	1.1	1.4	2.3	2.4	2.0	1.1	1.0	1.1	0.9	2.3	2.1	0.9	1.3	0.5	0.6	2.8	1.6	2.5	2.5	2.4	1.8	1.5	2.3	1.9	2.4	1.6	1.9	2.1	1.9	1.8
188	1.1	1.2	1.2	1.3	1.1	1.1	0.3	1.1	1.3	1.3	0.4	0.9	0.6	0.0	0.1	0.1	1.2	0.9	0.1	0.1	0.1	0.9	1.1	0.9	0.9	2.6	0.5	0.6	1.3	0.6	1.3	0.0	1.2	1.8	1.5	1.1	0.4	1.2	0.6	0.8	0.1	0.2	0.3
189	1.3	0.0	1.1	0.2	0.0	1.1	0.7	0.1	0.9	0.9	0.8	0.2	0.3	0.0	0.1	0.1	0.0	0.9	1.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.5	0.5	0.1	0.6	1.3	0.0	0.0	0.4	0.4	1.1	0.8	0.0	0.4	0.4	0.1	0.2	0.3
190	0.1	1.3	0.0	0.2	0.0	1.1	1.3	0.1	1.3	1.3	1.5	1.2	0.3	1.1	1.1	1.0	1.2	0.2	1.1	0.1	0.1	0.2	0.1	0.9	0.9	0.1	0.5	0.5	1.3	0.6	0.0	1.3	1.2	0.4	1.4	0.1	0.4	0.0	0.4	0.4	1.2	0.2	0.3
191	1.1	1.2	0.0	0.2	1.1	1.1	1.3	0.1	1.3	1.3	1.5	1.2	1.3	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	1.3	1.6	1.3	1.5	1.3	1.3	1.2	1.5	1.4	1.3	1.5	1.2	1.4	1.5	1.2	1.3	1.3
192	1.3	1.3	1.1	1.0	1.1	1.1	0.7	1.1	0.9	0.9	0.8	0.9	0.6	1.1	1.4	1.2	1.2	0.9	1.1	1.0	1.1	0.9	1.1	0.9	0.9	1.3	0.5	0.6	1.4	0.6	1.3	1.2	1.2	0.7	0.6	1.1	0.8	1.2	0.6	0.8	1.0	0.9	0.8
193	1.1	1.2	1.2	1.3	1.1	1.1	1.3	0.1	1.3	0.2	0.4	1.2	0.3	1.1	1.1	1.0	0.0	0.2	1.3	1.2	0.1	0.2	0.1	0.3	0.2	1.2	0.4	0.5	0.1	0.4	1.3	0.0	1.2	1.5	0.4	1.3	0.4	1.2	0.4	0.4	0.1	0.2	0.3
194	0.1	1.3	0.0	1.0	1.1	1.1	0.7	0.1	0.9	0.9	0.8	0.9	0.3	0.0	0.1	1.2	0.0	0.9	0.1	0.1	1.1	0.2	1.1	0.9	0.9	0.1	2.3	2.8	0.1	2.7	0.0	1.2	2.4	0.4	0.4	1.1	0.4	1.2	2.6	0.8	1.0	0.2	0.8
195	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	1.3	1.3	0.4	0.2	0.3	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	1.3	1.6	1.3	1.5	1.3	1.3	1.2	1.5	1.4	1.3	1.5	1.2	0.4	1.5	1.2	1.3	1.3
196	0.1	0.0	0.0	0.2	0.0	0.0	0.3	1.3	0.2	1.3	0.4	0.2	0.3	0.0	1.1	0.1	1.2	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	1.3	0.4	0.5	0.1	0.4	0.0	0.0	0.0	0.7	0.6	1.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3
197	1.3	1.3	1.1	1.0	1.1	1.1	0.7	1.1	0.9	0.9	0.8	0.2	0.6	0.0	1.1	1.0	0.0	0.2	0.1	1.2	0.1	1.2	0.1	0.3	0.2	0.1	2.3	0.5	0.1	2.7	0.0	0.0	0.0	2.8	0.6	1.1	0.8	1.2	2.6	0.8	1.2	0.2	0.8
198	1.3	0.0	0.0	0.2	0.0	1.1	1.3	1.3	0.9	1.3	1.5	0.2	0.6	0.0	1.1	1.0	1.2	0.9	0.1	1.2	0.1	0.9	1.3	1.5	0.2	0.1	1.3	0.5	1.3	1.5	1.3	1.3	1.2	0.4	0.4	0.1	1.5	1.2	1.4	1.5	0.1	1.3	0.8
199	0.1	0.0	1.2	1.0	0.0	1.1	0.7	0.1	1.3	0.2	0.4	0.2	0.6	1.1	0.1	0.1	1.2	0.2	0.1	0.1	1.1	0.2	1.1	0.9	0.9	1.3	0.5	0.6	0.1	0.4	0.0	0.0	1.2	0.7	0.6	1.1	0.4	0.0	0.4	0.8	1.0	0.9	0.8
200	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	1.3	1.3	1.5	1.2	1.3	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	1.3	1.6	1.3	1.5	1.3	1.3	1.2	1.5	1.4	1.3	1.5	1.2	1.4	1.5	1.2	1.3	1.3
201	1.1	0.0	0.0	0.2	0.0	0.0	0.7	0.1	0.9	0.2	2.0	0.9	1.6	1.1	1.1	0.1	1.2	1.4	0.1	1.0	0.1	0.2	1.1	0.3	1.4	1.2	1.3	0.5	0.1	0.6	0.0	0.0	0.0	0.7	0.6	0.1	0.4	0.0	0.6	0.8	0.1	0.2	1.3
202	1.1	1.2	1.2	0.2	1.1	1.1	1.3	1.3	1.3	1.3	1.5	1.2	1.3	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	1.3	1.6	1.3	1.5	1.3	1.3	1.2	1.5	1.4	1.3	1.5	1.2	1.4	1.5	1.2	1.3	1.3
203	1.1	0.0	1.2	0.2	1.1	1.1	1.3	1.1	0.2	1.3	0.4	0.2	1.3	1.1	0.1	0.1	1.2	1.4	0.1	0.1	0.1	1.2	0.1	0.3	1.4	1.2	1.3	0.6	0.1	0.4	0.0	0.0	0.0	0.7	0.4	0.1	0.4	0.0	0.4	0.4	1.2	0.9	0.8
204	1.1	1.3	1.2	0.2	0.0	1.1	0.3	1.3	1.3	1.3	0.4	1.2	1.3	1.1	1.1	1.0	1.2	0.2	1.3	1.2	1.3	0.9	1.3	1.5	1.4	1.3	0.5	0.6	0.1	1.5	1.3	1.3	0.0	2.8	2.5	1.1	1.5	1.2	1.4	1.5	1.2	0.9	1.3
205	1.1	1.2	1.2	1.3	1.1	1.1	1.3	0.1	1.3	1.3	0.4	0.2	0.3	1.1	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.6	0.1	0.6	0.0	0.0	1.2	0.4	0.4	1.3	0.4	1.2	0.6	0.4	0.1	0.2	0.8
206	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	1.3	1.3	1.5	1.2	1.3	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	1.3	1.6	1.3	1.5	1.3	1.3	1.2	1.5	1.4	1.3	1.5	1.2	1.4	1.5	1.2	1.3	1.3
207	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	1.3	1.3	0.4	1.2	1.3	1.1	1.1	0.1	0.0	1.4	1.3	1.2	0.1	0.2	1.3	1.5	1.4	1.2	1.3	1.6	1.3	0.4	0.0	0.0	0.0	0.4	1.4	1.3	0.4	0.0	0.4	0.4	0.1	0.2	1.3
208	1.1	1.2	1.1	1.3	1.1	1.1	0.3	1.3	0.2	0.2	0.4	0.2	0.6	1.1	1.1	1.0	1.2	0.2	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	0.4	0.5	1.3	0.4	1.3	0.0	1.2	0.4	1.4	1.3	0.8	0.0	1.4	0.4	0.1	0.2	1.3
209	1.1	1.2	1.2	1.3	1.1	1.1	0.3	1.3	1.3	1.3	1.5	1.2	0.3	0.0	1.1	1.0	0.0	0.2	1.3	1.2	1.3	1.2	0.1	0.3	1.4	1.2	0.4	0.5	1.3	0.4	1.3	1.3	1.2	0.4	1.4	1.3	0.4	0.0	0.4	0.4	1.2	1.3	1.3
210	1.1	0.0	1.1	0.2	1.1	1.1	0.3	2.3	0.2	1.3	0.8	0.9	1.6	1.1	1.1	1.0	1.2	0.2	1.1	1.0	1.1	1.9	1.3	0.3	1.4	1.2	0.4	0.5	1.3	1.5	0.0	0.0	1.2	0.7	0.4	1.1	1.9	2.4	0.4	0.8	1.0	1.3	1.3
211	0.1	1.2	1.2	1.0	0.0	1.1	0.3	1.3	0.2	0.2	0.8	1.2	2.6	3.3	2.6	3.4	2.4	0.9	1.1	1.0	1.1	1.9	0.1	0.3	0.2	0.1	0.4	0.5	1.3	0.4	1.3	0.0	0.0	1.5	1.4	1.3	1.5	0.0	0.6	0.8	1.2	0.2	0.3
212	0.1	0.0	0.0	0.2	0.0	0.0	0.3	0.1	0.2	0.2	0.4	0.9	0.6	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.4	0.0	0.0	0.0	0.7	0.4	0.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3
213	1.1	1.2	0.0	1.0	1.1	1.1	0.7	1.3	0.9	1.3	0.8	1.2	1.3	1.1	1.4	1.2	1.2	0.9	1.3	1.2	1.3	1.2	1.3	1.5	2.1	1.2	1.4	1.7	1.3	1.5	1.3	1.2	1.2	0.7	0.6	1.1	0.8	1.2	1.4	1.5	1.0	1.3	1.3
214	1.1	1.2	1.1	1.3	1.1	1.1	0.3	1.3	1.3	1.3	0.4	1.2	0.6	1.1	0.1	1.0	1.2	1.4	0.1	1.2	0.1	0.2	1.3	0.3	0.2	1.2	1.3	0.5	1.3	1.5	0.0	0.0	1.2	0.4	0.6	1.3	0.4	1.2	0.4	1.5	1.2	0.2	0.3
215	1.3	0.0	1.1	2.2	0.0	0.0	0.7	0.1	0.9	0.2	0.8	0.9	0.6	1.1	0.1	0.1	0.0	0.9	1.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.4	0.0	0.6	0.4	1.2	1.3	1.3
216	1.3	1.3	0.0	1.0	0.0	0.0	0.3	1.1	0.2	0.2	0.4	0.2	0.6	0.0	1.1	1.0	0.0	0.9	1.1	1.0	1.1	0.9	0.1	1.5	0.2	0.1	0.4	0.5	0.1	0.4	1.3	0.0	0.0	0.4	1.4	0.1	0.4	0.0	0.4	0.8	0.1	0.2	0.3
217	0.1	1.2	1.2	1.3	1.1	1.1	0.3	0.1	0.2	0.2	0.4	0.2	0.3	1.1	1.1	1.0	1.2	0.2	0.1	0.1	0.1	0.2	1.3	0.3	0.2	1.2	0.5	0.6	0.1	0.4	1.3	0.0	0.0	0.4	0.4	0.1	0.4	0.0	1.4	0.4	0.1	0.2	0.3
218	0.1	0.0	2.2	2.2	0.0	1.1	1.3	0.1	0.9	0.2	0.4	0.2	1.3	0.0	0.1	0.1	1.2	0.9	1.1	1.0	1.1	0.9	1.1	0.9	0.9	1.3	0.5	0.6	0.1	0.4	1.3	1.2	1.2	0.7	0.4	0.1	1.5	0.0	0.6	0.4	1.0	1.9	1.8
219	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.1	0.9	0.9	0.4	1.2	1.3	1.1	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	1.1	1.5	1.4	1.2	1.3	1.6	1.3	1.5	1.3	1.3	3.6	2.8	1.4	1.3	1.5	1.2	0.6	0.8	0.1	0.2	0.8
220	1.1	1.2	1.2	1.3	1.1	1.1	1.3	0.1	1.3	1.3	1.5	1.2	0.3	1.1	1.1	1.0	1.2	0.2	0.1	1.2	1.3	0.2	1.3	1.5	1.4	1.2	1.3	1.6	0.1	0.4	1.3	1.3	1.2	0.4	1.4	0.1	1.5	1.2	1.4	1.5	1.2	1.3	0.3
221	1.1	1.2	1.1	1.0	1.1	1.1	0.7	1.3	1.3	1.3	1.5	1.2	1.3	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	1.4	0.1	1.3	1.6	1.3	1.5	1.3	1.3	1.2	0.4	0.4	0.1	0.4	0.0	0.4	0.4	1.2	1.3	1.3
222	0.1	1.2	1.2	1.3	1.1	1.1	0.3	1.1	1.3	1.3	0.4	0.2	1.3	1.1	1.4	1.2	1.2	1.4	1.3	1.2	1.3	1.2	0.1	0.3	1.4	1.2	0.4	0.5	0.1	1.5	1.3	0.0	1.2	1.5	1.4	1.3	0.4	0.0	0.4	1.5	1.2	1.3	1.3
223	0.1	0.0	1.2	0.2	1.1	1.1	0.3	2.3	1.3	1.3	0.4	0.2	1.3	0.0	0.1	3.4	1.2	0.9	1.1	3.2	0.1	2.9	2.3	2.1	0.9	0.1	0.5	0.6	0.1	0.6	1.3	0.0	0.0	1.5	1.4	0.1	0.4	0.0	0.4	0.4	2.1	1.9	1.8
224	0.1	0.0	0.0	1.0	1.1	0.0	0.7	0.1	0.2	1.3	0.4	0.2	1.3	0.0	1.1	1.0	0.0	0.2	1.3	0.1	0.1	1.2	0.1	0.3	0.2	1.2	1.3	0.5	1.3	0.4	0.0	1.2	0.0	0.7	1.4	1.3	0.4	0.0	1.4	0.4	0.1	0.2	0.3
225	0.1	0.0	1.2	1.3	0.0	0.0	0.3	1.1	0.2	0.2	1.5	0.2	0.3	1.1	0.1	1.0	0.0	0.9	0.1	0.1	0.1	0.9	1.3	1.5	0.2	0.1	1.3	0.5	0.1	0.6	0.0	1.2	1.2	1.5	0.4	0.1	0.4	1.2	1.4	1.5	1.2	1.3	1.3

Z-Score test: Pecentage of |Z| score >3.29

Sets	A1	A2	A3	A4	A5	A6	A7	B1	C1	C2	C3	C4	C5	C6	D1	D2	D3	D4	D5	D6	D7	D8	E1	E2	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	F7	F8	G1	G2	G3	G4	G5	G6	G7
226	1.1	0.0	0.0	0.2	0.0	0.0	0.3	1.3	0.2	0.9	0.4	0.2	0.6	1.1	0.1	1.0	1.2	0.2	1.1	1.0	1.3	0.9	0.1	0.3	1.4	1.2	1.3	0.5	0.1	0.6	1.3	1.2	1.2	0.4	0.4	0.1	0.4	0.0	0.4	0.8	1.0	1.3	0.3
227	1.1	1.2	1.2	0.2	1.1	1.1	0.3	1.3	1.3	1.3	0.4	1.2	0.3	0.0	0.1	0.1	0.0	0.2	1.1	0.1	0.1	1.2	1.3	1.5	0.2	1.2	0.4	0.6	0.1	0.4	0.0	0.0	0.0	1.5	1.4	1.3	0.4	0.0	0.4	0.4	0.1	0.2	0.3
228	0.1	0.0	0.0	1.3	1.1	1.1	1.3	0.1	0.2	0.9	0.8	0.2	0.3	1.1	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.4	0.0	0.0	1.2	0.7	0.6	1.1	0.4	1.2	1.4	0.4	0.1	0.2	0.3
229	0.1	0.0	0.0	0.2	0.0	0.0	0.3	0.1	0.2	0.2	0.4	0.2	0.3	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3
230	0.1	0.0	0.0	0.2	0.0	0.0	0.3	1.1	0.2	0.2	0.4	0.2	0.3	0.0	0.1	0.1	0.0	0.9	1.1	1.0	1.1	0.9	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.4	0.0	0.4	0.4	0.1	1.3	1.3
231	1.3	1.3	1.1	0.2	2.2	1.1	0.7	0.1	0.9	0.2	0.4	2.0	1.6	1.1	0.1	0.1	1.2	2.0	1.1	2.1	1.1	1.9	1.1	0.9	0.9	0.1	0.4	0.6	0.1	0.4	1.3	1.2	1.2	0.7	0.4	0.1	0.8	1.2	0.6	0.8	2.1	1.9	0.8
232	1.3	1.3	1.1	1.0	1.1	2.3	1.7	1.1	2.1	2.1	2.0	2.0	0.6	1.1	0.1	1.2	0.0	0.9	0.1	0.1	0.1	1.2	0.1	0.3	0.9	0.1	1.3	1.6	0.1	0.4	1.3	0.0	1.2	0.4	1.4	0.1	0.4	0.0	1.4	0.4	0.1	1.3	1.3
233	0.1	1.2	1.2	2.2	1.1	1.1	1.3	2.3	0.9	0.2	0.4	1.2	0.6	1.1	1.1	1.0	1.2	0.9	0.1	0.1	0.1	2.9	0.1	1.5	0.2	1.2	1.3	1.6	0.1	1.5	1.3	1.2	0.0	0.7	1.4	1.3	1.9	1.2	0.6	0.4	0.1	0.9	0.8
234	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	1.3	1.3	1.5	1.2	1.3	2.2	1.4	1.2	0.0	0.2	1.1	1.0	1.1	0.9	1.1	0.9	2.1	0.1	0.4	0.6	1.4	0.4	0.0	0.0	1.2	1.8	0.6	0.1	1.5	0.0	0.6	0.8	0.1	0.9	0.8
235	0.1	0.0	1.2	0.2	0.0	0.0	0.3	1.1	1.3	0.2	0.4	0.2	0.6	2.2	2.6	1.2	2.4	2.0	1.1	1.0	1.1	1.9	2.3	2.1	2.1	0.1	0.5	1.7	0.1	0.4	0.0	1.2	1.2	1.8	1.5	2.3	1.9	2.4	0.4	1.9	2.1	1.9	0.8
236	1.3	1.3	1.1	0.2	0.0	0.0	0.7	0.1	1.3	1.3	0.4	3.1	1.3	2.2	1.1	0.1	1.2	2.0	2.3	0.1	2.3	1.9	3.5	3.3	0.2	0.1	2.3	2.8	0.1	0.4	1.3	3.8	2.4	1.5	2.5	1.3	3.1	3.7	2.6	3.0	3.3	3.0	2.8
237	1.1	0.0	0.0	0.2	0.0	0.0	0.3	0.1	1.3	1.3	1.5	0.9	0.3	0.0	0.1	1.0	1.2	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	1.3	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.8	1.2	0.4	0.4	0.1	0.2	0.8
238	2.6	1.3	1.1	2.2	0.0	0.0	1.3	1.1	0.2	0.2	0.8	0.2	0.6	2.2	1.4	2.3	1.2	2.0	2.3	3.2	2.3	2.9	2.3	2.1	2.1	0.1	0.5	1.7	2.8	0.6	0.0	2.5	2.4	0.7	0.4	0.1	1.9	2.4	1.6	1.9	3.3	1.9	2.8
239	1.1	0.0	0.0	1.3	1.1	1.1	1.3	0.1	0.2	1.3	0.4	1.2	0.3	1.1	1.1	1.0	1.2	0.2	1.3	1.2	0.1	0.2	0.1	1.5	0.2	0.1	0.4	0.5	1.3	1.5	0.0	0.0	1.2	1.5	1.4	0.1	1.5	1.2	1.4	1.5	0.1	1.3	1.3
240	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	0.9	0.9	0.4	1.2	1.3	1.1	0.1	1.2	0.0	0.9	0.1	0.1	0.1	1.2	1.3	1.5	1.4	1.2	0.4	0.5	1.3	1.5	1.3	1.3	0.0	1.5	1.4	1.3	0.4	0.0	1.4	0.4	1.0	0.9	1.8
241	0.1	0.0	1.2	1.0	1.1	1.1	0.3	1.1	0.9	0.2	0.4	0.2	0.6	0.0	0.1	1.2	1.2	1.4	1.3	0.1	1.3	1.2	0.1	0.3	0.2	0.1	0.5	0.6	0.1	0.6	1.3	0.0	0.0	0.4	0.4	1.3	0.4	0.0	0.4	0.4	1.0	0.2	0.8
242	1.1	0.0	1.2	0.2	1.1	1.1	0.3	1.3	0.2	0.2	0.4	0.2	1.3	0.0	1.1	1.0	0.0	0.2	0.1	1.2	1.3	0.2	0.1	0.3	0.2	0.1	1.3	1.6	1.3	1.5	0.0	0.0	0.0	0.4	1.4	0.1	0.4	0.0	1.4	1.5	0.1	1.3	1.3
243	0.1	0.0	0.0	0.2	1.1	1.1	1.3	0.1	1.3	0.2	0.4	1.2	1.3	1.1	0.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	1.3	0.5	0.1	1.5	1.3	1.3	0.0	0.4	0.4	1.3	0.4	0.0	0.4	0.4	0.1	0.2	0.3
244	2.6	1.3	0.0	0.2	1.1	0.0	1.3	1.3	0.9	0.2	1.5	0.2	1.3	1.1	1.1	0.1	1.2	0.9	0.1	1.2	0.1	0.2	1.3	0.3	0.2	1.2	0.4	1.6	1.3	0.4	1.3	0.0	0.0	0.4	1.4	0.1	0.4	1.2	0.4	1.5	0.1	1.3	1.3
245	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	1.3	1.3	0.4	0.2	1.3	0.0	1.1	0.1	1.2	0.2	0.1	0.1	1.3	0.2	1.3	1.5	1.4	1.2	1.3	1.6	1.3	1.5	1.3	1.3	0.0	1.5	1.4	0.1	0.4	1.2	0.4	1.5	1.2	1.3	1.3
246	1.1	1.2	0.0	0.2	1.1	1.1	0.7	1.1	0.9	0.9	0.4	0.9	0.3	1.1	1.1	1.0	0.0	0.2	0.1	0.1	0.1	1.2	1.3	1.5	0.2	1.2	0.4	0.5	0.1	0.4	0.0	0.0	0.0	0.7	0.6	1.1	0.8	1.2	0.6	0.8	1.0	0.9	0.8
247	1.1	1.2	1.2	1.3	1.1	0.0	0.3	1.3	1.3	0.2	0.4	1.2	1.3	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	1.3	1.6	1.3	1.5	1.3	1.3	1.2	1.5	1.4	1.3	1.5	1.2	1.4	1.5	1.2	1.3	1.3
248	0.1	0.0	1.2	0.2	0.0	0.0	0.3	1.3	0.2	0.2	0.4	0.2	0.3	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3
249	0.1	1.2	1.2	0.2	1.1	1.1	0.3	0.1	0.2	0.2	0.8	0.2	0.3	0.0	1.1	1.0	0.0	0.2	0.1	1.0	0.1	0.2	1.1	0.9	0.9	0.1	0.4	0.5	1.4	1.5	0.0	0.0	0.0	0.4	0.4	0.1	0.4	1.2	0.6	0.4	0.1	0.2	0.3
250	0.1	0.0	0.0	0.2	0.0	0.0	0.3	0.1	0.2	0.2	0.4	0.2	0.3	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3
251	0.1	1.3	1.1	1.0	1.1	1.1	0.7	1.1	0.9	2.1	2.0	3.1	2.6	1.1	1.1	0.1	1.2	2.0	1.1	1.2	0.1	1.2	1.3	1.5	1.4	1.2	0.5	1.6	1.4	0.6	1.3	1.3	1.2	2.8	0.6	1.1	0.8	1.2	1.6	0.8	1.0	1.3	1.3
252	1.3	0.0	0.0	1.0	0.0	0.0	0.7	0.1	0.2	0.2	0.8	0.9	0.3	0.0	0.1	0.1	0.0	0.9	1.3	1.2	0.1	0.2	0.1	0.3	0.9	0.1	0.4	0.5	0.1	0.4	1.3	0.0	0.0	0.4	1.5	1.1	0.8	1.2	0.6	0.8	1.0	0.9	0.8
253	1.1	1.2	1.2	1.3	1.1	0.0	1.3	1.3	1.3	1.3	1.5	1.2	2.6	3.3	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	1.4	1.6	1.3	1.5	1.3	1.3	1.2	1.5	1.4	1.3	1.5	1.2	1.4	1.5	1.2	0.9	0.8
254	0.1	1.3	0.0	0.2	0.0	1.1	0.3	0.1	0.2	1.3	0.4	0.2	0.3	0.0	1.4	0.1	1.2	0.9	1.1	1.0	1.1	0.9	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.4	0.0	1.2	1.2	0.4	0.4	0.1	0.4	0.0	0.4	1.5	0.1	0.2	0.3
255	0.1	0.0	0.0	1.0	1.1	0.0	0.7	1.1	0.9	1.3	0.4	1.2	0.3	0.0	1.1	0.1	0.0	0.2	1.1	1.0	1.1	0.9	0.1	0.9	0.9	1.3	0.4	0.6	0.1	0.6	1.3	1.2	1.2	0.4	0.6	1.1	0.8	1.2	0.4	0.4	1.0	0.9	0.8
256	1.1	1.2	1.2	1.0	1.1	1.1	1.3	1.3	0.9	0.2	0.4	1.2	1.3	1.1	1.1	1.0	1.2	0.2	0.1	1.2	1.3	0.9	1.3	1.5	1.4	1.2	1.3	1.6	1.3	1.5	1.3	1.3	1.2	0.7	0.6	1.1	1.5	1.2	1.4	1.5	1.2	1.3	1.3
257	1.3	0.0	0.0	0.2	0.0	0.0	1.3	1.1	1.3	1.3	1.5	1.2	0.3	1.1	1.1	1.0	1.2	0.2	0.1	1.2	0.1	0.9	1.3	0.3	0.2	0.1	1.3	0.5	0.1	0.6	0.0	1.2	1.2	0.7	0.6	1.1	0.4	0.0	0.4	0.4	0.1	0.2	1.3
258	1.1	1.2	1.2	0.2	1.1	1.1	1.3	1.3	1.3	1.3	1.5	1.2	1.3	1.1	1.4	0.1	1.2	0.9	0.1	0.1	1.3	0.9	1.3	0.3	1.4	1.2	0.5	0.6	0.1	1.5	1.3	0.0	0.0	1.5	1.4	1.3	0.4	0.0	0.4	1.5	1.2	1.3	1.3
259	1.1	0.0	0.0	0.2	0.0	0.0	0.3	0.1	0.2	0.2	0.4	0.2	0.3	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3
260	0.1	1.3	2.2	0.2	1.1	1.1	0.3	1.1	0.2	0.2	0.8	0.2	0.6	0.0	0.1	1.2	0.0	0.9	2.3	1.0	2.3	0.2	0.1	0.9	0.2	1.2	0.4	0.6	0.1	0.4	0.0	0.0	1.2	0.4	0.4	1.1	0.4	1.2	0.4	0.8	0.1	1.3	0.3
261	0.1	1.3	1.1	0.2	0.0	0.0	0.7	0.1	0.9	0.9	0.4	1.2	0.6	1.1	0.1	1.2	0.0	0.2	0.1	1.0	0.1	0.2	0.1	0.9	0.9	0.1	0.4	0.6	1.4	0.4	0.0	1.2	2.4	0.4	1.5	1.1	0.8	1.2	1.4	0.4	0.1	1.9	0.3
262	0.1	1.3	0.0	1.0	0.0	1.1	0.7	1.1	0.2	0.2	1.5	0.2	0.3	0.0	0.1	0.1	0.0	0.9	0.1	0.1	1.1	0.2	0.1	0.3	0.2	0.1	0.5	0.6	0.1	0.4	1.3	1.3	0.0	0.4	0.4	0.1	0.4	1.2	0.4	0.4	0.1	0.2	0.8
263	1.1	1.2	1.1	1.0	1.1	1.1	0.7	1.1	0.9	0.9	2.0	2.0	1.6	0.0	1.4	1.2	1.2	0.9	1.1	1.0	1.1	0.9	1.1	0.9	0.9	1.3	0.5	0.6	1.4	0.6	1.3	1.2	1.2	0.7	0.6	1.1	0.8	1.2	0.6	0.8	1.0	0.9	0.8
264	0.1	1.2	1.2	1.3	0.0	1.1	0.7	1.1	1.3	1.3	1.5	1.2	0.6	1.1	0.1	0.1	1.2	0.2	2.3	1.0	1.1	0.9	1.1	0.9	0.9	0.1	0.5	0.6	0.1	0.4	0.0	1.2	1.2	0.7	0.4	0.1	1.5	1.2	1.4	0.8	0.1	0.9	0.3
265	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.1	1.3	1.3	0.8	1.2	0.6	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	0.9	1.3	1.5	1.4	1.3	1.3	1.6	1.3	0.6	0.0	1.3	1.2	1.5	1.4	1.3	1.5	1.2	0.6	1.5	1.2	1.3	1.3
266	0.1	1.2	1.2	0.2	0.0	0.0	0.3	1.1	0.2	0.2	0.4	0.2	0.3	1.1	0.1	0.1	0.0	0.2	0.1	1.0	1.1	0.9	0.1	0.9	0.2	0.1	0.4	0.5	1.4	0.4	0.0	1.2	0.0	0.4	0.6	1.1	0.8	1.2	0.6	0.8	1.0	0.9	0.8
267	0.1	1.3	1.2	0.2	0.0	0.0	0.3	0.1	0.2	0.2	0.8	0.2	0.3	1.1	0.1	0.1	0.0	0.9	1.1	1.0	1.1	0.9	1.1	0.9	0.2	0.1	0.4	0.5	0.1	0.4	0.0	1.3	0.0	0.7	0.6	1.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3
268	0.1	2.5	1.1	1.0	0.0	0.0	0.3	1.1	0.2	0.2	1.5	1.2	1.3	2.2	2.6	2.3	2.4	2.0	0.1	0.1	1.3	1.2	1.1	0.9	0.9	1.2	1.4	1.7	1.3	1.5	1.3	1.2	1.2	1.5	1.5	1.3	1.9	0.0	0.4	0.4	3.3	3.0	2.8
269	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	1.3	1.3	1.5	1.2	1.3	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	1.3	1.6	1.3	1.5	1.3	1.3	1.2	1.5	1.4	1.3	1.5	1.2	1.4	1.5	1.2	1.3	1.3
270	0.1	0.0	0.0	1.0	1.1	1.1	0.7	1.1	0.9	0.9	0.8	0.9	0.6	1.1	1.4	1.2	1.2	0.9	1.1	1.0	1.1	0.9	1.1	0.9	0.9	1.3	0.5	0.6	0.1	0.6	0.0	1.2	0.0	1.5	1.4	1.3	0.8	0.0	0.6	0.4	1.0	0.9	0.3

Z-Score test: Pecentage of |Z| score >3.29

Sets	A1	A2	A3	A4	A5	A6	A7	B1	C1	C2	C3	C4	C5	C6	D1	D2	D3	D4	D5	D6	D7	D8	E1	E2	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	F7	F8	G1	G2	G3	G4	G5	G6	G7
271	1.1	1.2	1.2	1.0	1.1	1.1	1.3	1.3	1.3	1.3	1.5	1.2	1.3	1.1	1.1	0.1	0.0	0.2	0.1	1.0	1.3	1.2	1.3	1.5	0.2	1.2	1.3	1.6	1.3	1.5	1.3	1.3	1.2	0.4	0.4	0.1	1.5	1.2	0.4	1.5	1.2	1.3	1.3
272	0.1	1.3	0.0	1.0	0.0	1.1	0.3	1.1	0.2	0.9	0.8	2.0	1.6	0.0	0.1	0.1	0.0	0.9	0.1	0.1	1.1	0.2	0.1	0.3	0.9	1.2	0.5	0.6	0.1	1.5	0.0	0.0	0.0	0.7	0.4	0.1	0.8	0.0	0.4	0.4	1.0	0.9	0.8
273	1.3	1.2	1.2	1.3	3.3	3.4	2.7	1.3	3.2	2.1	2.0	2.0	0.6	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	1.3	1.6	1.3	1.5	1.3	1.3	1.2	2.8	2.5	1.3	1.5	1.2	1.4	1.5	1.2	1.3	1.3
274	0.1	0.0	0.0	0.2	0.0	0.0	0.3	0.1	0.2	0.2	0.4	0.2	0.3	0.0	0.1	0.1	0.0	0.9	0.1	1.0	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.4	0.0	0.0	1.2	0.7	0.4	0.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3
275	0.1	1.2	0.0	0.2	1.1	1.1	0.3	1.3	0.2	1.3	1.5	1.2	1.3	1.1	0.1	0.1	0.0	0.9	1.1	1.0	0.1	0.2	0.1	0.3	1.4	1.2	0.4	0.6	1.3	1.5	1.3	0.0	0.0	0.4	0.4	0.1	0.4	0.0	0.4	0.4	1.0	1.3	1.3
276	0.1	1.2	0.0	0.2	1.1	1.1	0.3	0.1	0.2	1.3	0.4	0.2	1.3	1.1	0.1	0.1	0.0	0.9	0.1	1.0	0.1	0.2	0.1	0.3	0.2	1.2	0.4	0.5	0.1	1.5	1.3	0.0	0.0	0.4	0.4	0.1	0.4	0.0	0.4	0.4	1.2	1.3	1.3
277	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	1.3	1.3	1.5	1.2	1.3	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	0.9	1.3	1.5	1.4	1.2	1.3	1.6	1.3	1.5	1.3	1.3	1.2	0.7	1.4	1.3	1.5	1.2	1.4	1.5	1.2	3.0	2.8
278	0.1	1.2	1.2	1.0	1.1	1.1	0.7	2.3	2.1	2.1	2.0	0.9	0.6	1.1	1.1	0.1	1.2	0.9	1.1	2.1	1.1	1.9	2.3	2.1	2.1	1.3	0.4	0.5	1.4	0.4	0.0	1.2	0.0	0.7	0.6	0.1	0.8	0.0	0.6	0.8	1.0	0.2	0.8
279	1.3	1.2	0.0	0.2	1.1	0.0	0.7	1.1	1.3	0.2	0.8	0.2	1.3	2.2	1.1	1.0	1.2	0.9	1.1	1.0	0.1	0.9	0.1	0.3	0.9	1.2	0.5	0.5	1.4	0.4	1.3	1.2	0.0	0.7	1.4	0.1	1.5	0.0	1.6	1.5	1.0	0.9	0.8
280	0.1	0.0	1.2	1.0	1.1	0.0	0.7	0.1	1.3	0.2	0.4	0.2	1.3	1.1	1.4	0.1	0.0	0.9	1.1	1.0	1.1	0.9	1.3	1.5	1.4	1.3	0.5	0.5	0.1	0.6	1.3	1.3	1.2	1.8	1.5	0.1	0.8	0.0	0.6	0.4	1.0	0.9	0.8
281	1.1	0.0	1.1	1.0	1.1	1.1	2.7	1.1	2.1	2.1	2.0	3.1	0.6	0.0	0.1	0.1	1.2	0.9	1.1	1.0	2.3	1.9	0.1	0.3	0.9	0.1	1.4	1.7	0.1	0.4	0.0	0.0	1.2	1.8	2.5	3.5	0.4	0.0	0.4	0.4	0.1	0.2	0.3
282	2.6	2.5	1.1	1.0	1.1	1.1	0.7	1.1	0.9	0.9	0.8	0.9	0.6	1.1	1.4	1.2	1.2	0.9	1.1	1.0	1.1	0.9	1.1	0.9	0.9	0.1	0.4	0.5	0.1	0.4	1.3	0.0	0.0	0.4	0.4	0.1	0.4	0.0	0.6	0.4	1.0	0.2	0.3
283	0.1	0.0	0.0	0.2	0.0	1.1	0.3	0.1	0.2	0.2	0.4	0.2	0.3	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	1.4	0.6	0.1	0.6	0.0	0.0	0.0	0.7	0.4	0.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3
284	0.1	0.0	0.0	0.2	0.0	0.0	0.3	0.1	0.2	0.2	0.4	1.2	1.3	1.1	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	1.5	0.2	0.1	1.3	0.5	0.1	0.4	1.3	0.0	1.2	0.4	0.4	0.1	0.4	0.0	0.4	0.4	0.1	0.2	1.3
285	0.1	0.0	1.2	1.0	1.1	0.0	0.3	1.1	0.2	0.2	0.4	0.2	0.3	1.1	1.4	1.2	0.0	0.9	1.1	1.0	0.1	0.2	1.1	0.9	0.2	0.1	0.4	0.5	0.1	0.4	0.0	0.0	1.2	0.4	0.4	0.1	0.8	0.0	0.6	0.4	2.1	1.9	0.8
286	1.1	0.0	1.2	0.2	1.1	1.1	1.3	1.1	1.3	1.3	0.4	0.2	1.3	1.1	0.1	0.1	0.0	0.9	0.1	0.1	0.1	0.9	0.1	0.3	0.2	1.2	0.4	0.6	0.1	1.5	1.3	1.3	1.2	0.7	0.4	0.1	0.8	0.0	0.6	0.8	0.1	0.2	0.3
287	1.1	1.2	0.0	1.0	0.0	1.1	1.3	1.3	1.3	1.3	1.5	1.2	1.3	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	0.4	0.5	1.3	0.6	1.3	0.0	1.2	1.5	1.4	1.3	0.8	1.2	0.4	0.8	1.2	0.2	0.3
288	1.1	0.0	1.1	1.0	1.1	1.1	1.7	0.1	0.9	0.2	0.4	0.9	0.6	1.1	1.1	0.1	1.2	1.4	1.3	0.1	1.3	1.2	1.3	0.3	1.4	1.2	1.3	0.5	0.1	0.4	0.0	1.3	1.2	1.5	1.4	1.3	0.4	0.0	0.6	0.8	0.1	0.2	1.8
289	1.1	1.2	1.2	1.3	1.1	1.1	0.3	0.1	1.3	1.3	1.5	1.2	1.3	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.1	0.3	0.2	1.2	0.5	0.6	1.3	1.5	1.3	1.3	1.2	1.5	1.4	1.3	1.5	1.2	0.6	1.5	0.1	0.2	0.3
290	0.1	1.2	1.2	0.2	0.0	0.0	0.3	1.1	1.3	0.2	0.4	1.2	0.6	2.2	0.1	1.0	1.2	0.2	0.1	1.0	1.1	1.9	1.1	0.9	0.2	1.2	1.3	1.6	0.1	1.5	0.0	0.0	1.2	0.7	0.6	0.1	0.4	1.2	0.4	1.5	0.1	0.2	0.3
291	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	1.3	1.3	1.5	1.2	1.3	1.1	1.4	1.2	1.2	0.2	1.3	1.0	0.1	1.2	1.1	0.9	0.9	1.2	0.5	0.6	1.3	1.5	1.3	1.3	1.2	1.5	1.4	1.3	1.5	0.0	1.4	1.5	1.2	1.3	1.3
292	0.1	1.3	0.0	0.2	0.0	0.0	0.3	1.1	0.2	1.3	1.5	0.2	0.6	1.1	0.1	1.2	0.0	0.9	1.1	0.1	0.1	0.9	0.1	0.9	0.9	0.1	0.5	0.6	0.1	0.6	0.0	0.0	0.0	1.8	0.6	1.1	0.8	0.0	0.4	0.4	1.0	0.9	0.8
293	0.1	1.2	0.0	1.3	1.1	1.1	1.3	0.1	1.3	1.3	0.4	1.2	0.6	0.0	1.4	1.0	0.0	0.2	1.3	1.2	1.3	1.2	0.1	0.3	0.9	1.2	0.5	0.6	1.3	0.6	1.3	1.2	1.2	1.5	1.4	1.3	0.4	1.2	0.6	0.8	1.2	0.9	0.8
294	0.1	0.0	1.1	0.2	0.0	0.0	0.7	0.1	0.9	0.9	0.8	0.2	2.6	3.3	0.1	0.1	0.0	2.0	0.1	0.1	0.1	0.9	0.1	0.3	0.2	0.1	0.5	0.6	0.1	0.6	0.0	0.0	1.2	0.7	0.4	0.1	1.9	1.2	0.4	0.8	1.2	1.3	1.3
295	0.1	0.0	1.1	0.2	0.0	0.0	0.7	0.1	0.2	0.2	0.4	0.2	0.3	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.9	0.2	0.1	0.5	0.6	1.4	0.6	0.0	0.0	0.0	1.8	1.5	1.1	0.8	1.2	0.6	0.8	1.0	0.9	0.8
296	1.1	1.2	1.1	1.0	0.0	0.0	0.3	0.1	0.2	1.3	2.0	0.9	0.6	0.0	0.1	0.1	1.2	0.9	1.1	0.1	0.1	2.9	1.1	0.9	2.1	0.1	0.5	0.6	1.4	0.6	1.3	2.5	1.2	0.4	0.4	1.3	0.8	1.2	0.6	0.4	0.1	0.9	0.8
297	1.1	1.3	0.0	1.3	1.1	0.0	1.3	1.1	0.2	1.3	0.8	0.2	1.3	1.1	1.1	1.0	1.2	0.2	1.3	1.2	1.3	1.2	1.3	1.5	0.2	1.2	1.3	1.6	1.3	0.4	0.0	0.0	1.2	1.5	1.4	1.3	0.8	1.2	0.6	0.4	1.2	0.2	0.3
298	1.1	0.0	0.0	0.2	1.1	1.1	1.3	1.1	0.2	0.2	0.8	1.2	0.6	1.1	3.8	2.3	1.2	3.2	2.3	3.2	2.3	1.9	1.1	0.9	0.2	0.1	0.5	0.6	0.1	0.6	0.0	0.0	0.0	0.4	0.4	0.1	0.4	2.4	0.4	0.4	2.1	0.2	0.3
299	0.1	0.0	0.0	0.2	0.0	0.0	0.3	0.1	0.2	0.2	0.4	0.2	1.3	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.6	0.0	0.0	0.0	0.4	0.4	0.1	0.4	0.0	0.6	0.4	1.0	0.2	0.8
300	1.1	1.2	1.2	1.3	1.1	0.0	0.3	1.3	0.2	0.2	0.8	1.2	0.6	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	1.2	1.3	1.5	0.2	0.1	0.5	0.6	0.1	0.4	1.3	0.0	1.2	0.7	0.4	1.1	0.4	0.0	0.4	0.8	0.1	0.2	0.3
301	0.1	0.0	2.2	2.2	2.2	2.3	1.7	0.1	0.9	0.9	0.8	0.9	0.6	0.0	0.1	0.1	0.0	0.9	1.1	0.1	1.1	0.2	0.1	0.9	0.9	0.1	0.4	0.6	0.1	0.6	1.3	0.0	0.0	0.7	0.4	1.1	0.8	0.0	0.4	0.8	0.1	0.9	0.8
302	1.1	1.2	1.1	0.2	1.1	0.0	0.3	0.1	0.9	1.3	0.8	0.2	0.6	1.1	1.1	1.0	0.0	0.2	1.3	1.2	0.1	0.2	0.1	0.3	0.2	1.2	1.3	1.6	1.3	0.6	1.3	0.0	0.0	1.5	0.4	0.1	0.4	0.0	0.4	0.4	1.2	0.2	0.3
303	0.1	1.3	0.0	0.2	0.0	1.1	0.3	0.1	0.2	0.2	0.4	0.2	0.3	0.0	0.1	0.1	0.0	0.2	0.1	0.1	0.1	0.2	0.1	0.3	0.2	0.1	0.4	0.5	0.1	0.4	0.0	0.0	0.0	0.4	0.4	0.1	0.4	0.0	0.4	0.4	0.1	0.2	0.3
304	1.1	1.2	1.2	1.3	1.1	1.1	1.3	1.3	1.3	1.3	1.5	1.2	1.3	1.1	1.1	1.0	1.2	1.4	1.3	1.2	1.3	1.2	1.3	1.5	1.4	1.2	1.3	1.6	1.3	1.5	1.3	1.3	1.2	1.5	1.4	1.3	1.5	1.2	1.4	1.5	1.2	1.3	1.3
No. of cases Z > 3.25	1	1	2	1	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% cases Z > 3.25	0.33	0.33	0.66	0.33	0.66	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Remark: |Z|> 3.29

Zero case with percentage of |Z| score greater than one (1)

APPENDIX 6

QUESTIONNAIRE FOR EXPERT INTERVIEWS ON BWM AND MATURITY LEVEL REFINEMENT

AUN/SEED-Net

QUESTIONNAIRE

Establishing the weight of Attributes Contributing to Better Construction Waste Management in Building Construction

Dear Sir/ Madam,

I would like to seek your input in completing a survey that is part of double Ph.D. degree research that seeks to improve construction waste management (CWM). This double Ph.D. degree research is sponsored by the AUN/SEED-Net Collaborative Education Program (CEP) under the supervision of Assoc. Prof. Dr. Kriengsak PANUWATWANICH (at Sirindhorn International Institute of Technology, Thammasat University) and Assoc. Prof. Dr. Koji MATSUMOTO (at Hokkaido University).

About this survey

The aim of this survey is to compare the significant of attributes/ factors contributing to the better performance of CWM which will then be used as the input for establishing the weight of each attribute. The survey is the phase of the development process of the assessment model for CWM. You have been identified as an expert who can provide valuable input to this survey.

Confidentiality

The information will be used for academic purposes only. All information collected will be stored securely, and you will not be identified at any point in this research. Any reporting or summaries derived from the data will be presented in an aggregated form, without any individual identification or specific answers.

Questionnaire structure

This questionnaire contains three pages and consists of two main parts. Part I: Background of you and your company. Part II: Comparing the effect level among the attributes/ factors on the better performance of construction waste management.

Duration of the survey

The survey takes approximately 20 minutes to complete, and it would be very much appreciated if you could kindly finish it on or before **6th May 2024**.

The research team would be most grateful for your time and consideration in contributing to this research.

Please direct any inquiries about this research to:

Mr. Vuthea MIN (Doctoral Researcher), Email: minvuthea@gmail.com, Cell No.: +66-905909078

Thanks, and regards,

30th April 2024

Vuthea MIN	**Assoc. Prof. Dr. Kriengsak PANUWATWANICH**	**Assoc. Prof. Dr. Koji MATSUMOTO**
SIIT, Thammasat University, Thailand, and Hokkaido University, Japan	SIIT, Thammasat University, Thailand	Hokkaido University, Japan

BEST WORST METHOD ASSESSMENT FORM

Part I: Background Information

Note: Respondents are expected to have a minimum of approximately 10 years experience in building construction management.

Please provide the necessary information.

1.1) Country where your company is located (i.e., Cambodia or Thailand)

____

1.2) Your current position within your company:

____

1.3) Your highest level of education (e.g. master's degree in construction management):

____

1.4) Your years of experience in the construction industry:

____

1.5) Your professional qualification (e.g. Professional Engineer (PE))

____

Part II: Comparing the Effect Level Among the Attributes/ Factors on the Better Performance of Construction Waste Management

Construction Waste Management (CWM) is defined as the application of knowledge, skills, tools and techniques to construction activities to minimize construction waste (CW). There are five "main factors" could affect contractor's CWM at construction site, namely Governance and policy (GP), Material and equipment (ME), Requirements and specifications (RS), Construction information system (CIS), and Waste collection facilities (WCF). Each factor consists of several attributes as listed detailed below.

A) ATTRIBUTES

Governance and policy (GP)

2.1. Governance and policy (GP) is a factor that could contribute to the Better Performance of CWM. This factor consists of ***8 attributes***. To the best of your knowledge and experience, which is the MOST and the LEAST important attribute? Please select (X) ***one attribute as the MOST important*** and ***one attribute as the LEAST important***.

Code	Main criteria/ attribute	Most important	Least important
GP1	Properly following a WM plan		
GP2	Supervision of WM activities with clear instructions		
GP3	Establishment of a strict CWM policy within the company (including the CWM system)		
GP4	Implementing an effective organizational structure for WM		
GP5	Monitoring and auditing waste management systems periodically (e.g., every 3 months)		
GP6	Establishment of an appropriate WM plan in the earlier stage of each construction project		
GP7	Senior management's commitment to implementing waste management (WM) practices		
GP9	Including subcontractor responsibilities for WM targets in the contract		

2.2. You have selected X as the most important attribute. Please compare the importance of this attribute over the other attributes by using 1 to 9 measurement scale (1 shows equal importance and 9 means it is extremely more important.

Note:

1: Equal importance ***5: Strongly more important*** ***9: Extremely more important***

3: Moderately more important ***7: Very strongly more important*** ***2,4,6,8: Intermediate values***

	Most important / **Criteria**
	GP1: Properly following a WM plan
	GP2: Supervision of WM activities with clear instructions
	GP3: Establishment of a strict CWM policy within the company (including the CWM system)
	GP4: Implementing an effective organizational structure for WM
	GP5: Monitoring and auditing waste management systems periodically (e.g., every 3 months)
	GP6: Establishment of an appropriate WM plan in the earlier stage of each construction project
	GP7: Senior management's commitment to implementing waste management (WM) practices
	GP9: Including subcontractor responsibilities for WM targets in the contract

2.3. You have selected X as the LEAST important attribute. Please compare the importance of the other attributes over this least important attribute by using 1 to 9 measurement scale.

Least important / **Criteria**	
GP1: Properly following a WM plan	
GP2: Supervision of WM activities with clear instructions	
GP3: Establishment of a strict CWM policy within the company (including the CWM system)	
GP4: Implementing an effective organizational structure for WM	
GP5: Monitoring and auditing waste management systems periodically (e.g., every 3 months)	
GP6: Establishment of an appropriate WM plan in the earlier stage of each construction project	
GP7: Senior management's commitment to implementing waste management (WM) practices	
GP9: Including subcontractor responsibilities for WM targets in the contract	

Material and equipment (ME)

2.4. Material and equipment (ME) is a factor that could contribute to the Better Performance of CWM. This factor consists of ***8 attributes***. To the best of your knowledge and experience, which is the MOST and the LEAST important attribute? Please select (X) ***one attribute as the MOST important*** and ***one attribute as the LEAST important***.

Code	Main criteria/ attribute	Most important	Least important
ME1	Precise on-site material control (e.g., inspecting the materials when they arrive, etc.)		
ME2	Adequate protection of material transportation and handling (loading and unloading)		
ME3	Adequate protection of different categories of materials during storing and stacking		
ME4	High level of security at the project site (i.e., prevent theft and loss of materials)		
ME5	Adopting Just in Time delivery (JIT) system		
ME6	Precise material purchasing (i.e., preventing order errors, right sizes and quantities)		
ME7	Using quality, durable, and standardized materials (i.e., according to specification)		
ME8	On-time and accurate quantification of materials/bills of quantities		

2.5. You have selected X as the most important attribute. Please compare the importance of this attribute over the other attributes by using 1 to 9 measurement scale.

	Most important / **Criteria**
	ME1: Precise on-site material control (e.g., inspecting the materials when they arrive, etc.)
	ME2: Adequate protection of material transportation and handling (loading and unloading)
	ME3: Adequate protection of different categories of materials during storing and stacking
	ME4: High level of security at the project site (i.e., prevent theft and loss of materials)
	ME5: Adopting Just in Time delivery (JIT) system
	ME6: Precise material purchasing (i.e., preventing order errors, right sizes and quantities)
	ME7: Using quality, durable, and standardized materials (i.e., according to specification)
	ME8: On-time and accurate quantification of materials/bills of quantities

2.6. You have selected X as the LEAST important attribute. Please compare the importance of the other attributes over this least important attribute by using 1 to 9 measurement scale.

Least important / **Criteria**	
ME1: Precise on-site material control (e.g., inspecting the materials when they arrive, etc.)	
ME2: Adequate protection of material transportation and handling (loading and unloading)	
ME3: Adequate protection of different categories of materials during storing and stacking	
ME4: High level of security at the project site (i.e., prevent theft and loss of materials)	
ME5: Adopting Just in Time delivery (JIT) system	
ME6: Precise material purchasing (i.e., preventing order errors, right sizes and quantities)	
ME7: Using quality, durable, and standardized materials (i.e., according to specification)	
ME8: On-time and accurate quantification of materials/bills of quantities	

Requirements and specifications (RS)

2.7. Requirements and specifications (RS) is a factor that could contribute to the Better Performance of CWM. This factor consists of ***4 attributes***. To the best of your knowledge and experience, which is the MOST and the LEAST important attribute? Please select (X) ***one attribute as the MOST important*** and ***one attribute as the LEAST important***.

Code	Main criteria/ attribute	Most important	Least important
RS1	Minimizing design changes during construction		
RS2	Minimizing variation orders (VO)		
RS3	Detailed study and thorough understanding of specifications and drawings		
RS4	Implementing proper method statement for each activity, including minimizing waste from application processes		

2.8. You have selected X as the most important attribute. Please compare the importance of this attribute over the other attributes by using 1 to 9 measurement scale.

	Most important / **Criteria**
	RS1: Minimizing design changes during construction
	RS2: Minimizing variation orders (VO)
	RS3: Detailed study and thorough understanding of specifications and drawings
	RS4: Implementing proper method statement for each activity, including minimizing waste from application processes

2.9. You have selected X as the LEAST important attribute. Please compare the importance of the other attributes over this least important attribute by using 1 to 9 measurement scale.

Least important / **Criteria**	
RS1: Minimizing design changes during construction	
RS2: Minimizing variation orders (VO)	
RS3: Detailed study and thorough understanding of specifications and drawings	
RS4: Implementing proper method statement for each activity, including minimizing waste from application processes	

Construction information system (CIS)

2.10. Construction information system (CIS) is a factor that could contribute to the Better Performance of CWM. This factor consists of ***4 attributes***. To the best of your knowledge and experience, which is the MOST and the LEAST important attribute? Please select (X) ***one attribute as the MOST important*** and ***one attribute as the LEAST important***.

Code	Main criteria/ attribute	Most important	Least important
CIS1	Utilizing Building Information Modeling (BIM) for the project and be familiar with its application		
CIS2	Utilizing other related information technologies for the project and be familiar with their application		
CIS3	Professional quality management and certification (e.g., ISO, GREEN, etc.)		
CIS4	Keeping lessons learned repository about CWM		

2.11. You have selected X as the most important attribute. Please compare the importance of this attribute over the other attributes by using 1 to 9 measurement scale.

	Most important / **Criteria**
	CIS1: Utilizing Building Information Modeling (BIM) for the project and be familiar with its application
	CIS2: Utilizing other related information technologies for the project and be familiar with their application
	CIS3: Professional quality management and certification (e.g., ISO, GREEN, etc.)
	CIS4: Keeping lessons learned repository about CWM

2.12. You have selected X as the LEAST important attribute. Please compare the importance of the other attributes over this least important attribute by using 1 to 9 measurement scale.

Criteria / **Least important**	
CIS1: Utilizing Building Information Modeling (BIM) for the project and be familiar with its application	
CIS2: Utilizing other related information technologies for the project and be familiar with their application	
CIS3: Professional quality management and certification (e.g., ISO, GREEN, etc.)	
CIS4: Keeping lessons learned repository about CWM	

Waste collection facilities (WCF)

2.13. Waste collection facilities (WCF) is a factor that could contribute to the Better Performance of CWM. This factor consists of ***3 attributes***. To the best of your knowledge and experience, which is the MOST and the LEAST important attribute? Please select (X) ***one attribute as the MOST important*** and ***one attribute as the LEAST important***.

Code	Main criteria/ attribute	Most important	Least important
WCF1	Bins are installed on every floor		
WCF2	Storing construction waste in easily accessible areas		
WCF3	Setting up separated bins according to the waste type and sort out waste at the site		

2.14. You have selected X as the most important attribute. Please compare the importance of this attribute over the other attributes by using 1 to 9 measurement scale.

	Most important / **Criteria**
	WCF1: Bins are installed on every floor
	WCF2: Storing construction waste in easily accessible areas
	WCF3: Setting up separated bins according to the waste type and sort out waste at the site

2.15. You have selected X as the LEAST important attribute. Please compare the importance of the other attributes over this least important attribute by using 1 to 9 measurement scale.

Least important / **Criteria**	
WCF1: Bins are installed on every floor	
WCF2: Storing construction waste in easily accessible areas	
WCF3: Setting up separated bins according to the waste type and sort out waste at the site	

B) MAIN FACTORS

2.16. There are ***5 "main factors"*** as detailed above, could affect contractor's CWM at construction site. To the best of your knowledge and experience, what is the MOST and the LEAST important factor? Please select (X) ***one factor as the MOST important*** and ***one factor as the LEAST important***.

Code	Main criteria/ attribute	Most important	Least important
GP	Governance and policy		
ME	Material and equipment		
RS	Requirements and specifications		
CIS	Construction information system		
WCF	Waste collection facilities		

2.17. You have selected X as the most important factor. Please compare the importance of this factor over the other factors by using 1 to 9 measurement scale.

	Most important / **Criteria**
	GP: Governance and policy
	ME: Material and equipment
	RS: Requirements and specifications
	CIS: Construction information system
	WCF: Waste collection facilities

2.18. You have selected X as the LEAST important factor. Please compare the importance of the other factors over the least important factor by using 1 to 9 measurement scale.

Criteria / Least important	
GP: Governance and policy	
ME: Material and equipment	
RS: Requirements and specifications	
CIS: Construction information system	
WCF: Waste collection facilities	

Part III: Defining the maturity levels for this study

Five maturity levels were defined and refined with score ranges derived from a literature review for the development of the maturity model in this study. To facilitate a deeper understanding, we assess an attribute called "setting up separated bins according to the waste type and sort out waste at the site" as follows:

- **Level 1/ Initial (Bellow 1.5):** Processes are unstructured and unpredictable. Performance is at the foundational stage.
  Example: Your company *has no plan and practice* for "Setting up separated bins according to the waste type and sort out waste at the site". *There are no bins at any project sites.*
- **Level 2/ Developing (1.5-2.5):** Some processes may exist, but they are typically ad-hoc. Performance is emerging but inconsistent.
  Example: Your company *does not have a clear plan and practice* for "Setting up separated bins according to the waste type and sort out waste at the site". Instead of using separate bins, *a single bin is used to collect and mix all CW at each project site.*
- **Level 3/ Reactive (2.5-3.5):** Formal processes are in place with a reactive approach. Performance is generally consistent.
  Example: Your company *has a formal defined plan and practice* for "Setting up separated bins according to the waste type and sort out waste at the site". Separate bins are set up at project sites, but only *about 50% of the project sites implement this practice.*
- **Level 4/ Proactive (3.5-4.5):** Well-defined processes and plans with proactive approach. Performance is consistently strong.
  Example: Your company *has a formal well-defined plan and practice* for "Setting up separated bins according to the waste type and sort out waste at the site". Separate bins are used to collect and sort all CW. *Most projects are implementing this practice.*
- **Level 5/ Optimizing (4.5 or above):** Processes are optimized and integrated across the organization with continuously improving. Performance is exemplary.
  Example: Your company *has a standardized plan and practice* for "Setting up separated bins according to the waste type and sort out waste at the site". The setting up of separate bins is *strictly implemented at all project sites.*

To the best of your knowledge and experience, please rate (✓) the level of agreement on definition of 5 maturity levels.

☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree

Please comment for refinement (if disagree or neutral):

____

____

____

____

Further comment or question (if any):

Thank you very much for your valuable time in answering this questionnaire!

APPENDIX 7

GUIDING QUESTIONS FOR EXPERT FEEDBACK ON CW3M MODEL IMPLEMENTATION AND VALIDATION

AUN/SEED-Net

EXPERT FEEDBACK INTERVIEW

Maturity model for the assessment of construction waste management (CW3M)

Dear Sir/ Madam,

I would like to seek your input in completing expert feedback interview that is part of double Ph.D. degree research that seeks to improve construction waste management (CWM). This double Ph.D. degree research is sponsored by the AUN/SEED-Net Collaborative Education Program (CEP) under the supervision of Assoc. Prof. Dr. Kriengsak PANUWATWANICH (at Sirindhorn International Institute of Technology, Thammasat University) and Assoc. Prof. Dr. Koji MATSUMOTO (at Hokkaido University).

About this interview
The aim of this expert feedback interview is to gather feedback from experts on the use of the maturity model for assessing construction waste management (CW3M). You have been identified as an expert working as a contractor with expertise that can provide valuable input to this study.

Confidentiality
The information will be used for academic purposes only. All information collected will be stored securely, and you will not be identified at any point in this research. Any reporting or summaries derived from the data will be presented in an aggregated form, without any individual identification or specific answers.

Interview structure
We will provide you with the CW3M model to use in assessing your company's CWM performance over a period of time. Afterward, we will conduct an interview with you, structured around a set of questions contained on one page and divided into two main parts. Part I: Your background and your company. Part II: Expert feedback on the developed model, where we will ask for your insights on whether the CW3M model works effectively after your use.

Duration of the interview
The interview will take approximately 30 minutes to complete, and we can schedule it at any time between **13th - 20th August 2024.**

The research team would be most grateful for your time and consideration in contributing to this research.

Please direct any inquiries about this research to:

Mr. Vuthea MIN (Doctoral Researcher), Email: minvuthea@gmail.com, Cell No.: +66-905909078

Thank you and best regards,

13th August 2024

Vuthea MIN	Assoc. Prof. Dr. Kriengsak PANUWATWANICH	Assoc. Prof. Dr. Koji MATSUMOTO
SIIT, Thammasat University, Thailand, and Hokkaido University, Japan	SIIT, Thammasat University, Thailand	Hokkaido University, Japan

EXPERT FEEDBACK INTERVIEW ON DEVELOPED MODEL

Part I: Background Information

Note: Experts are expected to have a minimum of approximately 5 years of experience in building construction management and are currently working as a contractor.

Please provide the necessary information.

1.1) Country where your company is located (i.e., Cambodia or Thailand)

____

1.2) Your current position within your company:

____

1.3) Your highest level of education (e.g. master's degree in construction management):

____

1.4) Your years of experience in the construction industry:

____

1.5)Your current type of building project (e.g. residential building, commercial building etc.):

____

1.6) Number of employees in your company:

____

Part II: Expert feedback on developed model

After using the CW3M maturity model, please select the relative score for each feedback aspect below to indicate your level of satisfaction, with 1 representing "Poor", 2 "Average", 3 "Good", 4 "Very Good", and 5 "Excellent".

Feedback Aspects	Scoring				
	1	2	3	4	5
1. Degree of appropriateness	☐	☐	☐	☐	☐
2. Degree of objectivity	☐	☐	☐	☐	☐
3. Degree of replicability	☐	☐	☐	☐	☐
4. Degree of practicality	☐	☐	☐	☐	☐
5. Overall reliability	☐	☐	☐	☐	☐
6. Overall suitability for CWM for contractors in building construction	☐	☐	☐	☐	☐

Further comment or question (if any):

____
____
____

Thank you very much for your valuable time in allowing us to interview you!

BIOGRAPHY

Name-surname : **Vuthea MIN**
Date of birth : **05th February 1985**
Nationality : **Cambodian**
Place of birth : **Kratie, Cambodia**

Professional qualification :

- Project Management Professional (PMP) (No. 2749108)
- Professional Engineer (PE) (ID: 000806 PE/Bldg.)
- ASEAN Engineer
- Member of Project Management Institute (PMI)
- Associate Member of Japan Society of Civil Engineer

Education:

- 2022-2024: Ph.D. research in Construction Management at Hokkaido University, Japan (Under AUN/SEED-Net CEP double degree Ph.D. Scholarship)
- 2020-2024: Ph.D. research in Construction Management at SIIT, Thammasat University, Thailand (Under AUN/SEED-Net CEP double degree Ph.D. Scholarship)
- 2012-2014: M.Eng. Construction Engineering and Management at Khon Kaen University, Thailand (Under Princess Sirindhorn Scholarship)
- 2006-2010: B.Sc. Civil Engineering at University of Engineering and Technology, Lahore, Pakistan (Under Pakistan Prime Minister's Scholarship)

Publication:

Related to Ph.D. Thesis

International Journal

(1) **Min, V.,** Panuwatwanich, K.,&Matsumoto, K. (2024). Enhancing Performance of Construction Waste Management: Factor Analysis from the Building Contractors'

Perspectives. *Cleaner Waste Systems, 9, 100176*.
https://doi.org/10.1016/j.clwas.2024.100176

(2) **Min, V**., Panuwatwanich, K., & Matsumoto, K. Evaluating key attributes for enhancing contractors' performance in construction waste management: A Multi-Criteria Decision Analysis using the Best Worst Method (Under revision in the *"International Journal of Construction Management"*)

(3) **Min, V**., Panuwatwanich, K., & Matsumoto, K., Narong, L. Strategic construction waste management to promote sustainable development: Developing a maturity model for building contractors (Submitted to a journal)

International Conference

(4) **Min, V**., Panuwatwanich, K., & Matsumoto, K. (2023). Contractor's Controlling Factors Contributing to Effective Construction Waste Management in Building Construction. *International Conference on Construction in the 21st Century*, Netherlands.

Not related to Ph.D. Thesis:

International Journal

(5) **Vuthea MIN**, Narong Leungbootnak, Korb Srinavin, Preenithi Aksorn, Watcharapong Deewong (2016). Cambodian Construction Industry's Issues in the ASEAN Economic Community. *KICEM Journal of Construction Engineering and Project Management Vol. 6 PP. 1-10*.
https://doi.org/10.6106/JCEPM.2016.6.1.001

(6) **Vuthea MIN**, Narong Leungbootnak (2019). Influence Factors in the Construction Industry of Cambodia in the ASEAN Economic Community. *International Journal of Construction Project Management, Vol. 10 No. 2.*

(7) **Vuthea MIN**, Narong Leungbootnak (2019). Improvement of Cambodian Construction Industry in the ASEAN Economic Community. *International Journal of Construction Project Management*, Vol. 11 No. 1.

(8) Narong Leungbootnak, Apai Sruntummakul, **Vuthea MIN** (2015). Adjusting Planning Management and Control to the Owner Environment Case Study: Consultant Adjustment to the Owner Environment in Thailand. *KICEM Journal of Construction Engineering and Project Management. vol. 6 pp. 9-16*.

https://doi.org/10.6106/JCEPM.2015.5.3.010

International Conference

(9) **Vuthea MIN**, Narong Leungbootnak (2023). BIM application for resolving construction issues in Thailand: a consultant's case study. *Proceedings of the International Conference on Civil and Building Engineering Informatics (ICCBEI 2023),* Bangkok, Thailand.

(10) **Vuthea MIN**, Narong Leungbootnak (2014). Construction Industry of Cambodia towards AEC from Concerned Public Office Perspective. *Proceedings of the 3rd International Conference on Business and Communication (ICBC 2014)*, Kuala Lumpur, Malaysia.

(11) Narong Leungbootnak, **Vuthea MIN** (2019). Digitizing Transformation for Civil Engineer in Disruption Era. *Proceedings of the 24th National Convention on Civil Engineering (NCCE24)*, Udonthani, THAILAND. PP. 889-895, 2019.

Teaching/Training/ Speaker:

- August 2020-Present: Teaching Assistant (TA) for Professional master's degree course "Construction technology and Management for Tall Building Projects" at Asian Institute of Technology (AIT-solution), Pathum Thani, Thailand [part time]
- August 2014-2020 Teaching Assistant (TA) under Prof. Dr. Narong L., PMP, SPE, ACEP, APEC Engr [part time]
- July 14, 2022: Offer special lecture to government staffs at Ministry of Industry, Science, Technology & Innovation (Cambodia), titled "Project and construction management for professional practice"
- May 28, 2021: Offer special lecture to 4th & 5th year engineering students at Institute of Technology of Cambodia (ITC), titled "The professional practice of PM/CM in real projects".
- July 9, 2022: Guest speaker "KKU holds Alumni Sharing Session: Inspirational work experience in Thailand".
- May 6-30, 2016: Offer training to contractors on how to prepare professional reports, and project documents control, Yangon, Myanmar

Employment:

Future Engineering Consultants Co., Ltd:

- 2019-2020: Project Manager and Contract Manager, based on Bangkok, Thailand
- 2016-2019: Project coordinator, Asst. Project Manager, and Contract manager for construction of Ar Yu International hospital project (project budget approx. 70 million USD), based in Yangon Myanmar
- 2014-2016: Project coordinator based in Bangkok, Thailand
- Summary of main completed projects:
    - Project Manager and Contract Manager for the project of Geotechnical Investigation in New Hydrogen Manufacturing Unit (HMU-2), Rayong, Thailand
    - Project Manager and Contract Manager for UNICEF WASH Technical Manual Development, Myanmar
    - Project manager and Contract manager for T4 Wind Farm Rehabilitation project, Thailand
    - Asst. Project Manager, Project Coordinator & Contract Manager for the Construction of Ar Yu International Hospital, Myanmar
    - Project Coordinator and Contract Manager for design of UNESCAP Library building renovation project, Bangkok, Thailand

Sumitomo Mitsui Construction Co., Ltd.

- 2011-2012: Quality controller (QC) for construction of Neak Leung bridge, based in Kandal province, Cambodia

Borey Peng Houth Investment Co., Ltd

- 2010-2011: Quality controller (QC) for town house construction projects, based in Phnom Penh, Cambodia