DETERMINANTS OF CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT IN MAINLAND CHINA: A CONTRACTOR'S PERSPECTIVE

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Ph.D

The Hong Kong Polytechnic University

2016

The Hong Kong Polytechnic University

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Determinants of Construction and Demolition Waste Management in Mainland China: A Contractor's Perspective

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A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

January 2016

CERTIFICATE OF ORIGINALITY

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WU Zezhou (Name of student)

DEDICATION

To my beloved family

ABSTRACT

Construction and demolition (C&D) waste refers to the substances which are generated in the construction, renovation, and demolition activities of buildings and infrastructure. The materials involved in this stream of waste can be divided into two categories according to their chemical characteristics, namely inert materials and non-inert materials. The inert materials (e.g., concrete, bricks, sub-soil) refer to the components that hardly react chemically under common circumstances, while the non-inert materials can be easily involved in chemical reactions, such as rebar, wood. C&D waste is produced unavoidably as a by-product of construction activities. Illegal disposal of C&D waste management can lead to negative impacts. However, effective strategies can be conducted to minimise the negative influences caused by C&D waste.

There are several stakeholders involved in a construction project, each stakeholder can affect C&D waste generation from different aspects. This study focuses on contractor rather than developer or designer because the contractor is the direct C&D waste producer and C&D waste management implementer in a real-life project. In Mainland China, the C&D waste management practice is regarded to be inadequate at this stage. Therefore, there is a necessity to investigate the determinants that can promote contractor's adoption of effective C&D waste management measures in real-life projects.

The principal aim of this study is to investigate the determinants that affect the contractor's C&D waste management behaviour. Four specific objectives are proposed to be achieved:

1) To identify the potential critical factors that affect the contractor's behaviour of C&D waste management;
2) To develop measurement scales for investigating the contractor's C&D waste management behaviour and the potential determinants;
3) To explore the interrelationships between potential C&D waste management determinants and the contractor's actual behaviour;
4) To provide suggestions for promoting the implementation of effective C&D waste management in the current situation of Mainland China.

These objectives have been achieved through employing a combination of several research methods including literature review, focus group meeting, questionnaire survey, and interviews with industrial professionals. Through the literature review and the focus group meeting, eight constructs were identified, including (1) attitude towards behaviour, (2) social norm, (3) perceived behavioural control, (4) behavioural intention, (5) governmental supervision, (6) economic viability, (7) project constraints, and (8) behaviour, to formulate a preliminary theoretical framework. Based on the preliminary theoretical framework, seven hypotheses were proposed as follows:

Hypothesis 1 (H1): Attitude towards behaviour has a direct positive effect on the behavioural intention.

Hypothesis 2 (H2): Social norm has a direct positive effect on the behavioural intention.

Hypothesis 3 (H3): Perceived behavioural control has a direct positive effect on the behavioural intention.

Hypothesis 4 (H4): Behavioural intention has a direct positive effect on the behaviour.

Hypothesis 5 (H5): Governmental supervision has a direct positive effect on the behaviour.

Hypothesis 6 (H6): Economic viability has a direct positive effect on the behaviour.

Hypothesis 7 (H7): Project constraints have a direct negative effect on the behaviour.

A questionnaire survey was conducted to collect data for investigating the interrelationships between the eight constructs. The employed data analysis techniques included item analysis, reliability analysis, exploratory factor analysis, descriptive statistics, non-parametric test, structural equation modelling, and triangulation analysis. The results showed that attitude towards behaviour and social norm have significant positive effects on behavioural intention of C&D waste management, while perceived behavioural control has an insignificant effect on behavioural intention. Surprisingly, the behavioural intention was found to be an insignificant factor that determines contractor's C&D waste management behaviour. A possible explanation is that C&D waste management behaviour is more attributed to organisational behaviour rather than individual behaviour.

The findings of this study also revealed that the most significant determinant that influences contractor's C&D waste management behaviour is economic viability, demonstrating that improving the economic viability of waste minimisation can encourage the contractor to employ waste management measures more positively. Following economic viability is the factor of governmental supervision, indicating that appropriate and strict supervision from the government can improve contractor's waste management behaviour. The factor of project constraints was found to play an insignificant role in affecting contractor's C&D waste management behaviour. A possible reason is that C&D waste management is just a sub-objective in a construction project, attracting less focus than money saving or other main objectives.

To test the results derived from the questionnaire survey, a triangulation analysis was further employed through interviews with industrial professionals for a validation purpose. The feedback from these interviewees generally supported the research findings.

Overall, the research study revealed that, in order to promote C&D waste management in the current construction industry of Mainland China, the most important focuses should be given to the improvement of economic viability and the enhancement of governmental supervision.

PUBLICATIONS

1. Refereed Journal Papers

[1] **Zezhou Wu**, Liyin Shen, Ann T. W. Yu, Xiaoling Zhang, 2015. *A comparative analysis of waste management requirements between five green building rating systems for new residential buildings*. Journal of Cleaner Production 112, Part 1, 895-902.

[2] **Zezhou Wu**, Ann T. W. Yu, Liyin Shen, Guiwen Liu, 2014. *Quantifying construction and demolition waste: An analytical review.* Waste Management 34 (9), 1683-1692.

[3] **Zezhou Wu**, Hongqin Fan, Guiwen Liu, 2015. *Forecasting construction and demolition waste using gene expression programming*. ASCE Journal of Computing in Civil Engineering 29 (5), 04014059.

[4] **Zezhou Wu**, Rongli Xiang, Guiwen Liu, 2011. *Minimization management of construction and demolition waste under systemic view*. Construction Economy 2, 101-104.

[5] **Zezhou Wu,** Xiaoling Zhang, Min Wu, 2016. *Mitigating construction dust pollution: state of the art and the way forward*. Journal of Cleaner Production 112 Part 2: 1658-1666.

[6] Xiaoling Zhang, **Zezhou Wu**, Yong Feng, Pengpeng Xu, 2015. *"Turning green into gold": A framework for energy performance contracting (EPC) in China's real estate industry*. Journal of Cleaner Production 109: 166-173.

[7] Pengpeng Xu, Edwin H. W. Chan, Henk J. Visscher, Xiaoling Zhang, **Zezhou Wu**, 2015. *Sustainable building energy efficiency retrofit for hotel buildings using EPC mechanism in China: Analytic network process (ANP) approach*. Journal of Cleaner Production 107, 378-388.

2. Refereed Conference Papers

[1] **Zezhou Wu**, Ann T.W. Yu, Yigang Wei, 2015. *Predicting contractor's behavior toward construction and demolition waste management*, Proceedings of the 19th International Symposium on Advancement of Construction Management and Real Estate. Springer, 869 - 875.

[2] **Zezhou Wu**, Ann T. W. Yu, 2014. *Evaluating the effectiveness of construction and demolition waste management strategies*, Proceedings of the 18th International Symposium on Advancement of Construction Management and Real Estate. Springer, 531-538.

ACKNOWLEDGEMENTS

Writing a thesis is similar to implementing a project, it needs a huge dedication of time, energy, and patience. The road to the final target is really tough; however, I feel lucky because I have got so much support and help during this precious journey.

I would like to express my sincere gratitude to my chief supervisor, Dr. Ann T. W. Yu, for her continuous guidance and support during my Ph.D. study. Every time when I was stuck in somewhere, she would give her valuable guidance and encouragement to me, pointing the right way ahead. She has made great contribution to the formulation of this thesis.

My special thanks also go to my co-supervisor, Prof. Liyin Shen, who always called me 'young man' and delivered me positive and optimistic values. He has offered me excellent ideas on my study and taught me to be open-minded to the potentials.

I would like to extend my thanks to Dr. Hongqin Fan, who gave me the precious opportunity of being a research assistant in PolyU. His support was also very important to me when I was applying a Ph.D. opportunity.

I also would like to give my gratitude to Prof. Guiwen Liu, who was my supervisor when I was pursuing a master degree. He has offered me so many chances to broaden my horizons.

I would like to express my special thanks to the big BRE family. It provides a good platform to meet excellent people. My gratitude goes to Prof. Geoffrey Q.P. Shen, Prof. Edwin H.W. Chan, Prof. Heng Li, Prof. Francis K.W. WONG, Dr. Meng Ni, Dr. Yong Tao Tan, Dr. Michael C.H. YAM, Dr. Johnny K.W. Wong and other colleagues who I cannot list everyone herein. I also owe thanks to my friends in BRE, thank them for sharing the good time with me in PolyU.

My gratitude also goes to Dr. Paul Fox for his kindness of proofreading my thesis. Valuable suggestions were received from not only language use, but also academic aspects.

Finally, I would like to express my heartfelt thanks to my parents who have offered me continuous support and provided me a comfortable place where called ‘home’. Meanwhile, I thank my girlfriend, Qiaohui Chen, for coming into my life and giving me support. They are the most important impetus of motivating me forward.

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LIST OF ABBREVIATIONS

Abbreviation	Full Term
A&B	Attitude and Behaviour
AB	Attitude towards Behaviour
AMOS	Analyse of Moment Structures
ANOVA	Analysis of Variance
B	Behaviour
BI	Behavioural Intention
BREEAM	Building Research Establishment Environmental Assessment Methodology
C&D	Construction and Demolition
CFA	Confirmatory Factor Analysis
CIW	Civil and Infrastructural Works
CNB	Construction of New Buildings
CSA	Classification System Accumulation
CW	Construction Waste
DOB	Demolition of Old Buildings
DW	Demolition Waste
EV	Economic Viability
EFA	Exploratory Factor Analysis
ESGB	Evaluation Standard for Green Building
GBI	Green Building Index
GG	Green Globes
GRC	Generation Rate Calculation
GS	Governmental Supervision
HKEPD	Hong Kong Environmental Protection Department
KMO	Kaiser-Meyer-Olkin
LA	Lifetime Analysis
LEED	Leadership in Energy & Environmental Design
MOC	China Ministry of Construction
PBC	Perceived Behavioural Control
PC	Project Constraints
PL	Project Level
RL	Regional Level
SEM	Structural Equation Modelling
SMC	Squared Multiple Correlation
SN	Social Norm
SPSS	Statistical Package for the Social Sciences
SV	Site Visit
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
USEPA	United States Environmental Protection Agency

VM	Variables Modelling

CHAPTER 1 Introduction

1.1 Background

Construction and demolition (C&D) waste refers to the substances which are generated in the construction, renovation, and demolition activities of buildings and infrastructure. (HKEPD, 2013; USEPA, 2013b). According to its chemical characteristics, the materials involved in this stream of waste can be divided into two categories, namely inert materials and non-inert materials (HKEPD, 2013). The inert materials (e.g., concrete, bricks, sub-soil) refer to the components that hardly participated in chemical reactions under common circumstances, while the non-inert materials can be easily decomposed in chemical reactions, such as rebar, wood. As a by-product of construction activities, C&D waste is produced unavoidably. However, effective strategies can be conducted to minimise the generation of C&D waste.

In China, the situation of C&D waste management is not optimistic. In 2015, there were about 1.5 billion metric tons of concrete waste and 2 billion tons of subsoil generated (Xu et al., 2015). However, there are still a number of cities have not drafted their specific regulations on C&D waste disposal. Due to the fast urbanisation, it is forecast that the construction and demolition activities would increase and thus the amount of C&D waste would be even more enormous in the future (Wu et al., 2015a).

Despite the large amount of C&D waste, the landfills for C&D waste disposal are running out of space. In Hong Kong, the existing landfills will be exhausted by 2020 with the current increasing rate (HKEPD, 2015). In Mainland China, the situation is even worse. On 20 December 2015, a tragedy of landslide happened in Shenzhen because of the illegal dumping of C&D waste, causing 69 deaths with 8 persons reported missing (Wikipedi, 2015). In addition, improper treatment of C&D waste can result in hazardous environmental impacts and a waste of useful resources (Wu, 2012). For example, if it is disposed at a riverside without any protection measures, hazardous components might be generated as a result of a series of chemical reactions and these may flow into rivers with rainwater. In these circumstances, the river will be polluted and negative influences will result to the living species in the river. In addition, the unregulated disposal of C&D waste can have a negative visual impact on the locality as well.

Although C&D waste may bring bad influences to the environment, it has great possibility to be used as a useful resource after appropriate treatment. Dahlén and Lagerkvist (2010) argued that wastes can be viewed as 'resources in the wrong place'. Existing studies have also shown that effective C&D waste management can bring economic benefits to the various stakeholders (Coelho and de Brito, 2013; Zhao et al., 2010). To give a holistic picture, Lu and Yuan (2011) divided C&D waste management practices into two categories: hard technical measures and soft managerial measures. The hard technical measures refer to the environmentally friendly construction technologies, such as prefabrication, steel framework, recycled aggregates. The soft managerial measures comprise the regional economic instruments and on-site management measures, such as waste disposal charging scheme, on-site sorting.

Echoed with the above-mentioned academic studies, C&D waste management measures are suggested in industrial guidelines as well. For instance, the C&D waste management performance is a crucial assessment component in green building rating systems. In terms of the green building rating systems in the US, UK and China, the relative significance indices of C&D waste management were 10%, 8.16% and 11.84%, respectively (Wu et al., 2015b). C&D waste management measures are suggested in the rating systems and follow the '3R' principle, which includes reduce, reuse and recycle.

C&D waste is generated throughout the whole lifecycle of construction projects. Therefore, it makes sense to consider C&D waste management from a lifecycle viewpoint. In line with the growing public acceptance of a sustainable development philosophy, more focus should be paid on C&D waste management. Effective C&D waste management is considered to be an essential solution to achieve the visions of landfill space conservation, environmental impact reduction, job opportunity creation and project expense reduction (USEPA, 2013b). Therefore, letting the construction stakeholders pursue and promote effective C&D waste management is of significant importance.

In construction projects, there are a number of key elements involved such as human beings, machines, materials, etc. However, the most important element was considered to be the individuals who participate in the direct construction activities (Yuan and Shen, 2011). In a construction project, no matter what construction methods are selected, what materials are used, what machines are involved, they are determined and operated by human beings. Human beings are the only one to manage and control all the other resources together in order to achieve the final project objectives and effective C&D waste management. However, in the current situation, though regulations have been set on C&D waste management and mature technologies have been introduced in practice, the C&D waste management practice in real-life projects was regarded to be inadequate (Ajayi et al., 2015; Wu et al., 2015c). Therefore, investigating the determinants that can promote the adoption of C&D waste management measures is of importance to achieve success and sustainability of C&D waste management.

1.2 Research scope

In order to conduct a more concentrated and in-depth research study, defining a clearly specified research scope is a prerequisite. The ‘C&D waste management’ in this study refers to the implementation of best practice measures of C&D waste reduction, reuse and recycling, excluding the straightforward disposal of C&D waste. This study is designed to be conducted focusing on the C&D waste management in Mainland China. Mainland China is selected because: 1) it bears the most dramatic and the largest construction market in the world: the construction spending in China reached almost US $1.8 trillion in 2013 (Sito, 2014); 2) at the current stage, on-site waste management is not mature in Mainland China, so there is a great potential for improvement that can be achieved (Lu and Yuan, 2010). Considering that contractor is the direct C&D waste producer and C&D waste management implementer in a real project, this study focuses on contractor rather than other stakeholders. The behaviour of contractor towards C&D waste management plays an important role in waste minimisation.

1.3 Research aim and objectives

The principal aim of this study is to investigate the determinants that affect contractor's C&D waste management behaviour.

The specific objectives of the research study are:

1) To identify the potential critical factors that affect the contractor's behaviour of C&D waste management;
2) To develop measurement scales for investigating the contractor's C&D waste management behaviour and the potential determinants;
3) To explore the interrelationships between potential C&D waste management determinants and the contractor's actual behaviour;
4) To provide suggestions for promoting the implementation of effective C&D waste management in the current situation of Mainland China.

In order to achieve the above-mentioned objectives, subsequent major tasks include establishing a conceptual framework to connect the identified constructs based on the literature review and the focus group meeting; developing scales to measure the eight identified constructs and exploring the interrelationships between each construct using statistical analysis techniques; and providing pertinent recommendations for promoting C&D waste management situation according to the derived results.

1.4 Research methods

In order to achieve the proposed research objectives, several research methods were adopted in this study, consisting of the literature review, focus group meeting, semi-structured questionnaire survey, and interviews with professionals.

The literature review is often used to collect the background information relevant to the proposed research study. It can be utilised to identify what the previous studies have done in a particular topic and to understand the current gaps in scholarly understanding. An insightful literature review based on a comprehensive literature can help the researcher to find out the insightful research problems in a specific field. Such a review not only involves the reading of relevant research publications, but also presents the existing research gaps. In this study, the potential factors that affect contractor's adoption of C&D waste management were identified using this method.

The focus group meeting method can be used to collect the opinions about an issue from different organisations, such as developers, contractors, government officers and the public. A focus group meeting often follows a structured flow which is led by a designated facilitator. The objective of the designated facilitator is to guide the participants to provide the best and detailed information concerning the specific topic. Unlike a brainstorming meeting, this method concentrates on one designated topic, and the participants share their opinions and give feedback to the facilitator. The facilitator will then investigate the responses to derive insightful knowledge. In this study, the focus group meeting method was utilised to assist in formulating the preliminary questionnaire.

The questionnaire survey method was employed in this study due to its effectiveness in collecting structured data from the respondents, especially in the social sciences. By providing a set of alternatives for each question, the collected data can be analysed comparatively. Besides, this method does not require the investigators to physically approach the respondents and can be used in spatially diverse locations. A semi-structured questionnaire survey was conducted in this study to collect data for the investigation of the interrelationships between the identified factors.

Interviews with professionals are usually adopted as a method in order to derive effective feedback from questions through communications. Using this method, ambiguity will be reduced because the interviewers can have instant communications with the interviewees. Another main reason for selecting the interview method is the guarantee of the quality of the collected data. In this study, interviews with professionals were conducted in order to validate the derived findings from the questionnaire survey.

1.5 Structure of the thesis

There are seven chapters in this thesis; each chapter serves different functions.

Chapter 1 gives an overall introduction of the research study. It highlights the research background, research scope, research aim and objectives, research methods, and the structure of the thesis.

Chapter 2 presents a holistic literature review of the current C&D waste management situation, together with prevailing attitudes and behaviour concerning C&D waste management. The topics covered in this chapter include C&D waste generation, fundamentals of C&D waste management, practices for C&D waste minimisation, and existing attitude and behaviour (A&B) research for C&D waste management.

Chapter 3 describes the methodologies selected in this study and the statistical techniques used for data analysis. The applied research methods include literature review, focus group meeting, semi-structured questionnaire survey, and interviews with professionals. The data analysis techniques used include the descriptive statistics, item analysis, reliability analysis, exploratory factor analysis, non-parametric analysis, structural equation modelling, and triangulation analysis.

Chapter 4 explains the preliminary proposed conceptual framework for investigating contractor's C&D management behaviour based on the Theory of Planned Behaviour (TPB). Apart from the basic constructs in TPB, additional contextual constructs are introduced focusing on the specific C&D waste management field, such as governmental supervision (GS), economic viability (EV) and project constraints (PC). Furthermore, seven theoretical hypotheses are proposed for further examination.

Chapter 5 introduces the development process of the questionnaire used for the formal survey. The initial measurement scales of the eight constructs and the formal questionnaire is tested using item analysis and exploratory factor analysis. The procedures used for data collection is introduced as well.

Chapter 6 presents the core of this study, the proposed theoretical hypotheses are tested in this chapter. Different statistical techniques are utilised to analyse the collected data and to improve the proposed preliminary theoretical framework. After getting the final model, a validation process is conducted by triangulation analysis with experienced professionals. Discussions are further presented reflecting to the results.

Chapter 7 provides a holistic summary of the study. The research objectives are reviewed compared with the research findings. Furthermore, significance, area of originality, limitations, and recommendations for future research are also clarified.

CHAPTER 2 Literature Review

2.1 Introduction

This chapter presents the existing literature related to C&D waste management as well as research in the field of attitude and behaviour (A&B). Firstly, this chapter introduces the definition of basic concepts relating to C&D waste management. Then, the C&D waste management generation background is presented. The fundamentals and practical C&D waste minimisation measures are further reviewed. Lastly, the current research into attitude and behaviour towards C&D waste management is addressed.

2.2 Generation of construction and demolition (C&D) waste

C&D waste is produced throughout the life cycle of a construction project. In this section, the definitions of C&D waste in Hong Kong, the United States, Japan, the European Union, and Mainland China are compared. The amounts and sources of C&D waste are also discussed, and subsequently, existing quantification methods are presented.

2.2.1 Definitions of C&D waste

The definitions of C&D waste vary amongst different political and administrative regions. For example, in Hong Kong, the Environmental Protection Department (EPD) defines C&D waste as 'a mixture of waste or surplus materials arising from construction activities such as site clearance, excavation, refurbishment, renovation, demolition and road works' (HKEPD, 2014). In the United States, the

Environmental Protection Agency (EPA) states C&D waste includes 'the debris generated during the construction, renovation, and demolition of buildings, roads, and bridges' (USEPA, 2013b). In Japan, C&D waste is regarded as a 'by-product' of construction activities rather than 'waste' (Nitivattananon and Borongan, 2007). In the European Union (EU), different countries give different definitions to C&D waste. For instance, some countries regard the materials from land levelling are C&D waste, while other countries do not (Yang et al., 2013).

Though the literal definition of C&D waste in different regions varies, there are some shared ideas amongst them. Firstly, C&D waste is regarded to be generated mainly from construction, renovation and demolition processes of the project lifecycle. Secondly, the source of C&D waste is not only buildings, but also civil engineering works. Thirdly, C&D waste includes all types of materials discarded from construction projects.

As this research focuses on the C&D waste management in Mainland China, the scope of C&D waste complies with the official definition given by the China Ministry of Construction (MOC). In a regulation promulgated by MOC in 2005, C&D waste was defined as *'wasted soil, materials and other stuff that is generated from construction, renovation, extension and demolition of buildings, infrastructures and other construction activities'* (MOC, 2013). The disposal of C&D waste should follow the principles of reduction, recycling, harmlessness and producers' responsibility; any company or person who disposes of C&D waste in a way that violates the requirements will be punished.

2.2.2 C&D waste amount

The annual generation amount of C&D waste in fast developing economies is immense. For example, in Hong Kong, the generation of C&D waste was 1,216,000 tons in 2011, accounting for 25% of total municipal solid waste (HKEPD, 2014). In common circumstance, the inert materials are disposed of at public fill reception facilities, while non-inert materials are dumped into landfills. On 1 December 2005, a charging scheme was started in Hong Kong for the first time, announcing that contractors should open particular accounts for disposing of C&D waste in disposal facilities. From 29 December 2010, a new waste acceptance criterion was implemented with the purpose of guiding the contractors to sort C&D waste before disposal and increase the usage life of disposal facilities. However, the government claimed that both reclamation sites and landfill space were running out, and would be full by 2020 (HKEPD, 2015).

In the US, an official report presented that the C&D waste amount was estimated as 136 million tons in the whole country, representing a generation rate of 1.27 kg per person per day (USEPA, 2013a). Various C&D waste management measures were introduced in government reports, to give some guidance, such as source reduction, materials recovery, and landfill disposal (USEPA, 2013c). It has been shown that C&D waste reduction and recycling can make contributions to landfill space conservation, environmental impact reduction, job opportunities creation and project expenses reduction.

According to the official website of the European Commission (EC), it was regarded that the amount of C&D waste accounted for approximately 25% - 30% of all waste generated in the EU (Yang et al., 2013). The level of C&D waste recycling varied significantly across the Union, the recycling rates from less than 10% to over 90% (Yang et al., 2013). To enhance the management of C&D waste, recommendations from a study entitled '*Management of construction and demolition waste in the EU - requirements resulting from the Waste Framework Directive and assessment of the situation in the medium term*' have been implemented, and other efforts have been made, such as the establishment of recycling markets, the taking of measures for hazardous components, etc.

Finding official data concerning the amount of C&D waste is difficult in Mainland China. In some studies, it was estimated that the urban C&D waste accounts for 30~40% of the total municipal solid generation (Lu et al., 2011; Zhao et al., 2010). Considering the fast development of the construction industry in Mainland China, it is reasonable to extrapolate that the amount of C&D waste is enormous. The large amount of construction waste had broad socio-economic and environmental influences (Wu et al., 2015a; Ye et al., 2012). Therefore, it is of great importance to pay more attention on C&D waste management.

2.2.3 Sources of C&D waste

C&D waste could be generated from different periods throughout the lifecycle of a construction project, such as the contractual stage, design stage, procurement stage, construction stage, usage stage, and demolition stage (Osmani et al., 2008; Shen et al., 2004).

In the contractual stage, C&D waste can be caused by contract errors. The professional practice noted by Mendis et al. (2013) showed that unfair risk transfers was an important reason of rework and waste generation. In the design stage, design changes and poor communication between the stakeholders were the main causes of C&D waste (Osmani et al., 2008; Wang et al., 2015). Another typical cause that leads to C&D waste is the selection of low quality construction materials or products (Baldwin et al., 2009). The change of design can generate a large amount of waste, especially when the construction work has been finished. Therefore, it is important to increase the efficiency of communication so as to avoid potential design changes. Also, designers/clients are encouraged to choose renewable materials with high quality in the design stage. In the transportation stage, C&D waste was often produced because of poor delivery management (Formoso et al., 2002). Inaccurate procurement can also cause the generation of C&D waste; the reasons could be ordering errors, purchase of unmatched materials or products, and over estimation of material needs (Formoso et al., 2002). Compared with the above-mentioned stages, C&D waste is produced directly during construction, usage, and demolition stages. For example, C&D waste could be generated from improper planning of construction materials storage and lack of supervision (Hao et al., 2008; Poon et al., 2001a). Construction technology also plays an important role in waste minimisation. Efficient technology and carefulness of materials usage could reduce C&D waste generation to a large extent (Wu et al., 2011). In the usage stage, waste is often produced because of additional decoration. A common situation is that the new owner of an estate has a willingness to re-decorate the flat/house, thus waste is unavoidable. The demolition stage is regarded to be the most significant stage that generates a vast amount of C&D waste. Poon's (1997) research showed that a large proportion of the original structure was treated as demolition waste without any recycling measures.

The amount of C&D waste accounts for a large portion of municipal solid waste. Environmental impacts, such as solid pollution, air pollution and water pollution, could be produced if C&D waste was not disposed of appropriately (Rodriguez et al., 2007). However, the materials constituting C&D waste, whether inert materials or non-inert materials, were regarded of great potential to be reused or recycled as secondary materials (Chen et al., 2013; Hashimoto et al., 2009). As a result, effective management of C&D waste is of great significance, and thus to be emphasised and promoted.

2.2.4 Quantification methods of C&D waste

Quantifying C&D waste generation is regarded as a prerequisite for the implementation of successful waste management. Various methods have been employed to quantify the C&D waste generation at both regional level (RL) and project level (PL). Wu et al. (2014) conducted an integrated review that systemically described and analysed all the existing methods. Six categories of existing C&D waste quantification methodologies were identified, including site visit (SV) method, waste generation rate (WGR) method, lifetime analysis (LA) method, classification system accumulation (CSA) method, variables modelling (VM) method and other particular methods. By dividing C&D waste into construction waste (CW) and demolition waste (DW), a decision tree was proposed for aiding the selection of the most appropriate quantification method in different scenarios, as shown in Fig. 2-1. From this figure, it can be seen that most of the quantification methods are similar for the estimation of construction waste and demolition waste. However, lifecycle analysis is only used for quantification of demolition waste other than construction waste. More detailed discussions and comparisons of these quantification methods are given according to their characteristics and implementation constraints, as shown in Table 2-1.

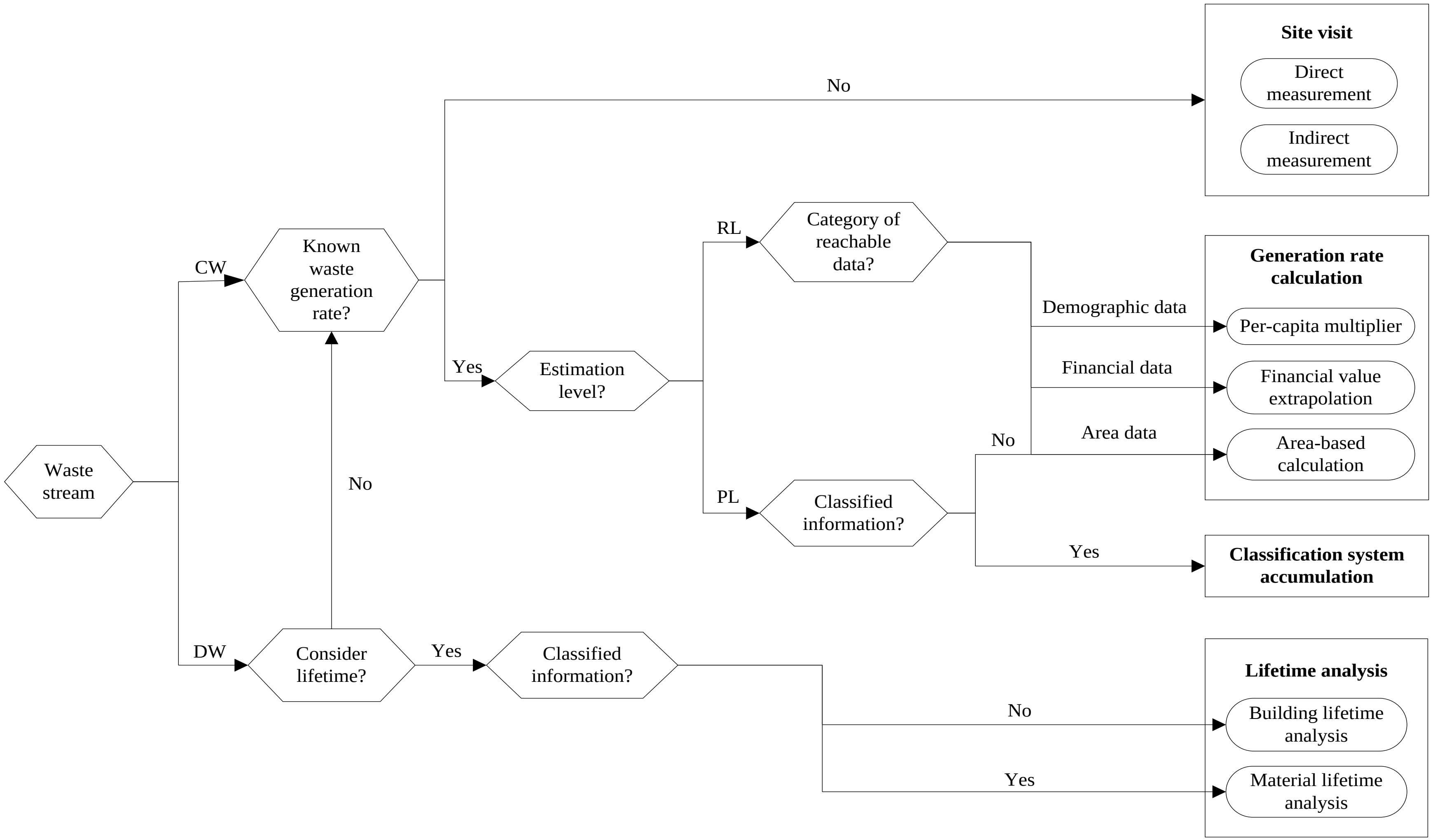

Fig. 2-1 Relevance tree for methodology selection

Table 2-1 Comparison of the current C&D waste quantification methodologies

Methodology		Typical Paper	Waste generation activity	Estimation level	Comments
SV	Direct measurement	(Lau et al., 2008), (Lu et al., 2011)	CNB, DOB, CIW	PL	Direct measurement of C&D waste can provide the most practical waste generation rates, which is the most basic information for C&D waste quantification. Besides, the waste generation rates enable the comparison and benchmark of C&D waste management in different economies. However, the direct measurement should first successfully seek the support from the contractors, and the consumption of time, money and labour is immense.
	Indirect measurement	(Poon et al., 2004)	CNB, DOB, CIW	PL	Indirect measurement can quickly supply general overview of the waste generation situation. However, the waste generation amounts derived from this method can only approximately reflect the facts.
GRC	Per-capita multiplier	(McBean and Fortin, 1993)	CNB, DOB, CIW	RL	Per-capita multiplier is a method developed from MSW quantification. The population statistics, which is very basic information for a region, are utilised. However, as C&D waste generation is more construction related, this method is not suggested if construction related statistics can be derived.
	Financial value extrapolation	(Yost and Halstead, 1996)	CNB, DOB, CIW	RL	Financial value extrapolation utilises financial value presented in construction/demolition permits as a converting factor to estimate the area of construction/demolition activities, hence the estimation of related construction activities. However, this method is not suggested when the area of construction/demolition activities can be directly derived.
	Area-based calculation	(Fatta et al., 2003), (Lage et al., 2010)	CNB, DOB, CIW	PL, RL	Area-based calculation is the most popular method in the literature. It can be employed to estimate all kinds of C&D waste at both project and regional levels. However, the demolition areas statistics may not available at regional level.

LA	Building lifetime analysis	(Poon, 1997)	DOB	RL	Building lifetime analysis is a method that estimates demolition areas, making it possible for quantifying DW without governmental demolition statistics. However, appropriate assumptions of building lifetime are required when conducting this method and the detailed wasted amount at material level cannot be derived.
	Material lifetime analysis	(Cochran and Townsend, 2010)	DOB	RL	Material lifetime analysis is a method that can estimate DW generation at material level. The lifetime of the material is considered. However, similar with building lifetime analysis, appropriate assumptions of material lifetime are required.
CSA		(Solis-Guzman et al., 2009), (Llatas, 2011)	CNB, DOB, CIW	PL, RL	CSA is a methodology developed based on GCC. This methodology can give more detailed information at material level, which makes it more feasible for the project managers and regional policy-makers to formulate effective and efficient waste management plans. However, a classification system is suggested to be established in advance.
VM		(Wimalasena et al., 2010)	CNB, DOB, CIW	PL, RL	VM is a methodology that can simulate the potential inter-relationships between waste generation affecting variables. This method has a great perspective in modelling future C&D waste generation. However, as the realistic data for C&D waste estimation is rare at this stage, this method has not got a wide application.
Others		(Shi and Xu, 2006)	CNB, DOB, CIW	PL, RL	Other methodologies are essentially supplementary for C&D waste quantification. However, due to various limitations, they cannot be generalized.

CNB – Construction of new buildings; DOB – Demolition of old buildings; CIW – Civil and infrastructural works; PL – Project level; RL – Regional level.

SV – Site visit; GRC – Generation rate calculation; LA – Lifetime analysis; CSA – Classification system accumulation; VM – Variables modelling.

2.3 Fundamentals of C&D waste management

2.3.1 Hierarchy model

In order to reduce the environmental impact and increase the management level of C&D waste, a hierarchy model was proposed by Peng et al. (1997), see Fig. 2-2. This model proposed six strategies for dealing with C&D waste and evaluated the environmental impact of each strategy. The six strategies are ‘reduce’, ‘reuse’, ‘recycle’, ‘compost’, ‘incinerate’ and ‘landfill’ respectively. In this order, their environmental influences are ranked from low to high. In particular, the first three strategies, namely reduce, reuse and recycle, are collectively called the ‘3Rs’ in the theory of circular economy.

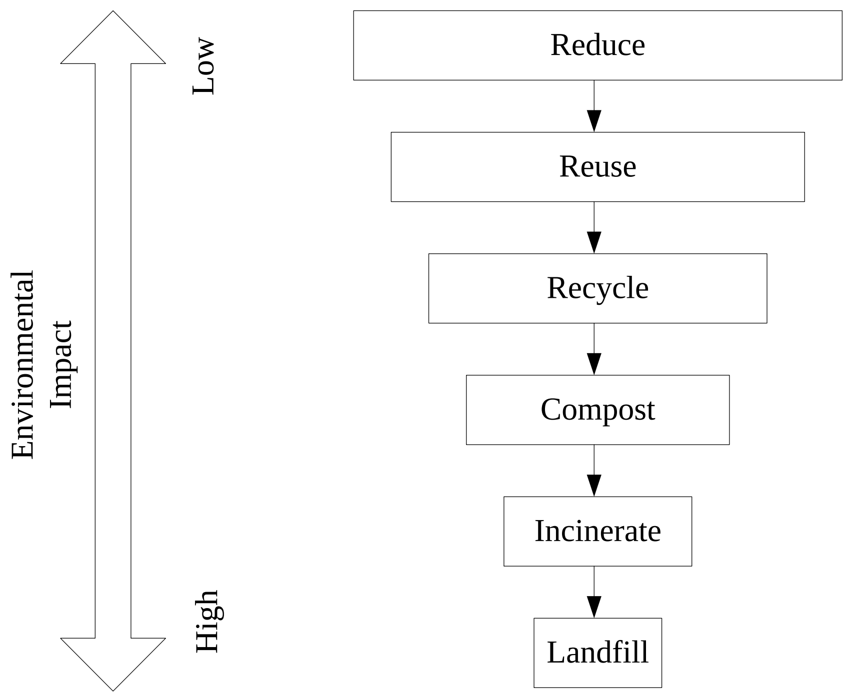

Fig. 2-2 Hierarchy model for C&D waste management (Peng et al., 1997)

The objective of ‘reduce’ is to prevent waste before it is generated. This strategy is regarded as the best possible solution to avoid environmental impacts. In a particular construction project, this strategy can be employed across the whole life cycle. For example, in the design stage, C&D waste can be prevented through the careful selection of materials and better design. In the construction stage, this stream of waste can be avoided by using more advanced techniques and employing workers with higher levels of skill.

The ‘reuse’ strategy requires the wasted materials to be used without any reproducing procedures from the manufacturers, only sorting, cleaning or repair will be implemented to the collected C&D waste. For instance, undamaged wasted bricks can be reused in other places or projects without any other pre-processing. The reuse process is straightforward, but the lifespan and performance of the material should be taken into consideration before being reused.

To implement the ‘recycling’ strategy, new materials will be produced from not only collected C&D waste, but also energy and other raw materials. The new materials are usually called secondary materials. Besides these environmental benefits, economical profits can also be gained from the recycling process. Among C&D waste components, metal materials are the most common recycled ones; they can be melted and used to make other products. However, when assessing the environmental and economic benefits, the process of transportation should be considered, and the quality of the secondary products should be guaranteed.

2.3.2 Life-cycle thinking

As introduced in section 2.2.3, the sources of C&D waste can be throughout the whole life-cycle of a project. Thus it is essential to consider C&D waste minimisation from a life-cycle perspective. Usually, the life-cycle of a particular project can be divided into the design, construction, operation and demolition stages.

In the design stage, three typical reasons leading to C&D waste generation in China's construction industry can be concluded as follows:

1) Design changes. It is common in China that the design schedule is changed during construction. Due to the design changes, a lot of structures which have already been built must be demolished for reconstruction. This will result in a huge production of construction waste.

2) Designer's choice of materials beyond the normal range. During the design stage, designers often like to specify special materials rather than ordinary materials; they often combine special materials which contractors are not familiar with. Because of the lack of related knowledge, these special construction materials are often wasted.

3) Lack of practical experiences. Similar to the above reasons, designers often lack practical experiences. They just product design schemes that they consider novel and striking. The contractors find it is difficult to realize this kind of design, which leads to low efficiency and wasted materials.

In the construction stage, waste is often generated from material packaging and purchased materials wastage. Apart from the potential reasons in the design stage, the actions that the contractor adopts are direct determinants of C&D waste generation. The main factors that may cause this situation are shown as follows:

1) Misunderstanding of design specification. The contractors may purchase materials that do not meet the ideal requirements according to misunderstanding of the design specification. Construction waste will be generated due to excessive procurement.

2) Poor level of materials management. Construction materials might be scattered during the transportation from factories to the construction site. On construction sites, it is often easy to find that materials and construction tools are messed up, which may lead these resources to eventually being wasted. In addition, if the construction materials are not carefully packaged, chemical reactions may happen, which lead to the materials not meeting the

construction standards.

3) Backward construction technology. In China, the technologies used in construction activities are generally laggard. Most of the construction workers lack professional training and environmental protection awareness. So, construction waste will be generated directly due to this reality.

In the operation/usage stage (meaning when the building is occupied and in use), C&D waste is mainly generated from the renovation of buildings. During the usage stage, the users (occupants) may find that the current building functions cannot satisfy their requirements. The old structure will be demolished and new materials or structures will replace them. In this process, C&D waste is generated inevitably.

In the demolition stage, a large amount of demolition waste will be generated. When conducting demolition to a building, almost all the structures including subsurface structure will be destroyed. The main reason for the large amount of demolition waste generation is the choice of inappropriate demolition methods. The main demolition methods implemented in China can be summarised as hammering, striking, crushing and exploding. C&D waste is mixed together and cannot be used for recycling.

2.4 Practices for C&D waste minimisation

2.4.1 Waste management in green building rating systems

As the concept of green building is becoming more and more popular with the public, the building developers are eager to obtain green building certification to increase the added value of buildings. The Green Building Rating System (GBRS) is a tool for evaluating whether a particular building is 'green' or not, and its corresponding rank is given according to the detailed assessment requirements. Wu et al. (2015b) examined five selected GBRSs (as shown in Table 2-2) worldwide and proposed a comparative analysis, attempting to give a better understanding of measures that assist in improving construction waste management. The foci of construction waste management in different GBRSs were investigated in three dimensions based on the '3Rs' principle which refers to reduce, reuse and recycle.

Table 2-2 Five selected green building rating systems

Green building rating system	**Abbreviation**	**Typical used regions**
Leadership in Energy & Environmental Design	LEED	United States, Canada, Brazil
Building Research Establishment Environmental Assessment Methodology	BREEAM	United Kindom, Netherlands, Norway
Green Globes	GG	Canada, United States
Evaluation Standard for Green Building	ESGB	China
Green Building Index	GBI	Malaysia

The research findings from Wu et al. (2015b) revealed that of the five rating systems studied, the highest relative significance index of waste management is given to ESGB, while the lowest belongs to GBI. In relation to the 3Rs principle, ESGB and GG focus more on the reduce principle, while the other three systems propose waste management measures that are largely based on the reuse and recycle principles.

Wu et al. (2015b) acknowledged that a challenging question is how to increase stakeholders' intentions towards adopting good practice in construction waste management. Although the requirements concerning construction waste management are proposed in GBRSs, it does not mean that the stakeholders who seek green building certification must follow the requirements strictly. After all, the green building ranking is given according to the overall score of a project. In other words, the stakeholders can selectively drop some requirements that they are unwilling to follow. As argued by Zhang et al. (2014), the most significant barrier hindering the application of green technologies was consideration of the cost-benefit ratio. The determinant for the stakeholders to adopt waste management measures is to what extent they can gain their profits. Therefore, how to offer the stakeholders clear evidences of tangible benefits from conducting waste management is a challenge that needs to be further tackled.

2.4.2 Typical technologies for C&D waste minimisation

There are many C&D waste recycling technologies in literature (Tam and Tam, 2006). Four typical technologies are abstracted from literature and described as follows.

2.4.2.1 Prefabrication

Currently, when conducting conventional construction methods, a large number of unwanted but unavoidable surplus materials will be produced on site. This will not only increase the investment of construction material procurement, but also occupy the limited space on the construction site, which eventually leads to low working efficiency.

To solve these problems, prefabrication has been introduced into practice. Prefabrication is a manufacturing and pre-assembly process, generally taking place at a specialized facility, in which various materials are joined to form a component part of the final installation (Chiang et al., 2006). This is a totally different process of assembly production: the components used in assembly are manufactured in a factory outside the construction site, and then transported there.

Prefabrication is an effective and efficient method to reduce C&D waste. This construction technology is being widely used in European countries, Japan and Singapore (Tam et al., 2007b). In Hong Kong, the government has already taken prefabrication as a method for reducing C&D waste, and this technology has been used in public housing projects. Chiang et al. (2006) indicated that prefabricated elements accounted for 17% of the total concrete volume used in Hong Kong public housing projects in 2002.

The advantages of adoption of prefabrication can be summarized as follows (Tam et al., 2007b):

- early confirmation of design;
- better supervision on site;
- reduce overall construction cost;
- shorten construction time;
- waste minimisation;
- integrity of the building design and construction;
- aesthetic issues on the building.

The prefabrication technology produces almost no construction waste because there is no need to use rebar or wood forms on the construction site (Chen et al., 2003).

2.4.2.2 Bar-code system

Construction workers play an important role in the production of C&D waste during the construction phase, because they are directly involved in construction activities. In practical projects, a major cause of material wastage was careless working and incorrect operation; worker attitudes towards construction operations could make a big difference in terms of construction waste generation (Chen et al., 2003). Thus construction workers' awareness of avoiding C&D waste plays an important role in waste reduction.

The construction workers could gain their environment protection awareness from education or training. But not all the construction workers have the chance to get a decent education; this situation is especially evident in mainland China. Incentive measures should be conducted in order to let the construction workers have a positive attitude towards waste reduction. The reward can be determined based on the amounts and values of materials they save; the more materials they save, the more rewards they will get (Chen et al., 2003). In order to monitor the effectiveness, the bar-code system can be introduced to facilitate this measure.

A bar code can be defined as a self-contained message with information encoded in the widths of bars and spaces in a printed pattern, which permits rapid and error-free data entry into any type of computer system. By itself the barcode system is neutral. The key is how you apply the barcode technology to give good and timely information about the extent of waste. Once a construction procedure is finished, the construction workers could be assessed by a project manager according to the actual amount and estimated amount. The functions provided by bar-code including (Chen et al., 2003):

- Automatically tracking real-time data of construction materials on the site;

- Automatically recording historical data of construction materials consumed in the project;
- Automatically monitoring materials consumption of working groups; and
- Automatically transferring real-time data of materials to head office via Intranet and/or Internet.

Usually, construction workers are assigned into different groups according to their working categories. Each group has a group leader who takes charge of withdrawing and returning materials. A storage keeper is responsible for recording the amount of materials consumed by each group. An identification card will be issued to the group leader for recording the amount of materials they have withdrawn and returned. Similar with the identification card, a particular material also has a specific code number (Chen et al., 2003).

2.4.2.3 Selective demolition

In the life-cycle of a construction project, it is generally agreed that the demolition phase causes the most wastes. The waste generation rate was often assumed as 100% when estimating the amount of demolition waste (Peng et al., 1997; Poon et al., 2004). This was acceptable if conventional demolition methodologies were chosen. However, it was verified that the waste percentage would be cut down to an extremely low level if selective demolition was conducted (Kourmpanis et al., 2008; Poon et al., 2004).

Selective demolition, which is also called deconstruction, is conducted as a reverse process to the construction process. Usually, complete selective demolition was conducted in combination with the top-down method (Kourmpanis et al., 2008). Different types and fractions of building materials were removed from the building structures step by step and separated on site in order to avoid mixing inert materials such as bricks, concrete with inert materials such as wood, paper, plastics and other materials (Poon et al., 2004).

Generally, in the demolition phase, C&D waste, together with domestic waste should be removed step by step, the sequence of selective demolition can be described as follows:

- Removing domestic wastes with obvious sale value, such as furniture, air-conditioning, and other household appliances;
- Removing metal components, such as window frames, metal pipes, metal doors, etc.;
- Removing timber components, for instance, wood doors, wooden floorboard, etc.;
- Removing hazardous C&D waste, such as asbestos and other hazardous materials;
- Removing other wastes, such as concrete, brick walls, etc.

The demolition of inert C&D waste should start after all the non-structure and non-inert materials have been stripped and removed. In China, it is reported that old buildings are mostly constructed using brick walls on concrete structure (Ouyang et al., 2011). So the most important components for selective demolition are bricks and concretes. After removing all the above mentioned domestic and non-inert building materials, the bricks and concrete elements should also be demolished separately. Basically, the sequence should be removing brick materials firstly, and stacking them orderly on the demolition site. Then, the demolition of concrete structure is conducted.

Comparing with conventional demolition, selective demolition has many advantages, such as:

- Separating hazardous components and materials that cannot be recycled from valuable recyclable materials;
- Substantially increasing the reuse and recycling rate of materials;
- Earn extra money from waste sale;
- Environmental friendly and resource saving.

But still, because this technique must be carried out by construction workers, some disadvantages might be caused:

- Increasing labour cost;
- Requiring more working hours and a longer time period.

Consequently, whether to select this technology depends on the practical situation. If there no compulsive requirements on the construction period, it is suggested to choose this technique - not only for the environment and profit earning, but also for the responsibility and culture of a company.

2.4.2.4 On-site sorting

At present, another technique has been proposed by the Hong Kong environmental protection department named on-site sorting. On-site sorting can be conducted in both the construction phase and the demolition phase. However, this method is usually used after selective demolition. Collected materials should be separated into various groups before transported them to disposal facilities. Using this technique, contractors are required to sort out and remove the hazardous or non-inert materials from the inert components, and pile different materials separately.

Three on-site sorting methods described by Poon et al. (2001b) are listed as follows.

Method 1

- Two refuse chutes for each block of building: one for inert waste and the other for non-inert waste.
- Separate collection of inert waste and non-inert waste from the refuse chutes.
- Inert waste and non-inert waste are cleared by different trucks and disposed of at public filling area and landfills separately.

Method 2

- One refuse chute for each block of building.
- Only one type of waste, either inert or non-inert waste, will be collected separately and removed within a period of time (e.g. every 1 or 2 days).

Method 3

- One refuse chute for each block.
- A sizable pit for waste storage on the ground level.
- Manual sorting of waste at the pit.
- Separate removal of sorted wastes.

Among the above three methods, method 1 was proved to be the best applicable on-site sorting method (Poon et al., 2001b). This was because it can gain the highest scores with the dominant factors such as site space occupation, management effort, labour and cost and interference with normal site activities.

Compared with off-site sorting disposal, on-site methods can save material handling cost and transportation cost, and allow the collection of more recyclable materials. But disadvantages also exist in the usage of this technique, such as the need for more site space, more skilled workers, and more equipment and labour investment. Therefore, just like selective demolition, when considering whether to choose this technology, similar factors should be taken into consideration.

2.5 Stakeholders' attitude and behaviour for waste management

The earliest study concerning attitude and behaviour towards C&D waste management was conducted by Lingard et al. (2000) in Australia. In this study, the employees' perceptions of a large contracting firm's waste management system were investigated. An eight-factor model of the waste management climate was identified and perceptions were found to differ between employee groupings. Managerial staff had a less positive perception of the waste management climate than did site workers. They regarded cost, time or quality objectives more important than environmental issues.

In Hong Kong, Poon et al. (2001a) surveyed the building industry participants' attitudes towards on-site waste sorting. It is found that the building construction participants are reluctant to carry out on-site waste sorting. Even when high a tipping fee is imposed, they have little incentive to perform on-site waste sorting which is considered to be time and labour demanding. Only through contractual requirements or legislation can on-site waste sorting be fully implemented.

Wong and Yip (2004) also investigated the practices and attitude of local project participants towards C&D waste management in Hong Kong. They found that 61% of the respondents did not take any measures to collect and separate C&D wastes and 64% of the projects did not use recycled building materials in construction.

Osmani et al. (2008) stated that the architects have a decisive role to play in helping to reduce waste by focusing on designing out waste. However, their findings showed that, in current practice, waste management is not a priority to consider in the design process. They held the view that waste is mainly produced during site operations and rarely generated during the design stages, though about one-third of construction waste could essentially arise from design decisions.

Begum et al. (2009) investigated the factors that affect contractor's attitude and behaviour regarding waste management in Malaysia. Logistic regression analysis was used to assess the relationship between various factors affecting contractor's attitude and behaviour regarding waste management. The results show that contractor's attitude and behaviour regarding waste management tend to differ based on the size of the contractor. Contractors that have positive attitude towards waste management also have satisfactory behaviour, supporting Ajzen's theory of planned behaviour. The most significant factors affecting contractor's behaviour on waste management are construction-related education among employees, contractor's experience in construction works, source-reduction measures, and reuse of materials, waste disposal behaviour and attitude towards waste management.

Echoed with Begum et al. (2009), Al-Sari et al. (2012) examined how the local contractor's waste management attitude and behaviour are influenced in the occupied Palestinian territory. A logistic regression model was also used to investigate the relationship between various attributes and the attitude and behaviour that the local contractors demonstrate towards waste management. It was found that the attitude towards the 3Rs principle of waste minimisation and the behaviour towards waste disposal are generally positive with smaller contractors. The authors generally observed that in the absence of a regulatory framework, the voluntary attitude and behaviour among the local contractors are mostly driven by direct economic considerations.

Knoeri et al. (2011) analysed construction stakeholders' decision-making regarding recycled construction materials in Switzerland. Stakeholders' decision-making was quantified with the analytical hierarchy process in a survey in combination with their behaviour. The results demonstrated that the stakeholder interaction is very important. For example, most stakeholders decide which material to apply based on interactions with other stakeholders.

Li and Yang (2014) explored the critical factors for the selection of waste management in Australian office building retrofit projects. The identified factors were grouped into five dimensions including industrial culture, organisational incentive, existing building information, design, and project delivery.

Hassan et al. (2015) used data from site observations and interviews to identify the main causes of C&D waste generation in Malaysian housing construction projects. The findings showed that different materials have different contributions to the total waste generation; however, the main causes of C&D waste are attributed to workers and management problems.

Sun et al. (2015) investigated the waste management practices and opinions of small builders in the UK. The results revealed that there is an elementary level of awareness amongst small builders; however, their relevant knowledge is limited and their attitudes toward sustainability are diverse and ambivalent.

Udawatta et al. (2015) implemented semi-structured interviews to understand the attitudes and behaviour of construction stakeholders on C&D waste management. The findings revealed that the most important factor that influences stakeholders' decisions in Malaysia is the financial return when employing C&D waste management. However, this may change if there is a special requirement to comply with a particular green building rating system. Therefore, it is suggested that legislation should be enforced to improve waste management culture until such practices become culturally embedded in organisations. Furthermore, end users' motivation is also a key to encourage stakeholders to implement C&D waste management.

Li et al. (2015) investigated designer's attitude and behaviour towards construction waste minimisation based on the theory of planned behaviour. The results showed that attitude and perceived behavioural control are the significant factors that can positively affect designer's waste minimisation behaviour. Measurements were suggested to improve designer's waste minimisation behaviour such as education programmes and legislation.

From the historical literature review, it can be found that the existing studies generally regarded attitude/intention the same as the actual behaviour. In the studies which involved A&B theories, contextual factors (e.g., economic viability) were not considered. This study aims to fill this research gap by involving both A&B theory and contextual factors.

2.6 Summary

This chapter gave a general review of C&D waste definitions in different regions including Hong Kong, the United States, Japan, the European Union and Mainland China. Two prevailing C&D waste management philosophies (i.e., hierarchy model and life-cycle thinking) were presented in this section; both of them are the fundamentals of implementing successful C&D waste management. The waste management requirements in five selected green building rating systems were compared based on the 3R principle. Furthermore, four popular C&D waste management measures, including prefabrication, bar-code system, selective demolition and on-site sorting, were selected and introduced in this section. It is believed these measures can improve the waste reduction and save the cost significantly. However, in the Chinese practice, these measures are not implemented very often. Therefore, it is significant to investigate the contractor's attitude and actual behaviour towards C&D waste management, and in what circumstance, the contractor will decide to implement effective C&D waste management. The next chapter presents the research design and methodology used in this study.

CHAPTER 3 Research Design and Methodology

3.1 Introduction

This chapter describes the research design and methodology adopted in this study. The research design is first introduced, followed by the specific research methods used in this study, such as the literature review, focus group meeting, semi-structured questionnaire survey, and interviews with professionals. Detailed description and discussion of the selected methods are subsequently presented. Furthermore, the data analysis techniques utilised in this study are explained.

3.2 Research design and methodology

A reasonable research design can assist in accomplishing the research objectives successfully and smoothly. Thus the research design developed herein is largely dependent on the proposed research objectives and the logic of this study. As stated in Chapter 1, the principal aim of this study is to investigate the determinants that affect contractor’s C&D waste management behaviour so as to clarify the interrelationships between them. In order to achieve this research aim, a research framework has been designed, as shown in Fig. 3-1. The research methods and corresponding analysis techniques selected in different steps are also presented in this figure.

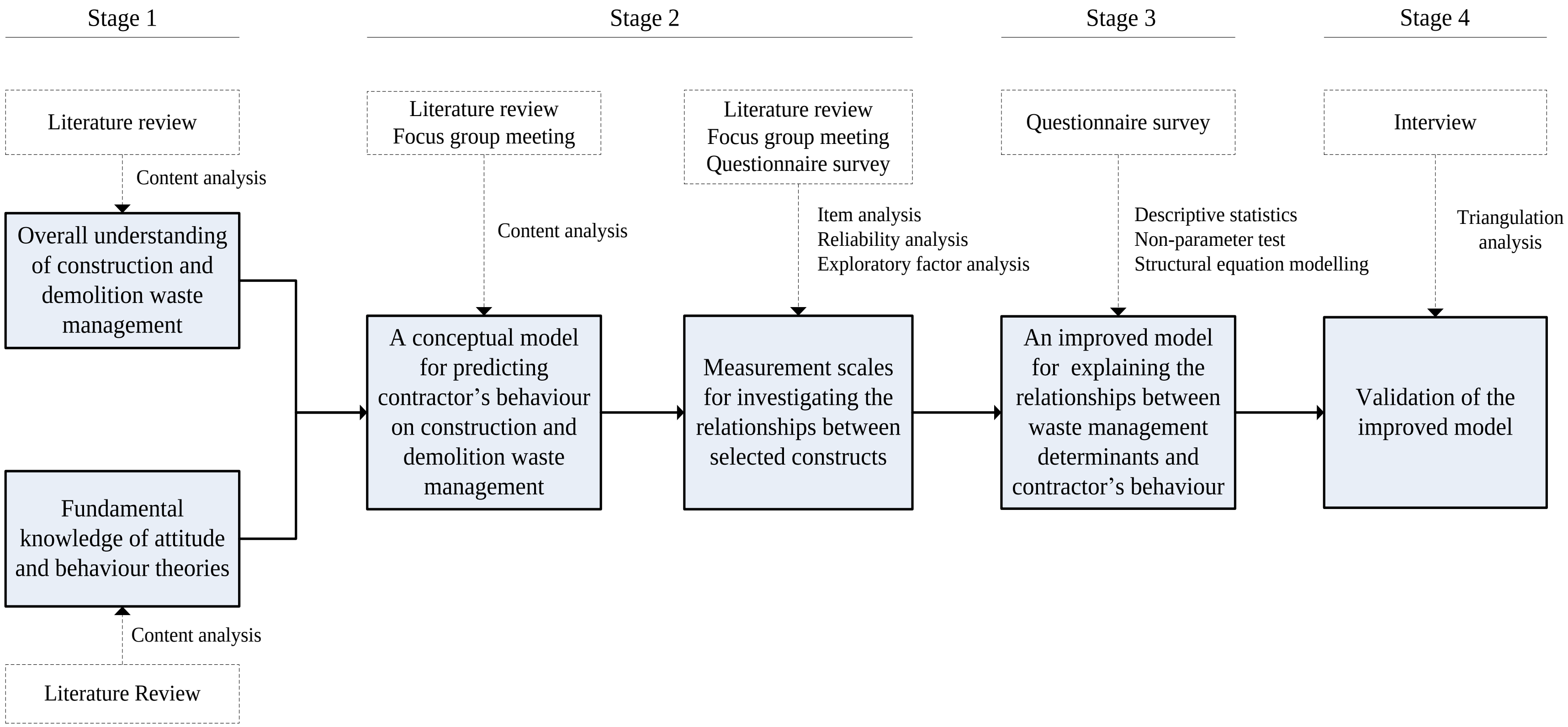

Fig. 3-1 Research framework

Stage 1: Overall understanding of C&D waste management and A&B theories

This study is a combination of C&D waste management and A&B theories. An in-depth and comprehensive understanding of existing knowledge provides the basis for the success of this study. To achieve this, the method of literature review was conducted and the collected literature was analysed using content analysis. Based on the outcomes of this step, useful knowledge was derived to promote the next step of developing a preliminary conceptual model.

Stage 2: A conceptual model for predicting contractor's behaviour on C&D waste management

This aim of this step is to establish a model for predicting contractor's behaviour on C&D waste management. The main research methods employed in this step include literature review and focus group meeting. The literature review was used to abstract the identified variables which have potentials to affect the contractor's behaviour on C&D waste management in existing studies. The focus group meeting was employed to invite experienced professionals and scholars who have relevant knowledge to give comments and suggestions to the initial conceptual model and the preliminary questionnaire.

Stage 3: Investigation of the relationships between potential waste management determinants and contractor's actual behaviour

The investigation of the relationships between potential waste management determinants and contractor's actual C&D waste management behaviour is the most important procedure for determining the final model. In this stage, a questionnaire survey method was utilised. A pilot study was first conducted to improve the questionnaire for the formal investigation. Statistical techniques were employed to analyse the collected data. Based on the analysis results, the proposed conceptual model was tested and improved, and the relationships among the identified constructs were investigated. The determinants of C&D waste management behaviour were identified.

Stage 4: Validation of the improved model

After identifying the relationships and determining the final model, a triangulation analysis was conducted to validate the statistical findings. Interviews were employed with voluntary professionals who had attended the questionnaire survey and left their contact information. The aim of this stage is to validate whether the improved final model can explain the underlying reasons of C&D waste management.

3.3 Literature review method

3.3.1 Introduction of literature review method

The literature review is the fundamental procedure of a study in almost all academic areas. The aim of the literature review is consolidating previous studies related to the research topic and thus understanding the current practice (Chow, 2005). This method is commonly used in formulating a proposal or publication of a research. An adequate and thorough literature review can assist in digging out insightful information in the existing literature.

3.3.2 Literature review method in this study

In this study, a large number of relevant publications were derived from academic databases. A comprehensive reading was conducted in order to obtain a holistic picture of each concept in this study. Firstly, the C&D waste management strategies and current status were reviewed. The databases for retrieving papers were the SCI database and the Scopus database because the papers included in these two databases are regarded to be of good quality. 'Construction and demolition waste management' was set as the keyword for searching papers and the time span was designated to be from 1990 to present. After the collection of relevant papers, a cross-referencing examination was further conducted to ensure the comprehensiveness of the research. Similar with the process of retrieving C&D waste management papers, a detailed review of theories on attitude and behaviour was performed. 'Attitude and behaviour theory' was set as the keyword and the first 50 most frequently cited papers in the SCI database were downloaded for further review. Through the literature review process, the current C&D waste management situation was well understood and the Theory of Planned Behaviour was selected as the basis for developing the preliminary theoretical framework.

3.4 Focus group meeting

3.4.1 Introduction of focus group meeting

The focus group meeting method requires relevant stakeholders or professionals to get together to collect opinions from them. In a focus group meeting, a facilitator guides the participants to provide their opinions on a specific topic following a structured guideline. The focus group meeting method concentrates on one designated topic, and the participants share their opinions and give feedback to the meeting leader. The facilitator will then deal with the responses. The focus group meeting method includes three advantages: deeper insights, interactive feedback, and low costs (Kokemuller and Media, 2015). Meanwhile, attention should be paid to two common disadvantages including groupthink and response accuracy when implementing this method (Kokemuller and Media, 2015).

3.4.2 Focus group meeting in this study

The focus group meeting method was used in this study to formulate the preliminary conceptual model and to design measurement scales for investigating the relationships between the identified constructs. Three representatives were invited to participate in the focus group meeting. The author was the meeting moderator to ask the participants' opinions of the potential constructs identified from the literature. Based on the discussion, the initial questionnaire was designed for further study.

3.5 Questionnaire survey

3.5.1 Introduction of questionnaire survey

The questionnaire survey is regarded to be an effective method for collecting data beyond the physical reach of the respondents and sampling the respondents' attitude and behaviour in spatially diverse locations (Yeung, 2007). It is usually designed to collect standardised data from the respondents by offering them a set of alternative choices for each question. This method can save both time and labour, thus it is frequently used in social science studies.

According to the response types, three questionnaire types can be derived: structured questionnaire, semi-structured questionnaire, and unstructured questionnaire (Fowler, 1995). The structured questionnaire contains only closed-ended questions, which means the potential answers for each question have been designed by the questionnaire designers and what the respondents need to do is just decide which alternative answer to choose. The unstructured questionnaire refers to the questionnaire which includes open-ended questions exclusively. There is no preset answer to the questions, letting the respondents answer the questions independently. The semi-structured questionnaire involves both closed-ended questions and open-ended questions. This kind of questionnaire is commonly used because it can reach a large sample and the individual interviewee can also give their personal comments to the related topic.

Generally speaking, the data or information collected from a questionnaire survey involves two major categories: attitudes and behaviour, which can be further divided into six aspects: 1) the current behaviour, 2) the past behaviour, 3) the future behaviour; 4) the current attitude, 5) the past attitude, and 6) the future attitude. Besides the two categories, a questionnaire should include the personal background information of the respondents, such as age, gender, education level, etc. The personal background information and behavioural data are objective questions, while the attitudinal questions are subjective.

3.5.1.1 Structure of a questionnaire

A formal questionnaire usually consists of four components: title, preface, main body, and closure. Each questionnaire must have a title at the beginning of a questionnaire, specifying the research theme of the questionnaire. An appropriate title should be clear to express the research topic and attracting the respondents to answer the questions.

In the preface section, the research background, research objectives, and the requirements of the response should be introduced in order to call for the interest from the potential respondents. It is important to clarify the confidentiality of the questionnaire survey to eliminate the concerns of the respondents. If there is a time limit for response collection, it should be noted when is appropriate for the returning time.

In the main body, the personal background information of respondents and the survey questions are included. The objective of collecting personal background information of the respondents is facilitating to categorise the respondents. Usually, there may be different attitudes or behaviour between various respondents in accordance with their age, gender, education level, occupation, etc. This kind of information can supply important references during data analysis procedures. The survey questions are the core of a questionnaire. Questions are listed to collect data from the respondents for further analysis. For the closed-ended questions, several potential options are listed for the respondents to select. In regard to the open-ended questions, there are no certain answers, the respondents can give their personal answers by themselves or even leave them unanswered.

At the end of a questionnaire, a closure statement is usually presented. It is not just informing the respondents that the questionnaire survey is coming to an end, but also an opportunity to express the gratefulness of the investigator to the respondents. The reliability of the questionnaire is determined by the respondents, who spend much of their precious time on responding the questions. Therefore, it is necessary to express gratitude for their effort and make them feel respected.

3.5.1.2 Principles of designing a questionnaire

A good questionnaire should bear two characteristics: conveying the question exactly and making the respondents readily to answer (Boynton, 2004). Dillman

(1978) claimed that a good questionnaire should satisfy the basic requirements of the research study. In addition to this, the questionnaire should be designed concisely and comfortably to be answered without any discrimination. The clear structure and easy-to-answer questions can ensure the initiative of respondents. In order to ensure the reliability of the collected data, Salant et al. (1994) introduced some principles that a good questionnaire should comply with, presented as follows.

1) Length. The length of a questionnaire should be controlled in 6-8 pages, and the time consumed to accomplish the response should be within 20 minutes. This is because a common situation is that the longer the questionnaire, the more difficult it is to get responses, and the harder to keep the responses reliable.

2) Introduction. A brief introduction of the research aims and significance is essential to attract the potential respondents to participate in the questionnaire survey. It would be more helpful if a brief guide can be supplied to suggest how to make the response.

3) Language. The language used in the questionnaire should be exact and easy to understand and follow. Complex terminologies and undefined abbreviations should be avoided to ensure the respondents can understand the exact meaning

of the questions. In addition, implicit and tendentious questions should be avoided.

4) Structure. To keep the interest of the respondents, the structure of a questionnaire should be simple and clear. The questions in the same section should be relevant and homogeneous while keeping exclusiveness.

5) Questions. It is encouraged to use closed-ended questions to collect respondents' information. The number of open-ended questions is suggested to be few, if unavoidable.

6) Scales. In the case of using a Likert scale to conduct the measurement, it should be noted that the reliability increases with the increasing number of points on the scale. However, when the number of points reaches 5, the increasing ratio of reliability is impaired. Therefore, Berdie (1989) indicated that the questionnaire with a 5-point Likert scale is the most reliable in most cases, and it is difficult to have a clear distinction if the number of points exceeds 5.

3.5.1.3 Steps of designing a questionnaire

In order to design a reliable questionnaire, five steps are usually followed: 1) determine the research topic and objective; 2) determine the key constructs; 3) draft initial questionnaires; 4) pilot study; and 5) finalise the formal questionnaire.

Step 1: Clarify research topic and objectives

Prior to the design of questionnaire, it is essential to clarify the research topic and objectives of the questionnaire. Related concepts involved in the survey were clearly defined. A concise research clarification ensured the following steps could be proceeded with smoothly.

Step 2: Preliminary determination of constructs

Based on the research topic and objectives, exploratory work was conducted to conceptualize the preliminary constructs in the questionnaire. In this procedure, the literature review and focus group meeting were conducted to derive a preliminary overview of the potential constructs involved in the questionnaire. Thus the questionnaire designer can formulate an objective understanding of the potential structure of the questionnaire, the potential respondents, data collection methods, etc.

Step 3: Draft initial questionnaire

After formulating the preliminary understanding of the questionnaire, the designer determines the questions involved in the questionnaire. In addition to personal background information questions, the measuring questions were determined to measure the constructs. This step involved the specific statement of the questions, the potential options for closed-ended questions, the sequence of the questions, the exact logic and structure of the questionnaire, etc.

Step 4: Pilot study

The developed initial questionnaire should not be used for a formal survey directly; a pilot study is a must for the formulation of the formal questionnaire. The aim of pilot study is to modify the initial questionnaire to eliminate existing errors and to ensure the reliability of the questionnaire. Although a pilot study cannot guarantee the success of the formal survey, it does increase the likelihood (van Teijlingen and Hundley, 2001). In the case that a pilot study leads to a major revision of the questionnaire, it is essential to conduct another round of pilot study before distributing the formal questionnaire.

Step 5: Finalise formal questionnaire

It is anticipated that the improved questionnaire can be used and distributed for data collection after conducting the above-mentioned steps. However, before the questionnaire can be distributed for a formal survey, the questionnaire was proofread by others to avoid typos and to keep the format consistent.

3.5.2 Data analysis techniques

Useful information cannot be extracted unless the collected raw data is analysed using appropriate data analysis techniques (Hair et al., 2006; Russo, 2004). In this study, a set of data analysis techniques were utilised to explore the insightful results based on the collected data. The selected analysis techniques include descriptive statistics, reliability analysis, factor analysis, non-parametric test, and structural equation modelling. The Statistical Package for the Social Sciences (SPSS) and Analyse of Moment Structures (AMOS) were employed for analysing the raw data.

3.5.2.1 Descriptive statistics

Descriptive statistics are an analysis technique that helps to show the collected data in a meaningful way. It can be used to organise, summarise, and interpret the data sets effectively, supplying basic conclusions on the measuring sample and related content (Lee, 2009). Through descriptive statistics, the data can be output as figures, making the sample visible and showing the distribution intuitively. In this study, descriptive statistical techniques were used to identify the characteristics of typical variables.

3.5.2.2 Reliability analysis

Reliability analysis is a technique that tests the degree of stability or consistency of the instruments, reflecting the degree of whether the derived results can be replicated (Hollnagel, 1993). Reliability consists of external reliability and internal reliability. External reliability is the consistency of the scale test in different times. Test-retest is the most useful way in testing external reliability. Internal reliability refers to whether each scale tests a single idea and the consistency of items in the scale. It is usually used in multiple-item scales. The higher the value for internal reliability means the smaller of the test's standard error. After the factor analysis, each level of the sub-scale internal validity α is usually lower than total-scale validity. Reliability analysis usually follows the factor analysis to test each sub-scale as well as total scale. A common used statistic for evaluating reliability is the Cronbach alpha coefficient (α).

It should be noted that reliability analysis is a technique for testing the results derived from the instruments rather than the instruments themselves (Wu, 2010). It is a requirement of the validity but not a sufficient condition. The lower reliability leads to a lower validity; however, a high reliability may not lead to a high validity. There are many arguments for the acceptable value of Cronbach alpha coefficient (α). For example, DeVellis (2012) stated that the value of 0.70 is the minimum acceptable threshold, and α between 0.70 and 0.80 is good and α above 0.80 is excellent. According to Henson (2001), the minimum value of α depends on the research purpose. If the purpose is for developing a questionnaire, a reliability coefficient between 0.50 and 0.60 is sufficient. If the research purpose is for basic research, a reliability coefficient value above 0.80 is necessary. As for the sub-scale, the minimum internal reliability coefficient of sub-scale should be above 0.50 and is better above 0.60 while the minimum threshold for the total-scale should be above 0.70 and is better above 0.80. In general, the acceptable value of reliability coefficient should be above 0.70 (Wu, 2010).

3.5.2.3 Exploratory factor analysis

The objective of exploratory factor analysis is categorise a large number of variables into a smaller number of hypothetical variables which can explain most of the observed variables (Kim and Mueller, 1978). Exploratory factor analysis can analyse the underlying structure of a set of questions based on the patterns of responses (De Vaus and de Vaus, 2001). Factor analysis can be used to evaluate the validity of the scales. The validity includes internal and external. Internal validity is regarded as the authenticity and the correctness of the research description. External validity refers to the validity of the research inference. The typical procedures of conducting factor analysis are described as follows: (1) identification of the variables; (2) calculate a correlation matrix for the variables; (3) extract the un-rotated factors; (4) rotate to make the factors more interpretable; and (5) interpret and name the rotated factors (Comrey and Lee, 2013).

The widely used factor extraction methods include principal components analysis, principal axis factoring, and maximum likelihood. The widely used rotation method includes Varimax, Quartimax, Equanmax, Direct Oblimin and Promax. The former three are categorised into orthogonal rotations. In orthogonal rotations, it is assumed that no correlation exists between factors. The latter two belong to the oblique rotation method, which is often used when there are correlations between factors. The selection rules for the appropriate number of factors include Eigenvalue-greater-than-one rule scree plot.

3.5.2.4 Non-parametric test

Non-parametric techniques do not make assumptions about the underlying population distribution of the variables being assessed. They are ideal for use when the data are measured on nominal and ordinal scales (Pallant, 2007). The major difference between parametric techniques and non-parametric techniques is that there is no need to make assumptions about the shape of the population distribution in non-parametric techniques.

There are four commonly used non-parametric techniques: Mann-Whitney U Test, Wilcoxon Signed Rank Test, Kruskal-Wallis Test, and Friedman Test. The comparisons of the four non-parametric techniques to their corresponding parametric techniques are listed in Table 3-1.

Table 3-1 Non-parametric techniques and corresponding parametric techniques

Non-parametric techniques	**Parametric techniques**
Mann-Whitney U Test	Independent-samples T-test
Wilcoxon Signed Rank Test	Paired-samples T-test
Kruskal-Wallis Test	One-way between-groups ANOVA
Friedman Test	One-way repeated-measures ANOVA

3.5.2.5 Structural equation modelling

Structural equation modelling (SEM) is a statistical technique for testing and validating causal relations through a combination of statistical data and qualitative causal assumptions. This technique can be used for both confirmatory and exploratory modelling, which means that they are suitable for both theory testing and theory development. During the modelling process, the variables are categories into different constructs and the assumptions may be modified according to the modelling results (Hair et al., 2006).

There are a number of advantages to the use of SEM. When relationships among factors are examined, the relationships are free of measurement error because the error has been estimated and removed, leaving only common variance. Reliability of measurement can be accounted for explicitly within the analysis by estimating and removing the measurement error. Additionally, complex relationships can be examined. When the phenomena of interest are complex and multidimensional, SEM is the only analysis that allows complete and simultaneous tests of all the relationships. In the social sciences we often pose hypotheses at the level of the construct. With other statistical methods these construct-level hypotheses are tested at the level of a measured variable (an observed variable with measurement error). Mismatching the level of hypothesis and level of analysis—although problematic, and often overlooked—may lead to faulty conclusions. A distinct advantage of SEM is the ability to test construct-level hypotheses at the appropriate level. Another critical advantage of SEM over the basic general linear model or simple regression is that variables that are dependent variables also can play the role of predictor variables in the model as a whole. This feature uniquely allows SEM to model mediation effects.

3.5.3 Questionnaire survey in this study

In this study, the potential affecting factors of C&D waste management behaviour were identified based on the information collected from literature review and focus group meeting. In order to analyse the interrelationships of the identified factors, a questionnaire was designed to be delivered and used for collecting data. The questionnaire is composed of nine parts. The first part deals with the personal background information of the respondents. The second part is for investigating the construct of attitude. The third part contains questions for investigating the respondents' subjective norms. The fourth part deals with the perceived behavioural control of respondents. The fifth part investigates the behavioural intentions of the respondents. The sixth part aims to test the level of governmental supervision. The seventh part evaluates the economic viability. The eighth part examines the project constraints. The last part is for evaluating contractor's actual C&D waste management behaviour.

3.6 Interviews with professionals

3.6.1 Introduction of interviews

After deriving the analysis results, interviews with professionals were employed to validate the research outcomes. Interviews were adopted because of the instant feedback of the respondents. The instant feedback provides the possibility of dispelling ambiguity because the interviewer is adjacent to the interviewee as the questions are being answered (Opdenakker, 2006). The telephone interview method instead of face-to-face interview was used in this study. This is because there is little evidence showing that telephone interviews produce lower quality data compared with face-to-face interviews, and telephones may allow the interviewees to feel more relaxed (Novick, 2008).

3.6.2 Interviews in this study

A series of semi-structured interviews were conducted with five professionals through telephone to identify the critical variables affecting contractor's behaviour of C&D waste management. All of them had more than five years of experiences in the area of construction management. During each interview, four issues were discussed: (1) their perceived level of C&D waste management; (2) C&D waste management strategies or technologies that have been used in their projects; (3) the most common difficulties and obstacles when implementing C&D waste management; and (4) their perceived determinants of C&D waste management behaviour in practice. The telephone interviews were conducted in November 2015. Each of the interviews was conducted in Mandarin and lasted at least half an hour.

3.7 Summary

This chapter provided a detailed description of the research framework used in this study. The selected research methods and data analysis techniques used to achieve the research objectives were described. The overall research design and process were first introduced, followed by the explanations of research methods and data analysis techniques. The next chapter describes the proposal of the preliminary theoretical model in this study.

CHAPTER 4 Development and Establishment of a Preliminary Theoretical Framework

4.1 Introduction

In this chapter, the development of the preliminary framework is presented. Firstly, two typical attitude and behaviour (A&B) theories are introduced. The Theory of Planned Behaviour (TPB) is selected as the basis of the establishment of the initial model. Then, three contextual constructs (i.e., governmental supervision, economic viability, and project constraints) are abstracted from the literature and incorporated into the TPB-based model to formulate the complete initial model. These three constructs are considered important because they are the most commonly investigated and discussed factors in existing C&D waste management research. Finally, based on the initial model, seven hypotheses are proposed for further investigation.

4.2 Attitude and behaviour (A&B) theories

In order to identify the relationships between contractor's attitude and behaviour towards C&D waste management, it is essential to identify a solid theoretical foundation for subsequent investigation. In this study, two prevailing A&B theories, namely Theory of Reasoned Action (TRA) and Theory of Planned Behaviour (TPB), were considered to formulate the model. They were selected because they have been proved to be mature theories in the A&B field (Armitage and Conner, 2001; Conner and Armitage, 1998; Pakpour et al., 2014).

4.2.1 Theory of reasoned action (TRA)

4.2.1.1 Introduction of TRA

In the very first studies on attitude and behaviour, attitude was considered to be the most significant factor that influences an individual's behaviour (Fishbein, 1967). During this initial period of discovery, scholars assumed that attitude approximately equals behaviour, and more than five hundred measurement methods were developed for measuring attitude (Droba, 1931). However, as behaviour research developed, researchers found that it was common that practical behaviour vary from attitude (Fishbein, 1967). As a result, the 'central position' of attitude as the most significant factor to predict behaviour was questioned.

In order to give a more complete prediction of behaviour, Fishbein and Ajzen (1975) proposed the Theory of Reasoned Action (TRA). TRA was developed based on the multi-attribute model by introducing a new construct - subjective norm, clarifying the causal relationships among attitude, subjective norm, behavioural intention and behaviour. The framework of TRA is presented in Fig. 4-1.

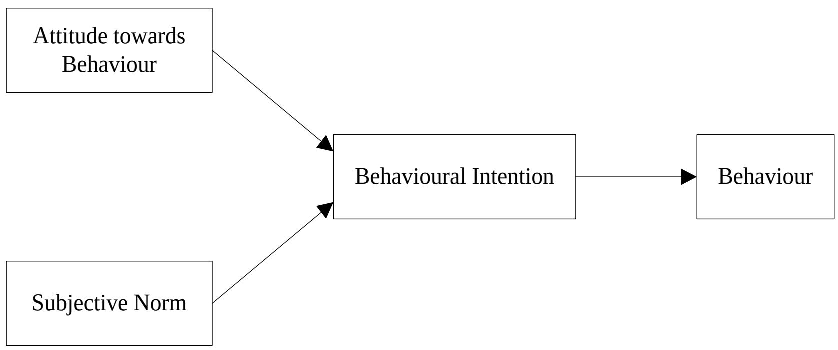

Fig. 4-1 Theory of reasoned action (Fishbein and Ajzen, 1975)

To utilise TRA, a premise is that the behaviour of an individual is rational. It is assumed that all behaviour is performed after information processing and analysis as well as reasonable thinking. Based on the premise, three basic assumptions are proposed in TRA:

1) the majority of individual's behaviour is reasonable and under the control of the individual himself;

2) the intention of a behaviour is the instant dominant factor;

3) the factors, such as gender, age, occupation, personality, have no direct influence upon behavioural intention; they influence intention only through attitude and subjective norm.

In TRA, there are a total of three constructs that influence behaviour, namely attitude towards behaviour, subject norm, and behavioural intention. The definition of each construct and relationships among the three constructs are explained in the following subsections.

1) Behavioural intention (BI)

The behavioural intention is defined as the indication of an individual's readiness to perform given behaviour (Ajzen, 2006b). It is regarded to be the immediate antecedent of behaviour, determined by individual's attitude towards the particular behaviour and subjective norm. Instead of the TRA framework, the relationships of the three constructs and behaviour can be described using the following equation:

$$B \approx BI = W_1AB + W_2SN$$

where B represents a particular behaviour, BI stands for behavioural intention, AB is the individual's attitude towards behaviour, and SN is the subjective norm. W_1 and W_2 represent the experienced weights of attitude and subjective norm.

From the equation, it can be seen that there is an obvious correlation between behavioural intention and behaviour. Behavioural intention is regarded as the most significant construct in predicting behaviour. It is claimed that the best way to predict behaviour is to evaluate the individual's intention towards the behaviour.

2) Attitude towards behaviour (AB)

The attitude towards a behaviour is defined as an individual's opinion of the possible results of a behaviour; it can be positive or negative (Ajzen, 2006a). The attitude towards behaviour is affected by the individual's behavioural beliefs and evaluation of consequences. 'Behavioural beliefs' mean the personal prediction of potential consequences of behaviour, such as 'implementing C&D waste management can increase the recycling level of waste'. 'Evaluation of consequences' is the individual's personal evaluation of the above consequences. For instance, 'the increased level of waste recycling can reduce environmental pollution'. In TRA, the individual's attitude is measured by the accumulation of each possible consequence multiplied by its personal evaluation. The relationship can be described using the following equation.

$$\mathrm{AB} = \sum_{i=1}^{n} (bb_i + ec_i)$$

where AB represents the attitude towards behaviour, bb_i is the belief of the appearance of potential consequence i (namely the perceived possibility of consequence i); ec_i presents the personal evaluation of consequence i; n is the total number of potential consequences.

3) Subjective norm (SN)

The subjective norm is defined as an individual's perceived pressure imposed by public or important referents to engage or not in particular behaviour (Ajzen, 2006c). The subjective norm is affected by the normative beliefs and corresponding motivation to apply them. 'Normative beliefs' are the perceived behaviour expectations of the individual's important referents (i.e., significant others, such as parents, spouse, friends). For example, 'my family members expect me to conduct C&D waste management'. 'Motivation to comply' is an individual's motivation to follow the referent's expectation, such as 'I always comply with my family member's expectation'. In TRA, the individual's subjective norm is determined by the important referents' expectations and their corresponding complying possibilities. The relationship can be described using the following equation.

$$\text{SN} = \sum_{j=1}^{r} \left(nb_j + mc_j \right)$$

where SN is the individual's subjective norm towards behaviour; nb_j is one important referent's expectation; mc_j represents the possibility to comply the expectation; r is the total number of referents.

4.2.1.2 Application and discussion of TRA

After the proposal of TRA, many scholars have conducted empirical research to test this theory in their fields. This theory got successful application in many fields, including weight losing behaviour (Sejwacz et al., 1980), American election voting behaviour (Fishbein et al., 1980), television viewing behaviour (Loken, 1983), mothers' infant-feeding behaviour (Manstead et al., 1983), coupon usage behaviour (Shimp and Kavas, 1984), seat-belt using behaviour (Budd et al., 1984), recreation behaviour (Young and Kent, 1985), dental health behaviour (Hendricks, 1988), etc. Jones (1989) investigated waste paper recycling in the north-western public university and found that there was a strong correlation between behavioural intention and behaviour.

In order to verify the effectiveness of TRA, Sheppard et al. (1988) conducted a meta-analysis based on the past studies. Their results demonstrated that TRA was applicable in many cases; however, they also found that the variability between behavioural intention and behaviour appeared to be large in some cases. There were some other scholars also argued that TRA could only be applied to volitional behaviour instead of resource required behaviour which requires technique, ability, opportunity and cooperation (Liska, 1984). Noted with these arguments, the Theory of Planned Behaviour (TPB) was further developed to deal with the above-mentioned problems.

4.2.2 Theory of planned behaviour (TPB)

4.2.2.1 Introduction of TPB

The theory of planned behaviour (TPB) is an extension of TRA, which introduces a new construct of perceived behavioural control (PBC) (Ajzen, 1985). PBC is the individual's perceived ease or difficulty to perform particular behaviour. It is determined by the control beliefs about the factors that may impede or facilitate the particular behaviour and the perceived power of these factors.

Compared to TRA, TPB can give more explanations on the behaviour that are not completely autonomic. The framework of TPB can be demonstrated in Fig. 4-2.

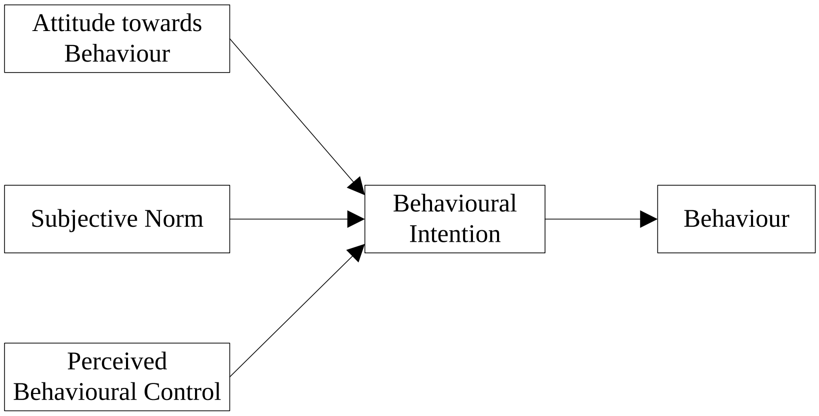

Fig. 4-2 Theory of planned behaviour (Ajzen, 1985)

In the presented framework, it can be seen that an individual's behaviour intention is mainly affected by his/her attitude towards behaviour, subjective norm, and perceived behavioural control. The more positive the person's attitude, the more support from important persons, and the more autonomic control of the particular behaviour, the more possible it is that the individual has behavioural intention, and the more possible that the individual performs this particular behaviour. In addition, the perceived behavioural control can directly affect the behaviour to some extent. The relationships of TPB can be explained using the following equations:

$$BI = W_1AB + W_2SN + W_3PBC$$

$$B = W_4BI + W_5PBC$$

where B represents particular behaviour, BI stands for behavioural intention, AB is the individual's attitude towards behaviour, SN is the subjective norm, and PBC stands for perceived behavioural control. W_1 to W_5 represent the experienced weights of each construct.

Similar to TPA, behaviour in TPB is also mainly predicted by intention. However, perceived behavioural control can also play direct influence on the person's decision of executing behaviour because there are limitations in volitional control.

4.2.2.2 Application and discussion of TPB

Since the proposal of TPB, this theory has been widely employed in the prediction of behaviour in many fields all over the world. TPB has been successfully applied in the following fields: weight loss behaviour (Schifter and Ajzen, 1985), leisure participation (Ajzen and Driver, 1991), dishonest and unethical actions of college students (Beck and Ajzen, 1991; Chang, 1998), conservation technology adoption decisions (Lynne et al., 1995), health-related behaviour (Godin and Kok, 1996), pollution reduction preferences of US environmental managers (Cordano and Frieze, 2000), hunting behaviour of outdoor recreationists (Hrubes et al., 2001), healthy eating (Conner et al., 2002), choice of travel mode (Bamberg et al., 2003), internet purchasing (George, 2004), quitting smoking (Moan and Rise, 2005), binge drinking (Norman et al., 2007), green hotel choice (Han et al., 2010), volunteer participation in collaborative watershed partnerships (Hauser et al., 2012), accommodation managers' crisis planning (Wang and Ritchie, 2012), fan participation behaviour in baseball (Cheng et al., 2012), infant restraint use

(Nelson et al., 2014), bike-sharing for holiday cycling (Kaplan et al., 2015), doing physical exercise (Carmen Neipp et al., 2015).

Though TPB received significant success in some fields in which TRA was not so successful, there are defects that cannot be ignored. Ajzen (1991) admitted that the actual behavioural control was more important than the perceived behavioural control, because the actual control contains the feasibility of opportunities and resources which is the prerequisite of performing behaviour. The actual control is different from the perceived behavioural control because the individual's perceived behaviour cannot be exact. For example, a student has a large extent of controlling himself to attend a class; however, his actual behaviour may be affected by unanticipated accidents (e.g., snowstorm or traffic accident). In such situation, the particular behaviour cannot be executed even though the individual has strong perceived behavioural control. Nevertheless, the perceived behavioural control is an acceptable substitute for actual behavioural control.

In the practical application, TPB is often utilised as a basis of establishing a predictive model; other constructs concerning the behaviour determination might be added to the basic model for prediction. For instance, Chu and Chiu (2003) made an extension of TPB by introducing two more constructs (i.e., choice from behaviour intention and perceived moral obligation) to investigate the household waste recycling behaviour in Taiwan. The results showed that their improved model was better than the initial TPB model.

4.3 Theoretical framework

4.3.1 Development of the theoretical framework

Currently, the TPB has already been successfully implemented in numerous fields and studies. However, as situations are different in implementing different behaviour, contextual constructs were suggested to be added based on the original TPB model in order to explain more variance in a particular case (Guagnano et al., 1995). As the implementation of C&D waste management is a behaviour in the context of the construction industry, some particular external construction-related factors can influence the behaviour directly as well, such as the governmental supervision, economic viability, and project constraints. Thus a theoretical framework is established focusing on the C&D waste management field based on the existing TPB framework, as shown in Fig. 4-3.

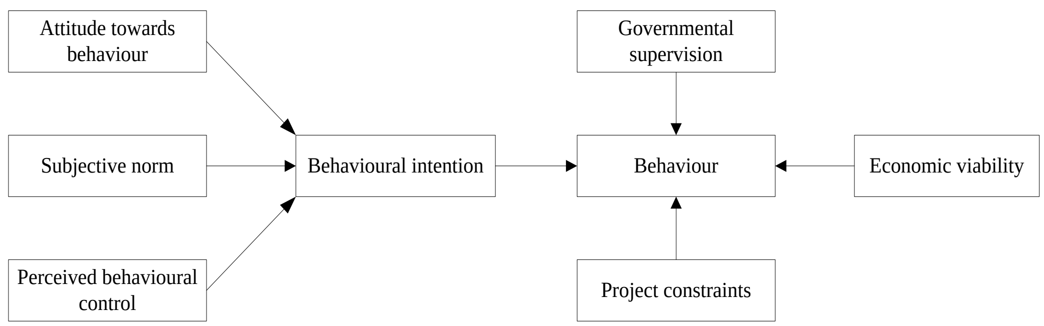

Fig. 4-3 The preliminary theoretical framework

In the framework, a total of eight constructs are involved, including attitude towards behaviour (AB), subjective norm (SN), perceived behavioural control (PBC), behavioural intention (BI), governmental supervision (GS), economic viability (EV), project constraints (PC), and behaviour (B). The newly introduced contextual constructs, such as GS, EV, and PC, are explained as follows.

Governmental supervision (GS) is considered because governmental regulations and corresponding supervision can significantly affect the behaviour of contractors. The influencing path is often direct: if something is forbidden by the government, the contractor must comply with the regulatory requirements. In terms of C&D waste management, if the government requires the contractor to dump C&D waste at landfills and impose hard punishment on illegal dumping, the behaviour of illegal dumping will be decreased significantly.

Economic viability (EV) is involved because contractors are companies that have the nature of benefit-earning. Thus the most prior objectives for contractors in a project are decreasing cost and making profit. If there is a conflict between environment and benefit, the project decision-makers normally opt for the latter one rather than the former one. In practice, C&D waste management measures are usually adopted incompletely in order to cut the construction cost, regardless of the potential environmental problems.

Project constraints (PC) also affect the adoption of C&D waste management measures directly. In real-life construction projects, there are many practical and unpredictable constraints, such as time, money, materials, labour. Contractors must select the most appropriate measures based on the project constraints. For instance, if the construction duration is very limited, the contractor may implement less C&D waste management measures to save time. Similarly, if the number of construction workers is not adequate, less focus will be paid on adopting effective C&D waste management.

4.3.2 Proposed hypotheses

According to the proposed theoretical framework, seven hypotheses are proposed as follows.

Hypothesis 1 (H1): Attitude towards behaviour has a direct positive effect on the behavioural intention.

Hypothesis 2 (H2): Social norm has a direct positive effect on the behavioural intention.

Hypothesis 3 (H3): Perceived behavioural control has a direct positive effect on the behavioural intention.

Hypothesis 4 (H4): Behavioural intention has a direct positive effect on the behaviour.

Hypothesis 5 (H5): Governmental supervision has a direct positive effect on the behaviour.

Hypothesis 6 (H6): Economic viability has a direct positive effect on the behaviour.

Hypothesis 7 (H7): Project constraints have a direct negative effect on the behaviour.

A major objective of this thesis is testing whether each of these proposed hypotheses is supportive or not.

4.4 Summary

This chapter introduced the establishment of the preliminary theoretical framework. Firstly, the typical mature theories concerning attitude and behaviour were introduced and the Theory of Planned Behaviour was selected as the basis of the theoretical framework. Subsequently, three contextual constructs (i.e., governmental supervision, economic viability, and project constraint) were added to the original TPB model because these three constructs were regarded to be significant in making C&D waste management decisions and frequently discussed in the literature. Finally, according to the proposed theoretical framework, seven hypotheses were proposed for further testing. The next chapter introduces the questionnaire design and data collection.

CHAPTER 5 Questionnaire Design and Data Collection

5.1 Introduction

This chapter introduces the process of questionnaire design and data collection. In the last chapter, a total of eight constructs were introduced to formulate the preliminary theoretical framework, in order to investigate the relationships between the identified constructs, an appropriate questionnaire is very important. The questionnaire is designed and improved based on literature and a focus group meeting. A pilot study is employed to refine the questionnaire to a final version. The tests of reliability and validity of the formal questionnaire are also presented in this chapter.

5.2 Determination of measurement scales

There are a total of eight constructs in the preliminary theoretical framework, namely attitude towards behaviour (AB), subjective norm (SN), perceived behavioural control (PBC), behavioural intention (BI), governmental supervision (GS), economic viability (EV), project constraints (PC), and behaviour (B). In order to investigate the relationships between the constructs, a questionnaire survey was employed.

The questionnaire used in the survey was initially designed based on previous literature: the measurement scales of the constructs of AB, SN, and PBC were developed from the mature TPB measurements, while the other five constructs were measured according to the existing C&D waste management research. A focus group meeting was organised to refine the initial measurement scales. Three participants were invited to attend the focus group meeting including one academic staff whose research area is focusing on C&D waste management and two industrial professionals who have been working in real-life projects for more than five years. Their knowledge can improve the initial measurements to be more rationale and realistic. Suggestions were received from both literal and structural aspects. The focus group meeting guide can be found in Appendix 1.

After the initial questionnaire has been improved, a pilot study was conducted in order to improve the reliability and validity of the questionnaire. The pilot study was conducted in July 2014, and a total of 84 responses were collected of which 78 were valid. In order to test the reliability and validity of the initial designed questionnaire, three analysis techniques were employed, namely item analysis, reliability analysis, and validity analysis. Based on the analysis results, the questionnaire was further improved by deleting and rewording some items, a formal questionnaire was formulated. Specific measurement scales in the formal questionnaire are presented in Table 5-1 to Table 5-8.

Table 5-1 Measurement of attitude towards behaviour

No.	Measurement
1	Effective C&D waste management can improve the environmental quality.
2	Effective C&D waste management can promote the sustainability development of the society.
3	Effective C&D waste management can improve the company's brand benefit.
4	Effective C&D waste management can improve the social image of the project.
5	Effective C&D waste management is worthy to be advocated.

Table 5-2 Measurement of subjective norm

No.	Measurement
1	My project manager expects me to employ effective C&D waste management.
2	My colleagues expect me to employ effective C&D waste management.
3	My family and friends expect me to employ effective C&D waste management.
4	My project owner expects me to employ effective C&D waste management.
5	The potential customers expect me to employ effective C&D waste management.
6	The local government expects me to employ effective C&D waste management.

Table 5-3 Measurement of perceived behavioural control

No.	Measurement
1	I have adequate opportunities to employ effective C&D waste management.
2	I have adequate supports to employ effective C&D waste management.
3	I have adequate time to employ effective C&D waste management.
4	I have adequate space to employ effective C&D waste management.
5	I have adequate experiences to employ effective C&D waste management.

Table 5-4 Measurement of behavioural intention

No.	Measurement
1	I intend to take actions to avoid C&D waste generation.
2	I intend to take actions to reuse or recycle C&D waste.
3	I intend to see the inappropriate dumping of C&D waste.
4	I intend to attend trainings on C&D waste minimisation.

Table 5-5 Measurement of governmental supervision

No.	Measurement
1	The government has complete and clear regulations on C&D waste management.
2	The government has particular department(s) for C&D waste management.
3	The government has a comprehensive supervision system for C&D waste management.
4	The government imposes strict punishment to illegal C&D waste dumping.

Table 5-6 Measurement of economic viability

No.	Measurement
1	On-site C&D waste management can reduce construction cost.
2	Decreasing C&D waste can save construction cost.
3	Effective C&D waste management can bring benefits to the company.
4	The current fee for discharging C&D waste is high.
5	The government has attractive policies to encourage minimising C&D waste.

Table 5-7 Measurement of project constraints

No.	Measurement
1	The project has enough workers for effective C&D waste management.
2	The project has enough money for effective C&D waste management.
3	The project has enough time for effective C&D waste management.
4	The project has enough space for effective C&D waste management.
5	The project has enough equipment for effective C&D waste management.
6	The current C&D waste recycling market is mature.

Table 5-8 Measurement of behaviour

No.	Measurement
1	I used to minimise C&D waste through appropriate on-site management.
2	I used to minimise C&D waste through appropriate material procurement.
3	I used to minimise C&D waste through advanced construction technologies.
4	I used to minimise C&D waste through on-site sorting.
5	I used to directly reuse C&D waste in my project.
6	I used to recycle C&D waste in my project.
7	I used to minimise C&D waste through other actions in my project.

In the measurement scales, the third item of BI measurement scale was designed as a reverse question and underlined using an italic font (see Appendix 2). The purpose of designing a reverse question is to test whether a respondent replied to the questionnaire carefully. In a specific measurement scale, the reverse question has an opposite meaning to the other questions. If a respondent gives a reverse question similar scoring to the other questions, it indicates that the respondent does not reply to the questionnaire carefully. There is a large possibility that the respondent filled out the questionnaires randomly, without careful thinking. If this is really the case, the whole response from this respondent should be discarded from the statistical analysis. In prior to the data analysis process, the scores assigned to the reverse question should be transformed. For example, if a respondent gives 1 point to the reverse question in a five point Likert scale, the score should be transformed to 5 before being used for data analysis.

5.3 Implementation of formal questionnaire survey

The questions in the formal questionnaire consist three main sections. The first section investigates the background information of the respondents, such as working category, gender, education level, the number of participated projects, etc. The second section deals with the measurement of the constructs. In the designed questionnaire, the proposed constructs are measured by items which are on a series of 5-point Likert scales, where '1' = strongly disagree, '2' = disagree, '3' = neutral, '4' = agree, and '5' = strongly agree. The third section is an open question, inquiring the respondents' suggestions and comments on the questionnaire and C&D waste management.

The questionnaires were distributed by two channels. The first channel was publishing the questionnaires on the internet and distributing them in professional forums using corresponding website link. The second channel was distributing the questionnaire through email. A 'snowball sampling' strategy was implemented, inviting the respondents to distribute the questionnaire to their colleagues. The data collection results showed that the second channel was much more effective than the first one. A total of 238 questionnaires were collected through the second channel while only 24 were collected from the first channel. However, from the first channel, it was more convenient to organise the data and to identify whether the respondents answered the questionnaire carefully because the time used for filling out the questionnaire could be recorded by the internet system.

In the questionnaire filtering process, three criteria were employed for filtering the effective responses: 1) the questionnaires with blank answer(s) should be filtered out; 2) the questionnaires with conflicting reverse question response should be filtered out; and 3) the questionnaires completed within 100 seconds should be filtered out. After the filtering process, 207 out of the collected 262 responses were valid, representing 79.01% of the total responses.

5.4 Testing the validity and reliability of the formal questionnaire

Testing the validity and reliability of the formal questionnaire is an essential process to ensure the questionnaire is valid and reliable. The typical procedures of determining a valid and reliable questionnaire are item analysis, exploratory factor analysis, and reliability analysis. In each procedure, there might be questions/items that should be deleted. If there are some questions/items deleted in the reliability analysis, another round of exploratory factor analysis should be conducted to test the validity of the questionnaire.

5.4.1 Item analysis

The aim of item analysis is testing the effectiveness of a particular question/item. The biggest difference between the item analysis and the reliability analysis is that the item analysis focuses on a single question/item while the reliability analysis emphasises in testing scales which include several questions/items.

The results of item analysis were presented in Table 5-9 to Table 5-16. From the tables, it can be seen that all the questions/items employed in the scales passed the T-test, namely no item needs to be deleted.

Table 5-9 Item analysis results of AB

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
AB1	Equal variances assumed	29.915	.000	-12.864	140	.000	-1.12043	.08710	-1.29262	-.94824
	Equal variances not assumed			-13.391	77.642	.000	-1.12043	.08367	-1.28701	-.95384
AB2	Equal variances assumed	88.905	.000	-15.691	140	.000	-1.30843	.08339	-1.47328	-1.14357
	Equal variances not assumed			-16.289	83.234	.000	-1.30843	.08033	-1.46819	-1.14867
AB3	Equal variances assumed	70.304	.000	-14.949	140	.000	-1.27901	.08556	-1.44817	-1.10986
	Equal variances not assumed			-15.451	92.497	.000	-1.27901	.08278	-1.44341	-1.11462
AB4	Equal variances assumed	59.759	.000	-15.066	140	.000	-1.25318	.08318	-1.41763	-1.08872
	Equal variances not assumed			-15.600	88.506	.000	-1.25318	.08033	-1.41281	-1.09355
AB5	Equal variances assumed	21.681	.000	-12.852	140	.000	-1.06399	.08279	-1.22767	-.90031
	Equal variances not assumed			-13.307	88.663	.000	-1.06399	.07996	-1.22287	-.90511

Table 5-10 Item analysis results of SN

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
SN1	Equal variances assumed	8.562	.004	-11.429	99	.000	-1.49314	.13065	-1.75237	-1.23391
	Equal variances not assumed			-11.305	84.883	.000	-1.49314	.13208	-1.75576	-1.23052
SN2	Equal variances assumed	4.276	.041	-12.492	99	.000	-1.55730	.12466	-1.80466	-1.30995
	Equal variances not assumed			-12.436	87.014	.000	-1.55730	.12522	-1.80620	-1.30841
SN3	Equal variances assumed	1.571	.213	-13.068	99	.000	-1.69330	.12958	-1.95041	-1.43620
	Equal variances not assumed			-13.348	94.442	.000	-1.69330	.12686	-1.94517	-1.44143
SN4	Equal variances assumed	28.387	.000	-10.544	99	.000	-1.39266	.13208	-1.65474	-1.13057
	Equal variances not assumed			-11.742	88.094	.000	-1.39266	.11860	-1.62835	-1.15696
SN5	Equal variances assumed	.774	.381	-16.163	99	.000	-1.74173	.10776	-1.95555	-1.52791
	Equal variances not assumed			-17.322	98.280	.000	-1.74173	.10055	-1.94126	-1.54219
SN6	Equal variances assumed	21.932	.000	-9.083	99	.000	-1.08111	.11903	-1.31729	-.84493
	Equal variances not assumed			-10.374	76.754	.000	-1.08111	.10421	-1.28864	-.87359

Table 5-11 Item analysis results of PBC

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
PBC1	Equal variances assumed	2.298	.132	-15.423	123	.000	-1.60834	.10428	-1.81476	-1.40192
	Equal variances not assumed			-15.127	105.548	.000	-1.60834	.10632	-1.81914	-1.39753
PBC2	Equal variances assumed	12.682	.001	-13.164	123	.000	-1.51518	.11510	-1.74302	-1.28734
	Equal variances not assumed			-12.796	96.521	.000	-1.51518	.11841	-1.75020	-1.28016
PBC3	Equal variances assumed	.426	.515	-14.447	123	.000	-1.72774	.11959	-1.96446	-1.49102
	Equal variances not assumed			-14.464	120.982	.000	-1.72774	.11945	-1.96422	-1.49126
PBC4	Equal variances assumed	.383	.537	-13.472	123	.000	-1.63819	.12160	-1.87888	-1.39749
	Equal variances not assumed			-13.518	121.807	.000	-1.63819	.12119	-1.87809	-1.39828
PBC5	Equal variances assumed	3.368	.069	-13.197	123	.000	-1.59444	.12082	-1.83359	-1.35529
	Equal variances not assumed			-13.036	112.070	.000	-1.59444	.12231	-1.83678	-1.35210

Table 5-12 Item analysis results of BI

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
BI1	Equal variances assumed	8.827	.003	-12.585	155	.000	-1.10484	.08779	-1.27826	-.93142
	Equal variances not assumed			-13.333	154.535	.000	-1.10484	.08287	-1.26854	-.94114
BI2	Equal variances assumed	9.443	.003	-11.030	155	.000	-1.11374	.10098	-1.31321	-.91427
	Equal variances not assumed			-11.782	154.996	.000	-1.11374	.09453	-1.30047	-.92702
BI3	Equal variances assumed	48.328	.000	-10.535	155	.000	-.80746	.07664	-.95886	-.65606
	Equal variances not assumed			-12.330	114.033	.000	-.80746	.06549	-.93719	-.67773
BI4	Equal variances assumed	9.768	.002	-11.393	155	.000	-1.11761	.09810	-1.31139	-.92383
	Equal variances not assumed			-12.185	154.999	.000	-1.11761	.09172	-1.29878	-.93643

Table 5-13 Item analysis results of GS

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
GS1	Equal variances assumed	.369	.544	-12.094	134	.000	-1.31387	.10864	-1.52874	-1.09899
	Equal variances not assumed			-12.173	114.596	.000	-1.31387	.10794	-1.52768	-1.10005
GS2	Equal variances assumed	2.867	.093	-13.912	134	.000	-1.54618	.11114	-1.76600	-1.32637
	Equal variances not assumed			-13.990	119.247	.000	-1.54618	.11052	-1.76501	-1.32735
GS3	Equal variances assumed	8.879	.003	-17.547	134	.000	-1.80229	.10271	-2.00544	-1.59915
	Equal variances not assumed			-17.589	131.772	.000	-1.80229	.10247	-2.00499	-1.59960
GS4	Equal variances assumed	20.958	.000	-15.945	134	.000	-1.73026	.10851	-1.94488	-1.51564
	Equal variances not assumed			-16.033	119.733	.000	-1.73026	.10792	-1.94393	-1.51659

Table 5-14 Item analysis results of EV

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
EV1	Equal variances assumed	17.934	.000	-5.715	145	.000	-.80379	.14064	-1.08177	-.52581
	Equal variances not assumed			-5.831	138.978	.000	-.80379	.13785	-1.07634	-.53124
EV2	Equal variances assumed	3.025	.084	-12.099	145	.000	-1.41806	.11720	-1.64970	-1.18642
	Equal variances not assumed			-12.354	138.300	.000	-1.41806	.11479	-1.64503	-1.19109
EV3	Equal variances assumed	4.300	.040	-9.047	145	.000	-1.18116	.13055	-1.43920	-.92312
	Equal variances not assumed			-9.210	140.935	.000	-1.18116	.12825	-1.43471	-.92761
EV4	Equal variances assumed	4.436	.037	-6.880	145	.000	-.94314	.13708	-1.21408	-.67221
	Equal variances not assumed			-6.993	142.072	.000	-.94314	.13487	-1.20976	-.67652
EV5	Equal variances assumed	.620	.432	-8.835	145	.000	-1.36176	.15412	-1.66638	-1.05714
	Equal variances not assumed			-8.804	140.377	.000	-1.36176	.15468	-1.66756	-1.05596

Table 5-15 Item analysis results of PC

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
PC1	Equal variances assumed	1.636	.203	-16.480	113	.000	-1.75348	.10640	-1.96427	-1.54269
	Equal variances not assumed			-16.498	111.708	.000	-1.75348	.10628	-1.96407	-1.54289
PC2	Equal variances assumed	4.307	.040	-16.337	113	.000	-1.73442	.10617	-1.94476	-1.52408
	Equal variances not assumed			-16.340	112.996	.000	-1.73442	.10615	-1.94472	-1.52413
PC3	Equal variances assumed	18.320	.000	-15.822	113	.000	-1.62855	.10293	-1.83248	-1.42463
	Equal variances not assumed			-15.781	103.005	.000	-1.62855	.10320	-1.83322	-1.42389
PC4	Equal variances assumed	4.981	.028	-10.225	113	.000	-1.29462	.12662	-1.54546	-1.04377
	Equal variances not assumed			-10.195	100.560	.000	-1.29462	.12699	-1.54654	-1.04269
PC5	Equal variances assumed	10.998	.001	-12.131	113	.000	-1.57532	.12986	-1.83259	-1.31804
	Equal variances not assumed			-12.100	102.958	.000	-1.57532	.13020	-1.83353	-1.31710
PC6	Equal variances assumed	15.590	.000	-7.506	113	.000	-.97338	.12967	-1.23029	-.71648
	Equal variances not assumed			-7.475	90.967	.000	-.97338	.13022	-1.23204	-.71472

Table 5-16 Item analysis results of B

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
B1	Equal variances assumed	3.500	.064	-13.777	116	.000	-1.92299	.13958	-2.19944	-1.64654
	Equal variances not assumed			-13.833	111.414	.000	-1.92299	.13901	-2.19844	-1.64753
B2	Equal variances assumed	1.830	.179	-11.547	116	.000	-1.83563	.15897	-2.15050	-1.52077
	Equal variances not assumed			-11.559	115.897	.000	-1.83563	.15880	-2.15016	-1.52111
B3	Equal variances assumed	7.254	.008	-14.996	116	.000	-2.10115	.14012	-2.37867	-1.82363
	Equal variances not assumed			-15.108	99.562	.000	-2.10115	.13907	-2.37708	-1.82522
B4	Equal variances assumed	5.374	.022	-16.351	116	.000	-2.11437	.12931	-2.37049	-1.85824
	Equal variances not assumed			-16.468	100.861	.000	-2.11437	.12839	-2.36907	-1.85967
B5	Equal variances assumed	.118	.732	-17.712	116	.000	-2.24310	.12664	-2.49393	-1.99227
	Equal variances not assumed			-17.745	115.377	.000	-2.24310	.12641	-2.49349	-1.99272
B6	Equal variances assumed	.127	.722	-16.647	116	.000	-2.26494	.13606	-2.53442	-1.99546
	Equal variances not assumed			-16.690	114.424	.000	-2.26494	.13571	-2.53376	-1.99612
B7	Equal variances assumed	.129	.720	-18.165	116	.000	-2.02701	.11159	-2.24802	-1.80600
	Equal variances not assumed			-18.202	115.177	.000	-2.02701	.11136	-2.24759	-1.80643

5.4.2 Exploratory factor analysis (EFA)

The aim of the exploratory factor analysis (EFA) is testing the validity of the questionnaire. In this study, the 42 measurement items involved in the questionnaire were subjected to EFA using an extraction method of principal components. Eigenvalues greater than 1 was set as the extraction criterion. In addition, varimax was defined as the rotation method. In the output options, the values of factor loading were suppressed if they are less than 0.4.

The analysis results revealed that the Kaiser-Meyer-Olkin (KMO) is 0.778 and the 'p' value is less than 0.001, indicating that the data is appropriate for performing EFA. According to the value of eigenvalue, ten factors can be identified from the 42 items, and 65.971% of the total variance can be explained, as shown in Table 5-17. The corresponding rotated component matrix can be found in Table 5-18.

Table 5-17 Total variance explained by the 10 factors

Component	**Initial Eigenvalues**			**Rotation Sums of Squared Loadings**		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.139	19.379	19.379	4.410	10.499	10.499
2	3.942	9.385	28.763	3.384	8.056	18.555
3	3.671	8.741	37.504	3.378	8.044	26.599
4	2.629	6.259	43.763	3.274	7.796	34.395
5	2.163	5.151	48.914	3.216	7.658	42.053
6	1.985	4.726	53.641	3.093	7.365	49.418
7	1.636	3.896	57.537	2.452	5.839	55.257
8	1.267	3.016	60.553	1.676	3.991	59.248
9	1.228	2.925	63.478	1.538	3.663	62.910
10	1.047	2.493	65.971	1.286	3.061	65.971
11	.971	2.312	68.284			
12	.906	2.158	70.442			
13	.903	2.149	72.591			
14	.850	2.024	74.615			
15	.803	1.912	76.527			
16	.730	1.738	78.265			
17	.679	1.617	79.882			
18	.656	1.563	81.444			
19	.607	1.445	82.889			
20	.552	1.315	84.204			
21	.542	1.290	85.494			
22	.500	1.191	86.686			
23	.478	1.138	87.824			
24	.474	1.129	88.953			
25	.438	1.044	89.997			
26	.409	.975	90.971			
27	.359	.855	91.826			
28	.352	.837	92.664			
29	.350	.833	93.496			
30	.335	.797	94.293			
31	.302	.719	95.012			
32	.292	.695	95.707			
33	.263	.625	96.332			
34	.248	.590	96.923			
35	.220	.524	97.447			
36	.205	.488	97.935			
37	.177	.420	98.356			

38	.168	.401	98.756			
39	.158	.375	99.132			
40	.128	.306	99.438			
41	.122	.291	99.729			
42	.114	.271	100.000			

Table 5-18 Rotated component matrix of the 10 factors

	Component									
	1	2	3	4	5	6	7	8	9	10
AB1				.705						
AB2				.749						
AB3				.772						
AB4				.786						
AB5				.769						
SN1			.794							
SN2			.772							
SN3			.668							
SN4			.556							.540
SN5			.738							
SN6			.524							.414
PBC1		.807								
PBC2		.671								
PBC3		.811								
PBC4		.770								
PBC5		.706								
BI1							.673			
BI2							.750			
BI3							.507			
BI4							.633			
GS1						.783				
GS2						.813				
GS3						.801				
GS4						.761				
EV1									.423	
EV2								.720		
EV3							.432	.601		
EV4									.699	
EV5						.438		.476		
PC1					.843					
PC2					.899					
PC3					.877					
PC4					.612					
PC5					.505					-.426
PC6									.561	
B1	.729									
B2	.604									
B3	.715									
B4	.781									

B5	.795									
B6	.802									
B7	.787									

From Table 5-18, it can be seen that the items included in factor 10 also have factor loadings lager than 0.4 in other factors. Thus, factor 10 can be deleted. Because SN4 has the largest factor loading in factor 10, it was excluded in the second round of EFA.

After several rounds of EFA, the items of EV4, PC6, B2, and EV1 were deleted subsequently. The KMO for the remaining items is 0.773 and the ‘p’ value is less than 0.001, indicating that the data is appropriate for performing EFA. Eight factors can be derived according to the eigenvalue value, representing 63.361% of the total variance, as shown in Table 5-19. The rotated matrix of the 8 factors showed that the questionnaire has a good validity, as shown in Table 5-20.

Table 5-19 Total variance explained by the 8 factors

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.686	20.227	20.227	4.08	10.737	10.737
2	3.746	9.857	30.084	3.408	8.967	19.704
3	3.411	8.976	39.06	3.244	8.537	28.242
4	2.553	6.719	45.779	3.222	8.478	36.72
5	2.037	5.361	51.14	3.028	7.969	44.688
6	1.872	4.927	56.067	3.016	7.936	52.624
7	1.569	4.13	60.197	2.44	6.422	59.046
8	1.202	3.164	63.361	1.64	4.316	63.361
9	.993	2.612	65.973			
10	.934	2.457	68.431			
11	.868	2.284	70.715			
12	.848	2.232	72.947			
13	.807	2.124	75.071			
14	.736	1.936	77.007			
15	.714	1.879	78.886			
16	.668	1.757	80.643			
17	.627	1.649	82.292			
18	.576	1.516	83.808			
19	.575	1.514	85.322			
20	.482	1.268	86.59			
21	.468	1.232	87.822			
22	.45	1.185	89.006			
23	.435	1.146	90.152			
24	.428	1.127	91.279			
25	.361	.951	92.23			
26	.352	.925	93.155			
27	.334	.879	94.034			
28	.327	.862	94.896			
29	.291	.767	95.663			
30	.268	.705	96.368			
31	.237	.623	96.99			
32	.228	.599	97.589			
33	.197	.52	98.109			
34	.181	.475	98.584			

35	.162	.427	99.011			
36	.133	.35	99.361			
37	.126	.331	99.692			
38	.117	.308	100			

Table 5-20 Rotated component matrix of the 8 factors

	Component							
	1	2	3	4	5	6	7	8
AB1				.711				
AB2				.740				
AB3				.768				
AB4				.787				
AB5				.766				
SN1						.826		
SN2						.778		
SN3						.617		
SN5						.721		
SN6						.555		
PBC1		.799						
PBC2		.687						
PBC3		.822						
PBC4		.751						
PBC5		.692						
BI1							.688	
BI2							.765	
BI3							.555	
BI4							.690	
GS1					.801			
GS2					.818			
GS3					.788			
GS4					.746			
EV1								
EV2								.765
EV3								.624
EV5								.478
PC1			.817					
PC2			.877					
PC3			.850					
PC4			.677					
PC5			.608					
B1	.708							
B3	.687							
B4	.816							
B5	.812							
B6	.818							
B7	.793							

5.4.3 Reliability analysis

Reliability analysis is aiming to test the consistence of the scales. In this study, there are a total of eight scales for testing. Cronbach's Alpha was used as the criterion to assess reliability. Generally, it is regarded that a scale is reliable if its Cronbach's Alpha value is larger than 0.7. The Cronbach's Alpha values of the eight scales are listed in Table 5-21.

Table 5-21 Cronbach's α values of the eight scales

Scale	**AB**	**SN**	**PBC**	**BI**	**GS**	**EV**	**PC**	**B**
Cronbacsh's Alpha	0.836	0.826	0.859	0.743	0.851	0.588	0.833	0.886

As shown in Table 5-21, there are seven scales with the Cronbach's Alpha values larger than 0.7, indicating that the reliability of these seven scales is acceptable. However, the Cronbacsh's Alpha of EV is less than 0.7. As shown in Table 5-22, the item-total statistics showed that the reliability of EV can be greatly improved by deleting item of EV5 (i.e., from 0.588 to 0.699). Thus the scale of EV is regarded reliable after deleting EV5. The Cronbach's Alpha for the integrated scale of the eight scales reached 0.877, indicating that the questionnaire is reliable.

Table 5-22 Item-total statistics of the scale of EV

	Scale Mean if Item Deleted	**Scale Variance if Item Deleted**	**Corrected Item-Total Correlation**	**Squared Multiple Correlation**	**Cronbach's Alpha if Item Deleted**
EV2	6.6039	2.435	.486	.308	.354
EV3	6.3623	2.630	.465	.297	.398
EV5	7.2657	2.672	.268	.073	.699

5.4.4 EFA after reliability analysis

As the item of EV5 was deleted during the reliability analysis, it is necessary to conduct another round of EFA. The results derived from the analysis showed that the KMO is 0.775 with a 'p' value less than 0.001, indicating that it is appropriate to conduct factor analysis. According to the eigenvalue, eight factors could be categorised, demonstrating 65.553% of the total variance, as shown in Table 5-23. From Table 5-24, the factor loading of each item in the rotated component matrix exceeds 0.5, indicating that the validity of the questionnaire is very good. This indicates that the current version of questionnaire has good validity and reliability.

Table 5-23 Total variance explained by the final items

Component	**Initial Eigenvalues**			**Rotation Sums of Squared Loadings**		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.592	21.089	21.089	4.039	11.219	11.219
2	3.679	10.219	31.308	3.398	9.438	20.657
3	3.314	9.206	40.514	3.207	8.909	29.567
4	2.516	6.990	47.504	3.154	8.761	38.327
5	2.028	5.633	53.136	3.006	8.350	46.677
6	1.772	4.922	58.058	2.914	8.096	54.773
7	1.568	4.356	62.414	2.372	6.590	61.363
8	1.130	3.139	65.553	1.508	4.189	65.553
9	.944	2.621	68.173			
10	.904	2.510	70.683			
11	.810	2.251	72.934			
12	.751	2.086	75.020			
13	.720	2.000	77.020			
14	.696	1.933	78.953			
15	.642	1.784	80.738			
16	.588	1.632	82.370			
17	.582	1.616	83.986			
18	.531	1.476	85.462			
19	.486	1.350	86.812			
20	.471	1.308	88.120			
21	.449	1.247	89.368			
22	.437	1.214	90.582			
23	.370	1.028	91.610			
24	.355	.986	92.596			
25	.347	.963	93.559			
26	.328	.912	94.471			
27	.304	.845	95.316			
28	.270	.751	96.067			
29	.248	.690	96.757			
30	.229	.635	97.392			
31	.205	.571	97.963			
32	.187	.519	98.482			
33	.165	.459	98.941			
34	.135	.375	99.316			
35	.129	.357	99.673			
36	.118	.327	100.000			

Table 5-24 Rotated component matrix of the final items

	Component							
	1	2	3	4	5	6	7	8
AB1			.720					
AB2			.737					
AB3			.771					
AB4			.791					
AB5			.762					
SN1					.829			
SN2					.772			
SN3					.617			
SN5					.718			
SN6					.560			
PBC1		.798						
PBC2		.677						
PBC3		.825						
PBC4		.762						
PBC5		.699						
BI1							.685	
BI2							.749	
BI3							.549	
BI4							.706	
GS1						.815		
GS2						.820		
GS3						.789		
GS4						.743		
EV2								.831
EV3								.704
PC1				.826				
PC2				.881				
PC3				.862				
PC4				.674				
PC5				.595				
B1	.713							
B3	.679							
B4	.810							
B5	.814							
B6	.825							
B7	.794							

5.5 Summary

This chapter presented the process of questionnaire design and data collection. The measurement scales were determined through a focus group meeting and a pilot study. In the formal questionnaire survey, a total of 262 questionnaires were collected, of which 207 were valid. Subsequently, item analysis, exploratory factor analysis, and reliability analysis were conducted to test the validity and reliability of the questionnaire. The items not satisfying the criteria would be excluded in the following analysis. The next chapter presents and discusses the data analysis results.

CHAPTER 6 Empirical Analysis of Contractor's Attitude and Behaviour for Managing C&D Waste

6.1 Introduction

This chapter reports the research findings derived from the collected data. In this chapter, the relationships between respondents' background information variables and C&D management behaviour are investigated using non-parametric tests. By using structural equation modelling (SEM), the proposed initial model is tested and improved according to the analysis results. A triangulation analysis is further employed to validate the improved model. Corresponding discussions are given to explain the analysis results.

6.2 Descriptive statistics

A total of 207 valid responses were collected and used for the analysis purpose. The responses with missing values were deleted before the analysis. Table 6-1 shows the background information of the respondents. It can be seen that the respondents engaging in cost control and project management are the two main components, taking up the percentage of around 60% in total. More than a half of the respondents were having working experience of less than 6 years. Numbers of male respondents were more than female, representing 74.4%. Nearly 80% of the respondents were bachelors, only 4.8% of the respondents having a master degree or above. Echoed with the working experience, nearly 70% of the respondents had participated in less than 6 projects. A total of 88.4% of the respondents were working in a high ranking company, 44.9% were working in premium contractors and 43.5% were working in companies ranked the first. Most respondents were working in residential projects, public sector and commercial projects, accounting for 43%, 21.5% and 14.5% respectively. Around three-quarters of the respondents were working in projects with a contract price of more than 50 million RMB (CNY) while one third of their working projects had more than 200 staff.

Table 6-1 Personal background information of the respondents

Variable	Category	Frequency	Percentage (%)	Cumulative percentage (%)
Working category	Company management	8	3.9	3.9
	Project management	55	26.6	30.5
	Construction engineering	33	15.9	46.4
	Cost control	72	34.8	81.2
	Quality control	5	2.4	83.6
	On-site construction	24	11.6	95.2
	Other	10	4.8	100
Working experience (years)	0 - 5	123	59.4	59.4
	6 - 10	55	26.6	86
	11 - 15	16	7.7	93.7
	16 years or above	13	6.3	100
Gender	Male	154	74.4	74.4
	Female	53	25.6	100
Education level	PhD	1	0.5	0.5
	Master	9	4.3	4.8
	Bachelor	165	79.7	84.5
	Senior high school or below	32	15.5	100
Number of participated project(s)	1 - 5	141	68.1	68.1
	6 - 10	34	16.4	84.5
	11 - 20	12	5.8	90.3
	21 or above	20	9.7	100
Company ranking	Premium	93	44.9	44.9
	Rank 1	90	43.5	88.4
	Rank 2	10	4.8	93.2
	Rank 3	2	1	94.2
	Other	12	5.8	100
Project type	Residential	89	43	43
	Commercial	30	14.5	57.5
	Office	18	8.7	66.2
	Industrial	8	3.9	70
	Infrastructure	52	25.1	95.2
	Other	10	4.8	100
Project price (million RMB)	0 - 10	5	2.4	2.4
	11 - 50	18	8.7	11.1
	51 - 100	43	20.8	31.9

	101 - 500	90	43.5	75.4
	501 - 1000	25	12.1	87.4
	Above 1000	26	12.6	100
Staff number	1 - 50	58	28	28
	51 - 100	35	16.9	44.9
	101 - 200	44	21.3	66.2
	Above 200	70	33.8	100

6.3 Non-parametric tests of background information variables

The personal background information variables involved in this study include working category, working experience, gender, education level, number of participated projects, company ranking, project type, project price and staff number. The non-parametric analysis is aiming to test whether these background information variables have significant influence to the C&D waste management behaviour. Because the variable of gender has only two categories, Mann-Whitney U test was employed to conduct the analysis. The other variables have more than two categories, thus Kruskal-Wallis test was used.

6.3.1 The influence of working category

Kruskal-Wallis test was employed to test the influence of working category to contractor's C&D waste management behaviour. The output of the analysis is presented in Table 6-2. It is found that the 'p' value is larger than 0.05, indicating that there is no difference in behaviour of C&D waste management between various working categories.

Table 6-2 Kruskal-Wallis test of working category

	BMean
Chi-Square	7.494
df	6
Asymp. Sig.	.278

6.3.2 The influence of working experience

Kruskal-Wallis test was employed to test the influence of working experience to contractor's C&D waste management behaviour. The output of the analysis is presented in Table 6-3. It is found that the 'p' value is larger than 0.05, indicating that there is no difference in behaviour of C&D waste management between different working experience groups.

Table 6-3 Kruskal-Wallis test of working experience

	BMean
Chi-Square	4.039
df	3
Asymp. Sig.	.257

6.3.3 The influence of gender

Mann-Whitney U test was employed to test the influence of gender to contractor's C&D waste management behaviour. The output of the analysis is presented in Table 6-4. It is found that the 'p' value is larger than 0.05, indicating that there is no difference in behaviour of C&D waste management between different gender groups.

Table 6-4 Mann-Whitney U test of gender

	BMean
Mann-Whitney U	3370.000
Wilcoxon W	4801.000
Z	-1.893
Asymp. Sig. (2-tailed)	.058

6.3.4 The influence of education level

Kruskal-Wallis test was employed to test the influence of education level to contractor's C&D waste management behaviour. The output of the analysis is presented in Table 6-5. It is found that the 'p' value is larger than 0.05, indicating that there is no difference in behaviour of C&D waste management between different education levels.

Table 6-5 Kruskal-Wallis test of education level

	BMean
Chi-Square	2.472
df	3
Asymp. Sig.	.480

6.3.5 The influence of number of participated projects

Kruskal-Wallis test was employed to test the influence of number of participated projects to contractor's C&D waste management behaviour. The output of the analysis is presented in Table 6-6. It is found that the 'p' value is larger than 0.05, indicating that there is no difference in behaviour of C&D waste management between different number of participated projects groups.

Table 6-6 Kruskal-Wallis test of number of participated projects

	BMean
Chi-Square	.773
df	6
Asymp. Sig.	.856

6.3.6 The influence of company ranking

Kruskal-Wallis test was employed to test the influence of company ranking to contractor's C&D waste management behaviour. The output of the analysis is presented in Table 6-7. It is found that the 'p' value is larger than 0.05, indicating that there is no difference in behaviour of C&D waste management between different company ranking groups.

Table 6-7 Kruskal-Wallis test of company ranking

	BMean
Chi-Square	6.449
df	4
Asymp. Sig.	.168

6.3.7 The influence of project type

Kruskal-Wallis test was employed to test the influence of project types to contractor's C&D waste management behaviour. The output of the analysis is presented in Table 6-8. It is found that the 'p' value is larger than 0.05, indicating that there is no difference in behaviour of C&D waste management between different project types.

Table 6-8 Kruskal-Wallis test of project type

	BMean
Chi-Square	7.307
df	5
Asymp. Sig.	.199

6.3.8 The influence of project price

Kruskal-Wallis test was employed to test the influence of project price to contractor's C&D waste management behaviour. The output of the analysis is presented in Table 6-9. It is found that the 'p' value is larger than 0.05, indicating that there is no difference in behaviour of C&D waste management between different project price groups.

Table 6-9 Kruskal-Wallis test of project price

	BMean
Chi-Square	11.307
df	5
Asymp. Sig.	.051

6.3.9 The influence of staff number

Kruskal-Wallis test was employed to test the influence of staff number to contractor's C&D waste management behaviour. The output of the analysis is presented in Table 6-10. It is found that the 'p' value is larger than 0.05, indicating that the there is no difference in behaviour of C&D waste management between different staff number groups.

Table 6-10 Kruskal-Wallis test of staff number

	BMean
Chi-Square	3.659
df	3
Asymp. Sig.	.301

6.4 Structural equation modelling

Structural equation modelling (SEM) is an analysis technique which integrates confirmatory factor analysis and path analysis. It is regarded as the second generation of multivariate analysis and has been employed in many disciplines. The benefit of this analysis method is that it cannot only identify the key constructs which are relevant in the theoretical model, but also the relationships between the constructs and the direction of influence between each pair (the path). In this sub-chapter, the confirmation factor analysis (CFA) and evolution of the preliminary model are introduced.

6.4.1 Assessment of model validity

Assessing the validity of the measurement model is an important and necessary procedure before investigating the relationships of the identified variables. This is because the measurement models are usually developed by the investigators for different cases, thus it is necessary to test the measurement models to check for their validity.

The validity of constructs contains two aspects: convergent validity and discriminant validity. Convergent validity refers to the level of correlation of one observed variable and other observed variables within their common construct. The commonality of the observed variables should be comparatively high. In general circumstances, the standardised factor loading of an observed variable is used to evaluate the convergent validity. The ideal standardised factor loading is larger than 0.7 while an observed variable with a factor loading less than 0.5 is supposed for deletion. In addition, an average variance extracted larger than 0.5 indicates a satisfactory convergent validity. The test of discriminant validity is aiming to find out whether a construct is significantly different from other constructs. A common used standard is that the average variance extracted from a construct should be higher than its highest squared correlation with other constructs.

A typical procedure for testing measurement model validity is that firstly testing the single construct to find out the convergent validity and then comparing the average variance extracted of a particular construct with its correlation coefficients with other constructs to investigate the discriminant validity.

6.4.1.1 Convergent validity of construct AB

The initial measurement model of the construct AB and the testing results are shown in Fig. 6-1. It can be seen that there are 5 initial indicators in the measurement model; the construct of AB is the latent variable, determining the 5 observed variables. The number of distinct sample moments is 15 and the number of distinct parameters to be estimated is 10, therefore, the degree of freedom of the default model is 5 (i.e., 15 - 10), which means the model is identifiable.

The estimation method used in the CFA analysis was maximum likelihood. The factor loadings and the Squared Multiple Correlations (SMCs) of the observed variables are presented in Fig. 6-1. It can be seen that all of the factor loadings are higher than the satisfied threshold of 0.5, indicating the acceptable convergent validity of the latent variable of AB.

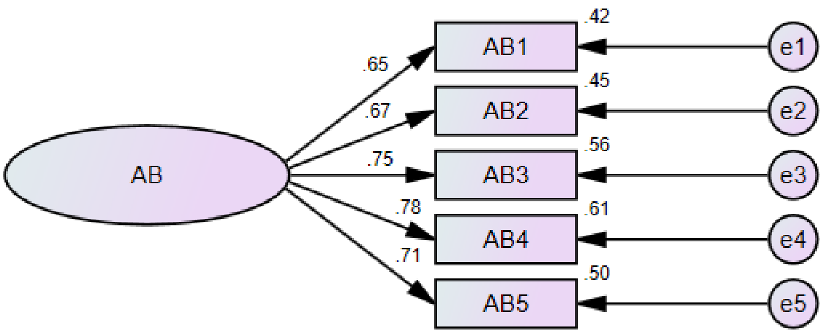

Fig. 6-1 Standardised regression weights of initial AB measurement model

6.4.1.2 Convergent validity of construct SN

The initial measurement model of the construct SN and the testing results are shown in Fig. 6-2. It can be seen that there are five initial indicators in the measurement model; the construct of SN is the latent variable, determining the five observed variables. The number of distinct sample moments is 15 and the number of distinct parameters to be estimated is 10, therefore, the degree of freedom of the default model is 5 (i.e., 15 - 10), which means the model is identifiable.

The estimation method used in the CFA analysis was maximum likelihood. The factor loadings and the SMCs of the observed variables are presented in Fig. 6-2. It can be seen that all of the factor loadings are higher than the acceptable threshold of 0.5 except the factor loading of SN6. The factor loading of SN6 is 0.47, less than the minimum requirement of 0.5. Thus the observed variable of SN6 was deleted.

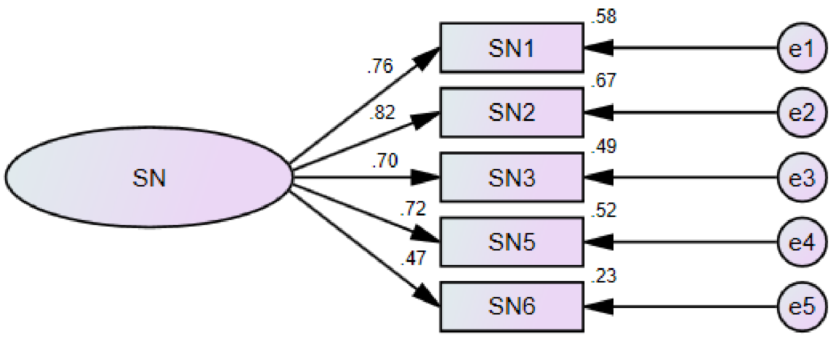

Fig. 6-2 Standardised regression weights of initial SN measurement model

After deleting SN6, the modified measurement model is shown as Fig. 6-3. In the modified measurement model of the construct SN, there are 4 initial indicators in the measurement model; the construct of SN is the latent variable, determining the 4 observed variables. The number of distinct sample moments is 10 and the number of distinct parameters to be estimated is 8, therefore, the degree of freedom of the default model is 2 (i.e., 10 - 8), which means the model is identifiable.

The estimation method used in the CFA analysis was maximum likelihood. The factor loadings and the SMCs of the observed variables are presented in Fig. 6-3. It can be seen that all of the factor loadings are higher than the acceptable threshold of 0.5, indicating the acceptable convergent validity of the latent variable of SN.

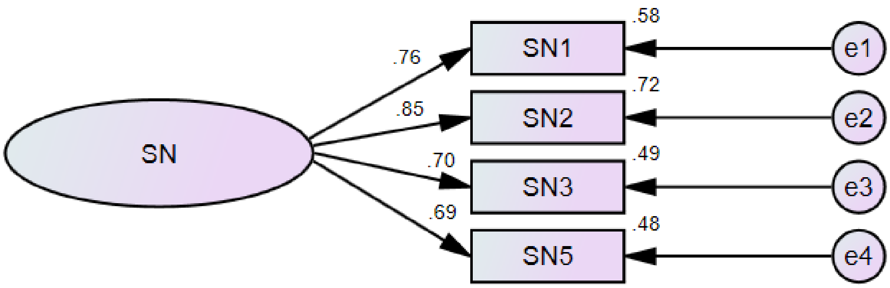

Fig. 6-3 Standardised regression weights of modified SN measurement model

6.4.1.3 *Convergent validity of construct PBC*

The initial measurement model of the construct PBC and the testing results are shown in Fig. 6-4. It can be seen that there are 5 initial indicators in the measurement model; the construct of PBC is the latent variable, determining the 5 observed variables. The number of distinct sample moments is 15 and the number of distinct parameters to be estimated is 10, therefore, the degree of freedom of the default model is 5 (i.e., 15 - 10), which means the model is identifiable.

The estimation method used in the CFA analysis was maximum likelihood. The factor loadings and the SMCs of the observed variables are presented in Fig. 6-4. It can be seen that all of the factor loadings are higher than the satisfied threshold of 0.5, indicating the acceptable convergent validity of the latent variable of PBC.

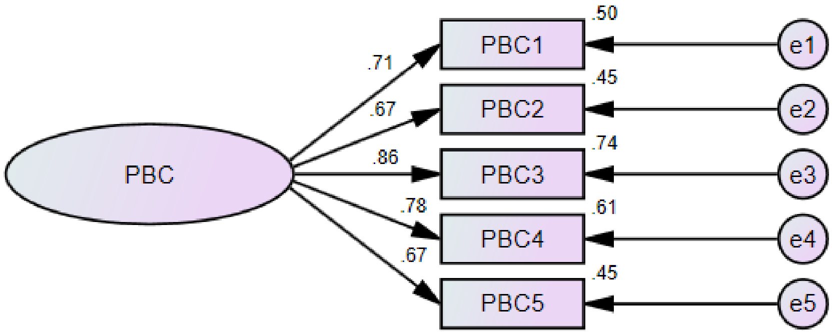

Fig. 6-4 Standardised regression weights of initial PBC measurement model

6.4.1.4 Convergent validity of construct BI

The initial measurement model of the construct BI and the testing results are shown in Fig. 6-5. It can be seen that there are 4 initial indicators in the measurement model; the construct of BI is the latent variable, determining the 4 observed variables. The number of distinct sample moments is 10 and the number of distinct parameters to be estimated is 8, therefore, the degree of freedom of the default model is 2 (i.e., 10 - 8), which means the model is identifiable.

The estimation method used in the CFA analysis was maximum likelihood. The factor loadings and the SMCs of the observed variables are presented in Fig. 6-5. It can be seen that all of the factor loadings are higher than the satisfied threshold of 0.5, indicating the acceptable convergent validity of the latent variable of BI.

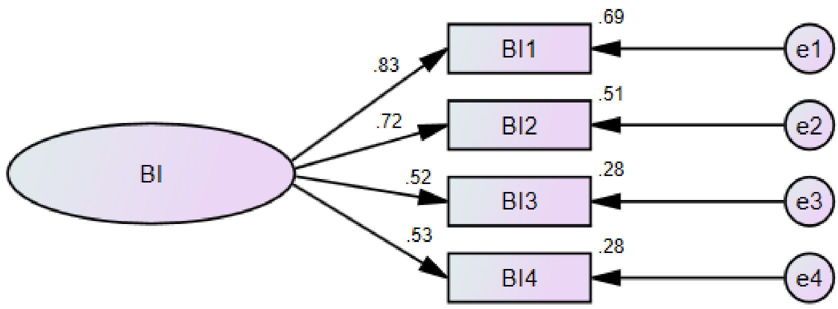

Fig. 6-5 Standardised regression weights of initial BI measurement model

6.4.1.5 *Convergent validity of construct GS*

The initial measurement model of the construct GS and the testing results are shown in Fig. 6-6. It can be seen that there are 4 initial indicators in the measurement model; the construct of GS is the latent variable, determining the 4 observed variables. The number of distinct sample moments is 10 and the number of distinct parameters to be estimated is 8, therefore, the degree of freedom of the default model is 2 (i.e., 10 - 8), which means the model is identifiable.

The estimation method used in the CFA analysis was maximum likelihood. The factor loadings and the SMCs of the observed variables are presented in Fig. 6-6. It can be seen that all of the factor loadings are higher than the acceptable threshold of 0.5, indicating the ideal convergent validity of the latent variable of GS.

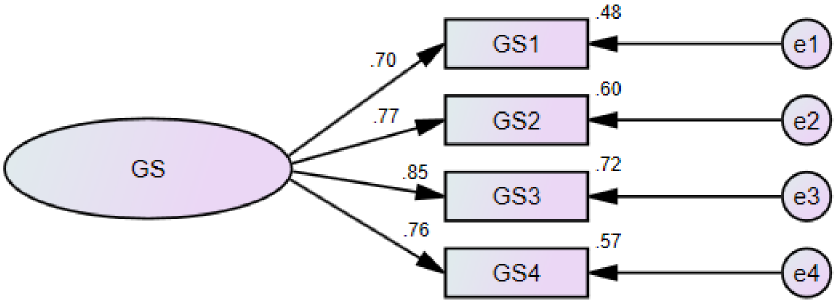

Fig. 6-6 Standardised regression weights of initial GS measurement model

6.4.1.6 Convergent validity of construct EV

The initial measurement model of the construct EV and the testing results are shown in Fig. 6-7. It can be seen that there are 2 initial indicators in the measurement model; the construct of EV is the latent variable, determining the 2 observed variables. The number of distinct sample moments is 3 and the number of distinct parameters to be estimated is 5. Therefore, the degree of freedom of the default model is -2 (i.e., 3 - 5). Thus the measurement model is unidentifiable. The convergent validity cannot be tested.

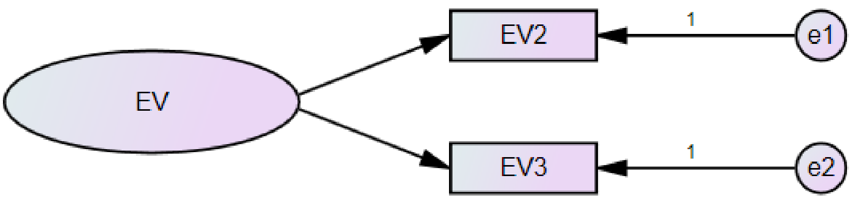

Fig. 6-7 Standardised regression weights of initial EV measurement model

6.4.1.7 Convergent validity of construct PC

The initial measurement model of the construct PC and the testing results are shown in Fig. 6-8. It can be seen that there are 5 initial indicators in the measurement model; the construct of PC is the latent variable, determining the 5 observed variables. The number of distinct sample moments is 15 and the number of distinct parameters to be estimated is 10, therefore, the degree of freedom of the default model is 5 (i.e., 15 - 10), which means the model is identifiable.

The estimation method used in the CFA analysis was maximum likelihood. The factor loadings and the SMCs of the observed variables are presented in Fig. 6-8. It can be seen that all of the factor loadings are higher than the acceptable threshold of 0.5 except the factor loading of PC5. The factor loading of PC5 is 0.44, less than the minimum requirement of 0.5. Thus the observed variable of PC5 was deleted.

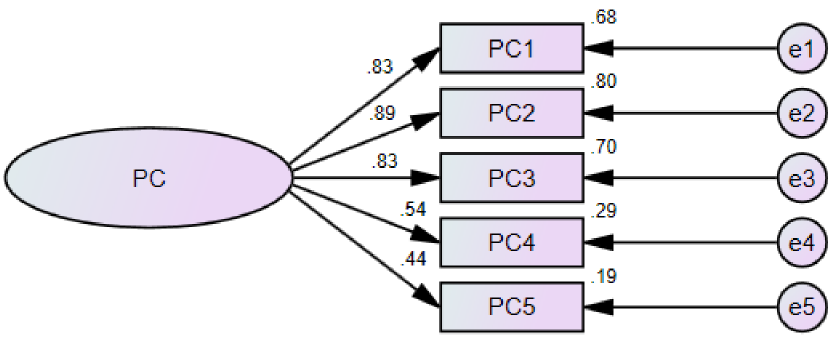

Fig. 6-8 Standardised regression weights of initial PC measurement model

After deleting PC5, the modified measurement model is shown as Fig. 6-9. In the modified measurement model of the construct PC, there are 4 initial indicators in the measurement model; the construct of PC is the latent variable, determining the 4 observed variables. The number of distinct sample moments is 10 and the number of distinct parameters to be estimated is 8, therefore, the degree of freedom of the default model is 2 (i.e., 10 - 8), which means the model is identifiable.

The estimation method used in the CFA analysis was maximum likelihood. The factor loadings and the SMCs of the observed variables are presented in Fig. 6-9. It can be seen that all of the factor loadings are higher than the acceptable threshold of 0.5, indicating the acceptable convergent validity of the latent variable of PC.

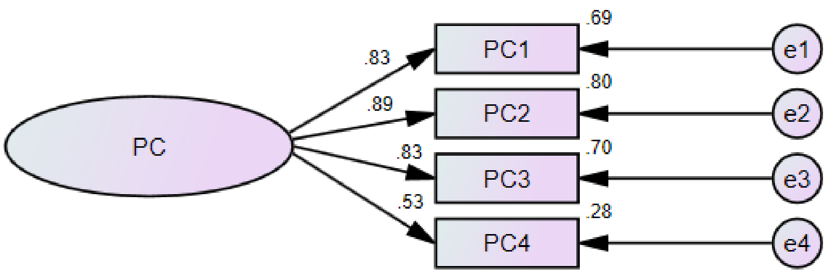

Fig. 6-9 Standardised regression weights of modified PC measurement model

6.4.1.8 Convergent validity of construct B

The initial measurement model of the construct B and the testing results are shown in Fig. 6-10. It can be seen that there are 6 initial indicators in the measurement model; the construct of B is the latent variable, determining the 6 observed variables. The number of distinct sample moments is 21 and the number of distinct parameters to be estimated is 12, therefore, the degree of freedom of the default model is 9 (i.e., 21 - 12), which means the model is identifiable.

The estimation method used in the CFA analysis was maximum likelihood. The factor loadings and the SMCs of the observed variables are presented in Fig. 6-10. It can be seen that all of the factor loadings are higher than the acceptable threshold of 0.5, indicating the acceptable convergent validity of the latent variable of B.

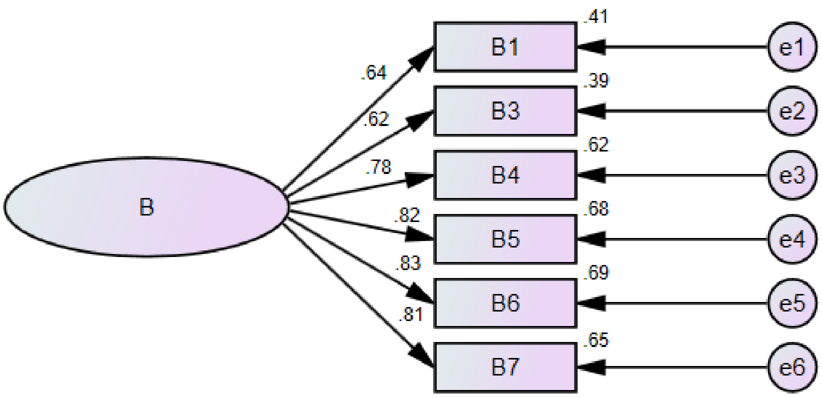

Fig. 6-10 Standardised regression weights of initial B measurement model

6.4.1.9 Confirmatory factor analysis of full measurement model

After the confirmatory factor analysis of each construct, it is necessary to conduct another confirmatory factor analysis involving all constructs. The initial measurement model of all constructs and the testing results are shown in Fig. 6-11. The estimation method used in the CFA analysis was maximum likelihood. Correlations have been made between the errors of observed variables as the modification indices suggested. It can be seen that there are a total of 34 observed variables in the measurement model. The number of distinct sample moments is 595 and the number of distinct parameters to be estimated is 99, therefore, the degree of freedom of the default model is 496 (i.e., 595 - 99), which means the model is identifiable.

The goodness-of-fit indices of the measurement model are presented in Table 6-11. As shown in Table 6-11, most goodness-of-fit measures are satisfied with the acceptable level, thus the model is supported by the sample data. The factor loadings and the SMCs of the observed variables are presented in Fig. 6-11. From Fig. 6-11, it can be seen that the factor loading of each construct exceeds the acceptable threshold of 0.5, thus no indicator is needed to be deleted from the measurement model.

Table 6-11 Goodness-of-fit of the full measurement model

Goodness-of-fit measure		**Level of acceptance fit**	**Fit statistics**
Absolute fit	χ^2/df	< 5 acceptable; < 3 good	1.571
	GFI	> 0.8 acceptable; > 0.9 good	0.835
	AGFI	> 0.8 acceptable; > 0.9 good	0.802
	RMSEA	< 0.1 acceptable; < 0.08 good	0.053
Incremental fit	NFI	> 0.9	0.801
	RFI	> 0.9	0.775
	IFI	> 0.9	0.917
	TLI	> 0.9	0.905
	CFI	> 0.9	0.916

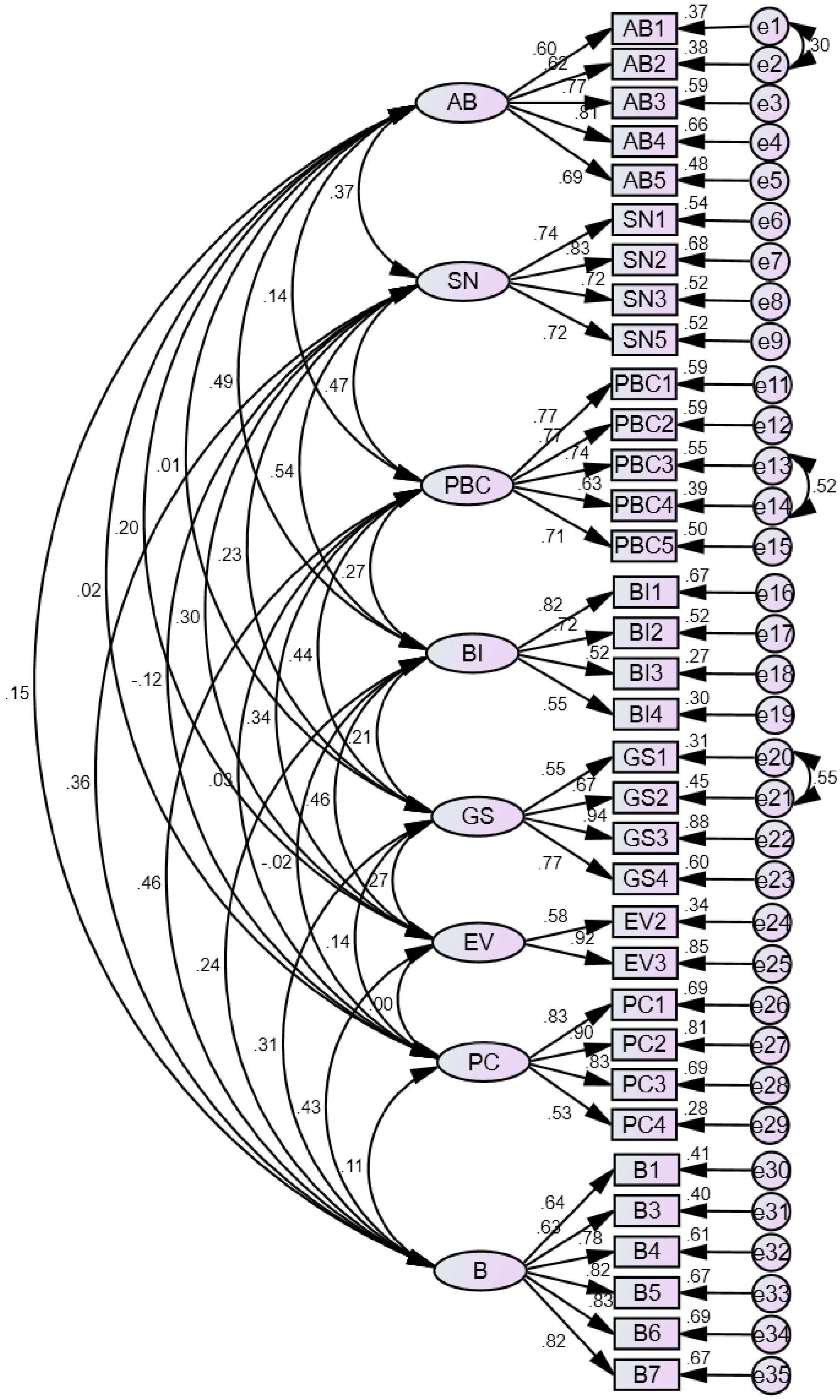

Fig. 6-11 Standardised regression weights of the full measurement model

6.4.1.10 Summary of confirmatory factor analysis

Through the confirmatory factor analysis, the validity of the measurement models was tested. Two observed variables were deleted because their factor loadings are less than 0.5. The two variables are SN6 and PC5. Thus in the process of path analysis, the two observed variables were excluded.

6.4.2 Testing hypotheses using structural equation modelling

6.4.2.1 Initial model

After the confirmatory factor analysis, the preliminary structural equation model was derived, as shown in Fig. 6-12. There are a total of eight constructs in the model; each latent variable has several observed variables to measure. The hypotheses underlying this model are clear to be identified, as listed in Table 6-12.

Table 6-12 Hypotheses in the initial model

Hypothesis	Description
H1	Attitude towards behaviour has a direct positive effect on the behavioural intention
H2	Social norm has a direct positive effect on the behavioural intention
H3	Perceived behavioural control has a direct positive effect on the behavioural intention
H4	Behavioural intention has a direct positive effect on the behaviour
H5	Governmental supervision has a direct positive effect on the behaviour
H6	Economic viability has a direct positive effect on the behaviour
H7	Project constraints have a direct negative effect on the behaviour

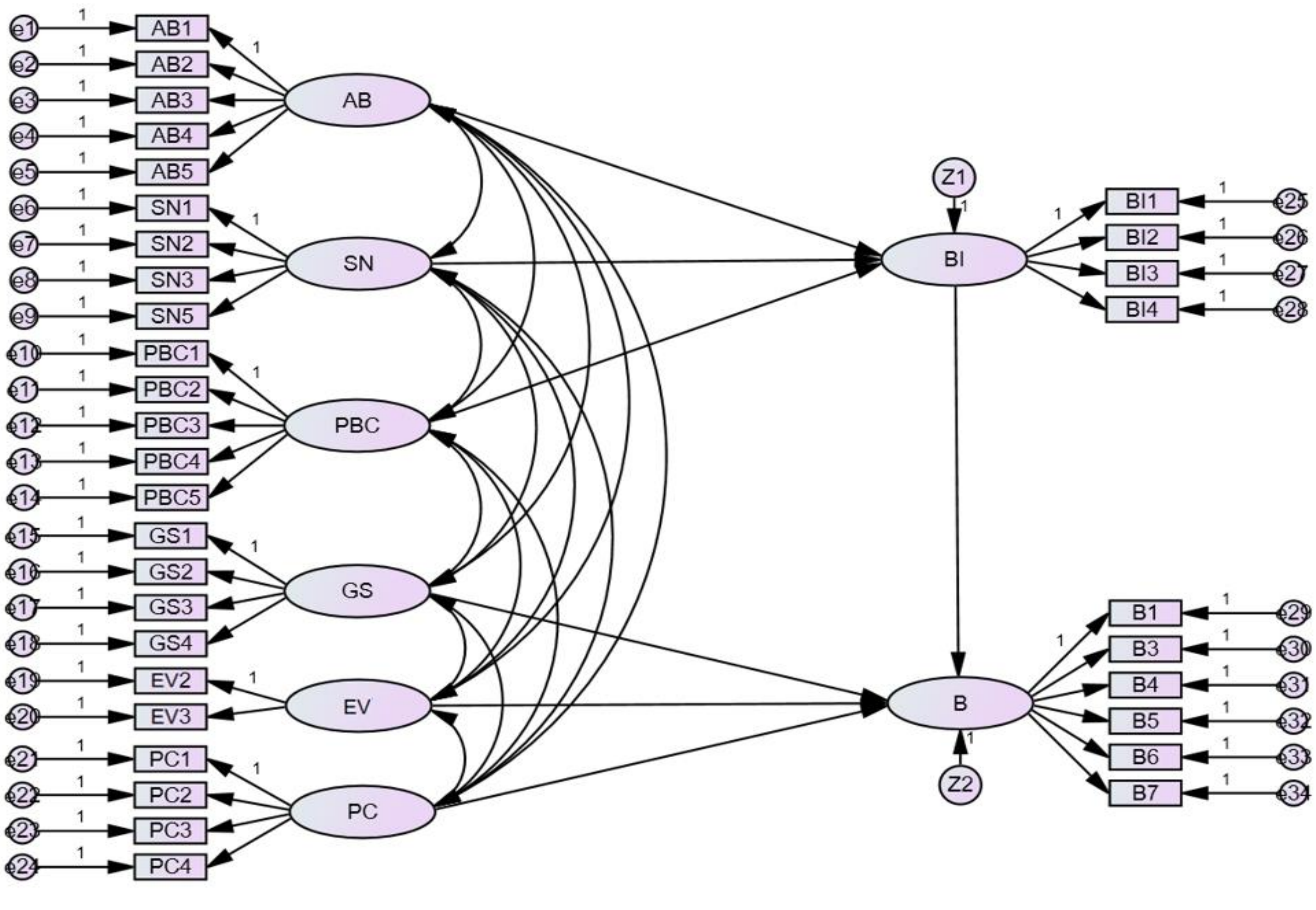

Fig. 6-12 Determinants of C&D waste management – initial model

In order to test the structural model, the estimation method should be determined first. There are several estimation methods available for conducting the analysis. However, each estimation method has its own restrictive limitations. It is necessary to check whether it is appropriate to select one particular estimation method.

The most commonly used estimation method in SEM is maximum likelihood. The condition for using this method is that the collected data should satisfy the multivariate normality. In practice, the criteria for testing multivariate normality are using the coefficients of skewness and kurtosis. If the absolute value of the skewness coefficient is lower than 2 and the absolute value of the kurtosis is lower than 7, it is regarded that the data satisfy the multivariate normality requirement.

The results of normality assessment in this study are presented in Table 6-13. From the table, it can be seen the absolute value skewness coefficient is lower than 2 and the absolute value of the kurtosis is lower than 7, thus the maximum likelihood can be used as the estimation method in this study.

Table 6-13 Assessment of normality – initial model

Variable	min	max	skew	c.r.	kurtosis	c.r.
B7	1	5	0.045	0.264	-0.814	-2.389
B6	1	5	0.233	1.371	-0.877	-2.576
B5	1	5	0.121	0.711	-0.845	-2.482
B4	1	5	0.154	0.906	-0.969	-2.846
B3	1	5	0.034	0.202	-1.03	-3.026
B1	1	5	0.326	1.912	-0.777	-2.283
BI4	1	5	-0.671	-3.94	1.062	3.119
BI3	2	5	-1.28	-7.518	1.4	4.113
BI2	1	5	-0.711	-4.177	1.148	3.371
BI1	2	5	-0.557	-3.272	0.604	1.772
PC4	1	5	-0.674	-3.961	0.322	0.947
PC3	1	5	-0.452	-2.657	-0.651	-1.913
PC2	1	5	-0.073	-0.429	-0.88	-2.583
PC1	1	5	0.156	0.918	-1.111	-3.263
EV3	1	5	-0.562	-3.302	-0.032	-0.095
EV2	1	5	-0.447	-2.628	-0.23	-0.675
GS4	1	5	-0.348	-2.041	-0.246	-0.721
GS3	1	5	-0.049	-0.29	-0.361	-1.061
GS2	1	5	-0.428	-2.516	0.091	0.267
GS1	1	5	-0.633	-3.719	0.764	2.243
PBC5	1	5	0.113	0.666	-0.233	-0.683
PBC4	1	5	0.059	0.348	-0.398	-1.17
PBC3	1	5	0.185	1.085	-0.115	-0.336
PBC2	1	5	0.417	2.451	-0.276	-0.81
PBC1	1	5	0.408	2.397	-0.31	-0.911
SN5	1	5	-0.379	-2.225	0.011	0.032
SN3	1	5	-0.271	-1.592	0.193	0.565
SN2	1	5	-0.104	-0.613	-0.134	-0.393
SN1	1	5	-0.317	-1.859	0.443	1.3
AB5	1	5	-1.348	-7.92	2.897	8.507
AB4	1	5	-1.078	-6.331	1.266	3.718
AB3	1	5	-0.845	-4.963	0.516	1.516
AB2	1	5	-0.831	-4.883	0.573	1.683
AB1	1	5	-1.613	-9.474	4.554	13.375
Multivariate					161.439	23.472

From Fig. 6-12, it can be seen that there are a total of 34 observed variables and 44 unobserved variables in the measurement model. The number of exogenous variables is 42 and the number of endogenous variables is 36. There are 595 distinct sample moments in the model and the number of distinct parameters to be estimated is 90, therefore, the degree of freedom of the default model is 505 (i.e., 595 - 90), which means the model is identifiable.

The analysis results of the initial model are shown in Table 6-14 and Table 6-15. From Table 6-14, it can be seen that there are some paths with insignificant p-values. From Table 6-15, it indicates that the initial model cannot fit the data well. Thus it is necessary to modify the initial model.

Table 6-14 Regression weights in the initial model

	Estimate	S.E.	C.R.	P
BI <--- AB	0.439	0.109	4.036	***
BI <--- SN	0.414	0.098	4.237	***
BI <--- PBC	0.034	0.08	0.428	0.668
B <--- GS	0.198	0.102	1.936	0.053
B <--- PC	0.076	0.062	1.228	0.22
B <--- EV	0.463	0.112	4.149	***
B <--- BI	0.067	0.091	0.741	0.459
AB1 <--- AB	1			
AB2 <--- AB	1.152	0.143	8.053	***
AB3 <--- AB	1.253	0.143	8.751	***
AB4 <--- AB	1.288	0.142	9.038	***
AB5 <--- AB	1.025	0.123	8.309	***
SN1 <--- SN	1			
SN2 <--- SN	1.152	0.107	10.745	***
SN3 <--- SN	1.119	0.116	9.643	***
SN5 <--- SN	1.011	0.106	9.572	***
PBC1 <--- PBC	1			
PBC2 <--- PBC	1.036	0.113	9.171	***
PBC3 <--- PBC	1.293	0.118	10.948	***
PBC4 <--- PBC	1.172	0.116	10.113	***
PBC5 <--- PBC	1.04	0.114	9.109	***
GS1 <--- GS	1			
GS2 <--- GS	1.222	0.135	9.055	***
GS3 <--- GS	1.516	0.151	10.007	***
GS4 <--- GS	1.369	0.147	9.325	***
EV2 <--- EV	1			
EV3 <--- EV	1.129	0.182	6.206	***
PC1 <--- PC	1			
PC2 <--- PC	1.025	0.069	14.755	***
PC3 <--- PC	0.916	0.067	13.741	***
PC4 <--- PC	0.525	0.068	7.754	***
BI1 <--- BI	1			
BI2 <--- BI	0.89	0.097	9.159	***
BI3 <--- BI	0.522	0.075	6.945	***
BI4 <--- BI	0.669	0.095	7.032	***
B1 <--- B	1			
B3 <--- B	1.05	0.135	7.772	***
B4 <--- B	1.283	0.139	9.253	***
B5 <--- B	1.346	0.141	9.572	***

B6 <--- B	1.429	0.147	9.686	***
B7 <--- B	1.203	0.126	9.516	***

Table 6-15 Goodness-of-fit of the initial model

Goodness-of-fit measure		**Level of acceptance fit**	**Fit statistics**
Absolute fit	χ^2/df	< 5 acceptable; < 3 good	1.829
	GFI	> 0.8 acceptable; > 0.9 good	0.806
	AGFI	> 0.8 acceptable; > 0.9 good	0.771
	RMSEA	< 0.1 acceptable; < 0.08 good	0.063
Incremental fit	NFI	> 0.9	0.764
	RFI	> 0.9	0.738
	IFI	> 0.9	0.877
	TLI	> 0.9	0.862
	CFI	> 0.9	0.875

The modification indices of regression weights are presented in Table 6-16. It can be seen there are no significant suggestions for increasing a new path between the latent variables. Therefore, in order to modify the initial model, it is suggested to delete the insignificant paths. According to Table 6-14 and the theoretical assumptions, PBC was deleted to formulate a new model because the path from PBC to BI is not significant, with a p-value of 0.668. This also means H3 is rejected, namely perceived behavioural control cannot have a direct positive effect on the behavioural intention.

Table 6-16 Modification indices of regression weights – initial model

	M.I.	Par Change		M.I.	Par Change
BI <--- EV	6.423	0.176	GS1 <--- BI3	5.618	0.185
B <--- PBC	4.421	0.17	GS1 <--- GS2	19.43	0.225
B7 <--- SN	6.229	0.216	GS1 <--- PBC5	4.015	-0.1
B7 <--- PBC1	7.033	0.146	GS1 <--- PBC3	4.627	-0.11
B7 <-- SN2	5.362	0.133	GS1 <--- PBC1	5.807	-0.13
B7 <--- SN1	10.22	0.188	PBC5 <--- B	6.779	0.191
B6 <--- SN1	6.389	-0.17	PBC5 <--- B6	7.48	0.111
B5 <--- SN1	6.76	0.168	PBC5 <--- B5	6.533	0.108
B5 <--- AB1	5.522	-0.17	PBC5 <--- B3	7.203	0.112
B4 <--- GS1	4.152	-0.13	PBC5 <--- B1	8.449	0.129
B1 <--- BI2	4.234	-0.17	PBC5 <--- SN5	4.626	0.128
BI4 <--- PC	7.64	-0.17	PBC4 <--- B	6.537	-0.17
BI4 <--- EV	4.632	0.177	PBC4 <--- B7	9.34	-0.13
BI4 <--- PC3	5.905	-0.13	PBC4 <--- B4	6.393	-0.1
BI4 <--- PC2	11.1	-0.17	PBC4 <--- B3	4.211	-0.08
BI4 <--- EV3	5.601	0.118	PBC4 <--- B1	4.638	-0.09
BI4 <--- GS2	4.181	0.104	PBC4 <--- BI2	6.628	-0.15
BI3 <--- PBC1	4.182	-0.09	PBC4 <--- PC2	5.423	-0.11
BI2 <--- EV	6.07	0.181	PBC4 <--- PBC3	4.605	0.105
BI2 <--- EV3	11.55	0.152	PBC4 <--- PBC2	6.69	-0.13
BI2 <--- PBC1	5.04	0.109	PBC3 <--- PBC4	7.954	0.125
BI2 <--- AB4	4.606	-0.12	PBC3 <--- SN5	6.158	-0.12
BI1 <--- PC4	10.92	0.144	PBC3 <--- SN1	4.104	-0.1
BI1 <--- PC2	4.661	0.082	PBC2 <--- SN	6.868	0.233
PC4 <--- AB	4.107	0.227	PBC2 <--- B	4.515	0.153
PC4 <--- BI	4.744	0.195	PBC2 <--- B7	4.278	0.096
PC4 <--- BI1	8.097	0.195	PBC2 <--- B4	9.491	0.129
PC4 <--- PBC1	4.642	-0.12	PBC2 <--- BI2	5.167	0.144
PC4 <--- AB4	5.678	0.15	PBC2 <--- PBC4	4.87	-0.12
PC3 <--- B1	4.123	-0.07	PBC2 <--- PBC1	9.415	0.173
PC3 <--- PBC3	4.507	-0.09	PBC2 <--- SN5	6.589	0.151
PC2 <--- B6	7.551	0.085	PBC2 <--- SN2	5.729	0.141
PC2 <--- BI4	4.504	-0.1	PBC2 <--- SN1	7.788	0.168
PC2 <--- PBC2	6.733	0.107	PBC1 <--- PC2	4.594	0.103
PC2 <--- PBC1	5.667	0.104	PBC1 <--- PBC2	9.98	0.156
PC1 <--- GS1	11.42	-0.17	SN5 <--- B1	4.206	0.08
EV3 <--- BI	8.277	0.274	SN5 <--- AB3	4.441	0.115
EV3 <--- BI4	8.733	0.203	SN3 <--- EV2	4.624	-0.1
EV3 <--- BI2	17.84	0.288	SN3 <--- AB5	4.375	0.142

EV3 <--- BI1	4.788	0.16	SN2 <--- GS1	4.331	-0.09
GS4 <--- GS2	4.343	-0.11	SN2 <--- SN1	4.676	0.104
GS3 <--- AB	4.336	-0.2	SN2 <--- AB5	5.568	-0.13
GS3 <--- BI3	7.336	-0.19	SN1 <--- B7	5.554	0.094
GS3 <--- GS1	5.296	-0.12	SN1 <--- B5	7.834	0.1
GS3 <--- SN1	4.073	-0.11	SN1 <--- BI4	6.614	-0.14
GS3 <--- AB4	6.042	-0.13	SN1 <--- PBC4	4.488	-0.1
GS2 <--- BI	4.89	0.188	SN1 <--- AB4	5.766	-0.13
GS2 <--- BI4	6.1	0.151	AB5 <--- SN2	5.872	-0.11
GS2 <--- BI3	12.22	0.27	AB4 <--- EV3	4.07	0.083
GS2 <--- GS1	26.49	0.281	AB4 <--- AB2	4.91	-0.11
GS2 <--- PBC3	4.909	-0.11	AB2 <--- AB1	6.381	0.157
GS2 <--- SN5	4.393	0.118	AB1 <--- B5	4.704	-0.08
GS2 <--- SN1	6.587	0.148	AB1 <--- AB2	6.075	0.122
GS1 <--- PBC	4.496	-0.17			

6.4.2.2 Modified model 1

After deleting the path from PBC to BI, the modified structural equation model was derived, as shown in Fig. 6-13. There are a total of seven constructs in the model; each latent variable has several observed variables to measure. The normality assessment results are presented in Table 6-17. From the table, it can be seen the absolute value skewness coefficient is lower than 2 and the absolute value of the kurtosis is lower than 7, thus the maximum likelihood is appropriate to be selected as the estimation method.

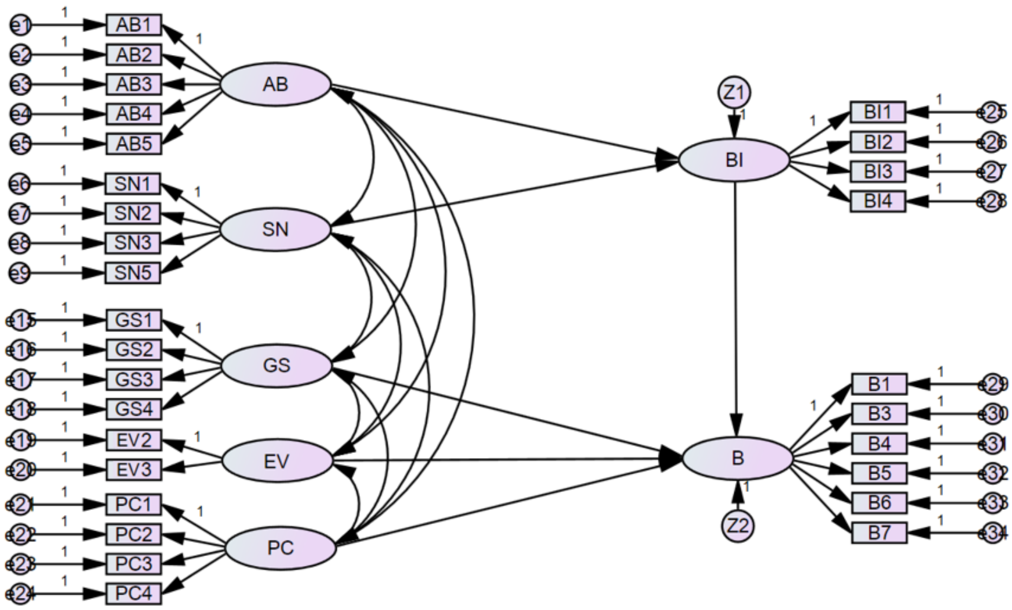

Fig. 6-13 Determinants of C&D waste management – modified model 1

Table 6-17 Assessment of normality – modified model 1

Variable	min	max	skew	c.r.	kurtosis	c.r.
B7	1	5	0.045	0.264	-0.814	-2.389
B6	1	5	0.233	1.371	-0.877	-2.576
B5	1	5	0.121	0.711	-0.845	-2.482
B4	1	5	0.154	0.906	-0.969	-2.846
B3	1	5	0.034	0.202	-1.03	-3.026
B1	1	5	0.326	1.912	-0.777	-2.283
BI4	1	5	-0.671	-3.94	1.062	3.119
BI3	2	5	-1.28	-7.518	1.4	4.113
BI2	1	5	-0.711	-4.177	1.148	3.371
BI1	2	5	-0.557	-3.272	0.604	1.772
PC4	1	5	-0.674	-3.961	0.322	0.947
PC3	1	5	-0.452	-2.657	-0.651	-1.913
PC2	1	5	-0.073	-0.429	-0.88	-2.583
PC1	1	5	0.156	0.918	-1.111	-3.263
EV3	1	5	-0.562	-3.302	-0.032	-0.095
EV2	1	5	-0.447	-2.628	-0.23	-0.675
GS4	1	5	-0.348	-2.041	-0.246	-0.721
GS3	1	5	-0.049	-0.29	-0.361	-1.061
GS2	1	5	-0.428	-2.516	0.091	0.267
GS1	1	5	-0.633	-3.719	0.764	2.243
SN5	1	5	-0.379	-2.225	0.011	0.032
SN3	1	5	-0.271	-1.592	0.193	0.565
SN2	1	5	-0.104	-0.613	-0.134	-0.393
SN1	1	5	-0.317	-1.859	0.443	1.3
AB5	1	5	-1.348	-7.92	2.897	8.507
AB4	1	5	-1.078	-6.331	1.266	3.718
AB3	1	5	-0.845	-4.963	0.516	1.516
AB2	1	5	-0.831	-4.883	0.573	1.683
AB1	1	5	-1.613	-9.474	4.554	13.375
Multivariate					134.165	22.761

From Fig. 6-13, it can be seen that there are a total of 29 observed variables and 38 unobserved variables in the measurement model. The number of exogenous variables is 36 and the number of endogenous variables is 31. There are 435 distinct sample moments in the model and the number of distinct parameters to be estimated is 74, therefore, the degree of freedom of the default model is 361 (i.e., 435 - 74), which means the model is identifiable.

The analysis results of the initial model are shown in Table 6-18 and Table 6-19. From Table 6-18, it can be seen that there are still some paths with insignificant p-values. From Table 6-19, it indicates that the modified model 1 can marginally fit the data.

Table 6-18 Regression weights in the modified model 1

	Estimate	**S.E.**	**C.R.**	**P**
BI <--- AB	.433	.108	3.997	***
BI <--- SN	.438	.087	5.054	***
B <--- GS	.191	.098	1.958	.050
B <--- PC	.074	.062	1.191	.234
B <--- EV	.446	.111	4.021	***
B <--- BI	.071	.090	.783	.433
AB1 <--- AB	1.000			
AB2 <--- AB	1.154	.144	8.036	***
AB3 <--- AB	1.257	.144	8.736	***
AB4 <--- AB	1.291	.143	9.017	***
AB5 <--- AB	1.029	.124	8.300	***
SN1 <--- SN	1.000			
SN2 <--- SN	1.140	.107	10.702	***
SN3 <--- SN	1.111	.115	9.638	***
SN5 <--- SN	1.005	.105	9.576	***
GS1 <--- GS	1.000			
GS2 <--- GS	1.211	.124	9.754	***
GS3 <--- GS	1.399	.135	10.357	***
GS4 <--- GS	1.270	.133	9.533	***
EV2 <--- EV	1.000			
EV3 <--- EV	1.223	.218	5.621	***
PC1 <--- PC	1.000			
PC2 <--- PC	1.025	.069	14.761	***
PC3 <--- PC	.916	.067	13.733	***
PC4 <--- PC	.525	.068	7.748	***
BI1 <--- BI	1.000			
BI2 <--- BI	.886	.097	9.158	***
BI3 <--- BI	.522	.075	6.970	***
BI4 <--- BI	.665	.095	7.016	***
B1 <--- B	1.000			
B3 <--- B	1.050	.135	7.752	***
B4 <--- B	1.284	.139	9.236	***
B5 <--- B	1.349	.141	9.559	***
B6 <--- B	1.430	.148	9.665	***
B7 <--- B	1.204	.127	9.492	***

Table 6-19 Goodness-of-fit of the modified model 1

Goodness-of-fit measure		**Level of acceptance fit**	**Fit statistics**
Absolute fit	χ^2/df	< 5 acceptable; < 3 good	1.800
	GFI	> 0.8 acceptable; > 0.9 good	0.834
	AGFI	> 0.8 acceptable; > 0.9 good	0.800
	RMSEA	< 0.1 acceptable; < 0.08 good	0.062
Incremental fit	NFI	> 0.9	0.794
	RFI	> 0.9	0.768
	IFI	> 0.9	0.896
	TLI	> 0.9	0.882
	CFI	> 0.9	0.895

The modification indices of regression weights are presented in Table 6-20. It can be seen there no significant suggestions for increasing a new path between the latent variables. Therefore, in order to modify the modified model 1, it is suggested to delete the insignificant paths. According to Table 6-18, the construct of BI was deleted to formulate a new model because the path from BI to B is not significant, with a p-value of 0.433. This means H4 is rejected, namely behavioural intention cannot have a direct positive effect on the behaviour. Because the constructs of AB and SN have significant relationships with BI, the two constructs were deleted as well in the new modified model 2. However, the estimation results revealed that AB and SN are the significant determinants of BI. The path weights from AB and SN to BI are 0.433 and 0.438 respectively.

Table 6-20 Modification indices of regression weights – modified model 1

	M.I.	Par Change		M.I.	Par Change
BI <--- EV	8.671	0.209	GS3 <--- AB	4.175	-0.207
B7 <--- SN	6.127	0.214	GS3 <--- BI3	8.027	-0.208
B7 <--- SN2	5.479	0.135	GS3 <--- GS4	8.08	0.127
B7 <--- SN1	10.245	0.189	GS3 <--- GS1	5.658	-0.124
B6 <--- SN1	6.371	-0.166	GS3 <--- SN1	4.217	-0.113
B5 <--- SN1	6.793	0.168	GS3 <--- AB4	5.904	-0.138
B5 <--- AB1	5.496	-0.168	GS2 <--- BI	4.136	0.167
B4 <--- GS1	4.212	-0.132	GS2 <--- BI4	5.794	0.143
B1 <--- BI2	4.211	-0.166	GS2 <--- BI3	10.937	0.249
BI4 <--- PC	7.594	-0.166	GS2 <--- GS4	5.393	-0.106
BI4 <--- EV	5.006	0.188	GS2 <--- GS1	19.545	0.235
BI4 <--- PC3	5.91	-0.126	GS2 <--- SN1	5.453	0.131
BI4 <--- PC2	11.02	-0.166	GS1 <--- B4	4.082	-0.08
BI4 <--- EV3	5.705	0.119	GS1 <--- BI3	4.525	0.162
BI4 <--- GS2	4.184	0.104	GS1 <--- GS2	13.603	0.183
BI2 <--- EV	7.077	0.2	SN5 <--- B4	4.201	0.077
BI2 <--- B4	4.009	0.072	SN5 <--- B1	4.717	0.085
BI2 <--- EV3	11.719	0.153	SN5 <--- AB3	4.597	0.117
BI2 <--- AB4	4.521	-0.114	SN3 <--- EV2	4.442	-0.101
BI1 <--- PC4	10.793	0.143	SN3 <--- AB5	4.503	0.145
BI1 <--- PC2	4.825	0.083	SN2 <--- GS1	5.227	-0.105
PC4 <--- AB	4.028	0.225	SN2 <--- SN1	4.54	0.103
PC4 <--- BI	4.857	0.196	SN2 <--- AB5	5.129	-0.127
PC4 <--- BI1	8.094	0.195	SN1 <--- AB	4.233	-0.196
PC4 <--- AB4	5.671	0.15	SN1 <--- B7	5.997	0.097
PC3 <--- B1	4.15	-0.072	SN1 <--- B5	8.074	0.102
PC2 <--- B6	7.531	0.085	SN1 <--- BI4	7.127	-0.146
PC2 <--- BI4	4.532	-0.104	SN1 <--- AB4	6.073	-0.132
PC1 <--- GS1	11.492	-0.173	AB5 <--- SN2	5.882	-0.111
EV3 <--- BI	7.076	0.252	AB4 <--- EV3	4.016	0.083
EV3 <--- BI4	8.311	0.197	AB4 <--- AB2	4.902	-0.105
EV3 <--- BI2	17.59	0.285	AB2 <--- AB1	6.491	0.158
GS4 <--- GS3	4.221	0.105	AB1 <--- B5	4.715	-0.076
GS4 <--- GS2	4.834	-0.119	AB1 <--- AB2	6.158	0.123

6.4.2.3 Modified model 2

After deleting the path from BI to B, the modified structural equation model was derived, as shown in Fig. 6-14. There are a total of four constructs in the model;

each latent variable has several observed variables to measure. The normality assessment results are presented in Table 6-21. From the table, it can be seen the absolute value skewness coefficient is lower than 2 and the absolute value of the kurtosis is lower than 7, thus the maximum likelihood is appropriate to be selected as the estimation method.

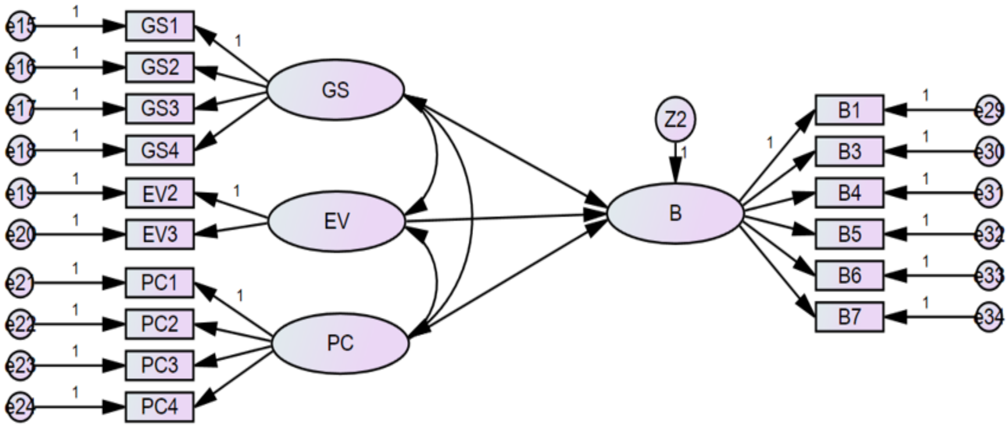

Fig. 6-14 Determinants of C&D waste management – modified model 2

Table 6-21 Assessment of normality – modified model 2

Variable	min	max	skew	c.r.	kurtosis	c.r.
B7	1	5	0.045	0.264	-0.814	-2.389
B6	1	5	0.233	1.371	-0.877	-2.576
B5	1	5	0.121	0.711	-0.845	-2.482
B4	1	5	0.154	0.906	-0.969	-2.846
B3	1	5	0.034	0.202	-1.03	-3.026
B1	1	5	0.326	1.912	-0.777	-2.283
PC4	1	5	-0.674	-3.961	0.322	0.947
PC3	1	5	-0.452	-2.657	-0.651	-1.913
PC2	1	5	-0.073	-0.429	-0.88	-2.583
PC1	1	5	0.156	0.918	-1.111	-3.263
EV3	1	5	-0.562	-3.302	-0.032	-0.095
EV2	1	5	-0.447	-2.628	-0.23	-0.675
GS4	1	5	-0.348	-2.041	-0.246	-0.721
GS3	1	5	-0.049	-0.29	-0.361	-1.061
GS2	1	5	-0.428	-2.516	0.091	0.267
GS1	1	5	-0.633	-3.719	0.764	2.243
Multivariate					39.578	11.863

From Fig. 6-14, it can be seen that there are a total of 16 observed variables and 21 unobserved variables in the measurement model. The number of exogenous variables is 20 and the number of endogenous variables is 17. There are 136 distinct sample moments in the model and the number of distinct parameters to be estimated is 38, therefore, the degree of freedom of the default model is 98 (i.e., 136 - 38), which means the model is identifiable.

The analysis results of the initial model are shown in Table 6-22 and Table 6-23. From Table 6-22, it can be seen that the path from PC to B has an insignificant p-value. From Table 6-23, most indices indicate that the modified model 2 can fit the data well.

Table 6-22 Regression weights in the modified model 2

	Estimate	**S.E.**	**C.R.**	**P**
B <--- GS	.205	.100	2.046	.041
B <--- PC	.074	.063	1.183	.237
B <--- EV	.452	.109	4.140	***
GS1 <--- GS	1.000			
GS2 <--- GS	1.208	.127	9.544	***
GS3 <--- GS	1.428	.139	10.268	***
GS4 <--- GS	1.296	.136	9.512	***
EV2 <--- EV	1.000			
EV3 <--- EV	1.248	.252	4.944	***
PC1 <--- PC	1.000			
PC2 <--- PC	1.023	.069	14.749	***
PC3 <--- PC	.915	.067	13.753	***
PC4 <--- PC	.524	.068	7.734	***
B1 <--- B	1.000			
B3 <--- B	1.048	.135	7.791	***
B4 <--- B	1.283	.138	9.287	***
B5 <--- B	1.347	.140	9.608	***
B6 <--- B	1.429	.147	9.723	***
B7 <--- B	1.201	.126	9.536	***

Table 6-23 Goodness-of-fit of the modified model 2

Goodness-of-fit measure		**Level of acceptance fit**	**Fit statistics**
Absolute fit	χ^2/df	< 5 acceptable; < 3 good	1.928
	GFI	> 0.8 acceptable; > 0.9 good	0.902
	AGFI	> 0.8 acceptable; > 0.9 good	0.864
	RMSEA	< 0.1 acceptable; < 0.08 good	0.067
Incremental fit	NFI	> 0.9	0.889
	RFI	> 0.9	0.864
	IFI	> 0.9	0.943
	TLI	> 0.9	0.930
	CFI	> 0.9	0.943

The modification indices of regression weights are presented in Table 6-24. It can be seen that there are no significant suggestions for increasing a new path between the latent variables. Therefore, in order to modify the modified model 2, it is suggested deleting the insignificant paths. According to Table 6-22, the construct of PC was deleted to formulate a new model because the path from PC to B is not significant, with a p-value of 0.237. This means H7 is rejected, namely project constraints cannot have a direct positive effect on the behaviour.

Table 6-24 Modification indices of regression weights – modified model 2

	M.I.	**Par Change**		**M.I.**	**Par Change**
B4 <--- GS1	4.131	-0.131	GS3 <--- GS4	6.411	0.112
PC3 <--- B1	4.201	-0.073	GS3 <--- GS1	5.948	-0.126
PC2 <--- B6	7.24	0.083	GS2 <--- GS4	4.86	-0.102
PC1 <--- GS1	11.468	-0.172	GS2 <--- GS1	21.334	0.248
GS4 <--- GS2	4.781	-0.118	GS1 <--- GS2	15.312	0.196

6.4.2.4 Modified model 3

After deleting the path from PC to B, the modified structural equation model was derived, as shown in Fig. 6-15. There are a total of three constructs in the model; each latent variable has several observed variables to measure. The normality assessment results are presented in Table 6-25. From the table, it can be seen the absolute value skewness coefficient is lower than 2 and the absolute value of the kurtosis is lower than 7, thus maximum likelihood is appropriate to be selected as the estimation method.

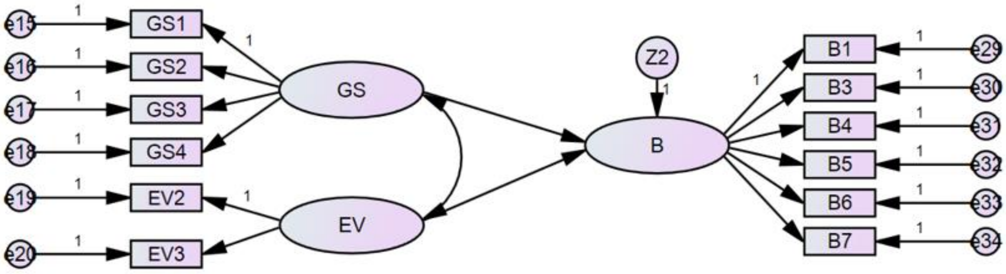

Fig. 6-15 Determinants of C&D waste management – modified model 3

Table 6-25 Assessment of normality – modified model 3

Variable	min	max	skew	c.r.	kurtosis	c.r.
B7	1	5	0.045	0.264	-0.814	-2.389
B6	1	5	0.233	1.371	-0.877	-2.576
B5	1	5	0.121	0.711	-0.845	-2.482
B4	1	5	0.154	0.906	-0.969	-2.846
B3	1	5	0.034	0.202	-1.03	-3.026
B1	1	5	0.326	1.912	-0.777	-2.283
EV3	1	5	-0.562	-3.302	-0.032	-0.095
EV2	1	5	-0.447	-2.628	-0.23	-0.675
GS4	1	5	-0.348	-2.041	-0.246	-0.721
GS3	1	5	-0.049	-0.29	-0.361	-1.061
GS2	1	5	-0.428	-2.516	0.091	0.267
GS1	1	5	-0.633	-3.719	0.764	2.243
Multivariate					24.103	9.459

From Fig. 6-15, it can be seen that there are a total of 12 observed variables and 16 unobserved variables in the measurement model. The number of exogenous variables is 15 and the number of endogenous variables is 13. There are 78 distinct sample moments in the model and the number of distinct parameters to be estimated is 27, therefore, the degree of freedom of the default model is 51 (i.e., 78 - 27), which means the model is identifiable.

The analysis results of the modified model 3 are shown in Table 6-26 and Table 6-27. From Table 6-26, it can be seen that the two paths from GS and EV to B are significant at the levels of 0.05 and 0.001 respectively. From Table 6-27, the goodness-of-fit indices indicate that the modified model 3 can fit the data very well. The results showed that there are two main determinants for the contractors to conduct C&D waste management, namely governmental supervision and economic viability. The hypotheses of H5 and H6 and are supported. The relationships of between the two determinants and the C&D waste management behaviour are shown in Fig. 6-16.

Table 6-26 Regression weights in the modified model 3

	Estimate	**S.E.**	**C.R.**	**P**
B <--- GS	.226	.099	2.273	.023
B <--- EV	.447	.109	4.100	***
GS1 <--- GS	1.000			
GS2 <--- GS	1.209	.127	9.493	***
GS3 <--- GS	1.436	.140	10.235	***
GS4 <--- GS	1.302	.137	9.486	***
EV2 <--- EV	1.000			
EV3 <--- EV	1.271	.263	4.840	***
B1 <--- B	1.000			
B3 <--- B	1.049	.135	7.779	***
B4 <--- B	1.285	.139	9.277	***
B5 <--- B	1.350	.141	9.600	***
B6 <--- B	1.431	.147	9.708	***
B7 <--- B	1.202	.126	9.520	***

Table 6-27 Goodness-of-fit of the modified model 3

Goodness-of-fit measure		Level of acceptance fit	Fit statistics
Absolute fit	χ^2/df	< 5 acceptable; < 3 good	2.160
	GFI	> 0.8 acceptable; > 0.9 good	0.919
	AGFI	> 0.8 acceptable; > 0.9 good	0.876
	RMSEA	< 0.1 acceptable; < 0.08 good	0.075
Incremental fit	NFI	> 0.9	0.909
	RFI	> 0.9	0.882
	IFI	> 0.9	0.949
	TLI	> 0.9	0.933
	CFI	> 0.9	0.948

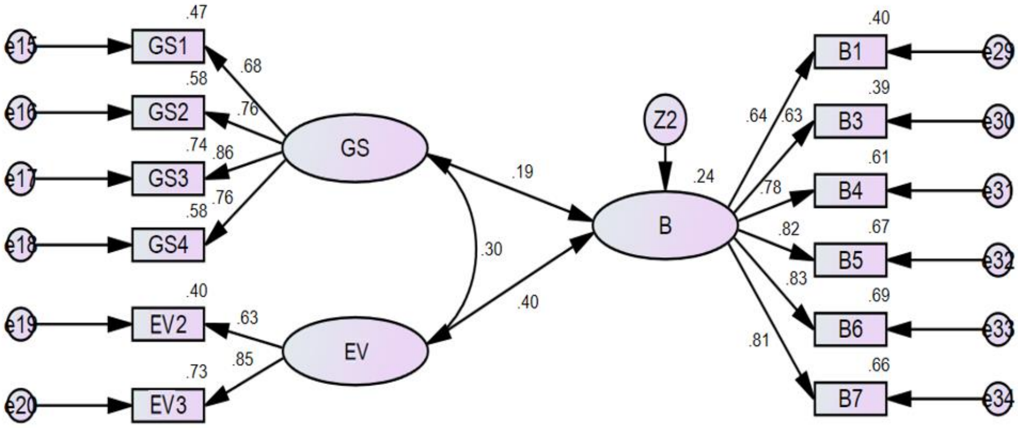

Fig. 6-16 Standardised estimation of modified model 3

From Fig. 6-16, it can be seen that the path weight from construct GS to B is 0.19, which means that when GS goes up by 1 standard deviation, B goes up by 0.19 standard deviation. Similarly, the path weight from construct EV to B is 0.40, which means that when EV goes up by 1 standard deviation, B goes up by 0.40 standard deviation.

6.5 Discussion of results

According to the above analysis, the proposed hypotheses were tested. The results are presented in Table 6-28.

Table 6-28 The results of the proposed hypotheses

Hypothesis	Description	Result
H1	Attitude towards behaviour has a direct positive effect on the behavioural intention	Supported
H2	Social norm has a direct positive effect on the behavioural intention	Supported
H3	Perceived behavioural control has a direct positive effect on the behavioural intention	Not supported
H4	Behavioural intention has a direct positive effect on the behaviour	Not supported
H5	Governmental supervision has a direct positive effect on the behaviour	Supported
H6	Economic viability has a direct positive effect on the behaviour	Supported
H7	Project constraints have a direct negative effect on the behaviour	Not supported

From the results, it is surprising to see that H4 is not supported, because behavioural intetion has been regarded as a significant determinant for other kinds of waste management, i.e., household waste (Pakpour et al., 2014) and food waste (Quested et al., 2013). However, from this study, it is regarded as an insignificant determinant for contractors to employ C&D waste management. This may be attributed to the fact that C&D waste management behaviour is different from other kinds of waste management. The behaviour of C&D waste management is not just an individual behaviour though it is conducted by individuals. Such behaviour is not solely determined by the general staff themselves, since there are influencing factors at company level. For example, companies must comply with related regulations to take actions. Meanwhile, they must consider whether they can earn benefits from their actions. After all, the nature of a company is earning money. This may be the underlying reasons why GS and EV are significant determinants for C&D waste management behaviour.

Taking these speculations in mind, a triangulation analysis was conducted to explore what are the real reasons. Five interviewees who participated in the formal questionnaire survey and who had provided their contact information were invited to attend telephone interviews to give their comments on the structural equation modelling results. The interview guide can be found in Appendix 4.

Through the interviews, it is found that the five interviewees shared similar opinions. They all agreed that the individual's intention is not a significant determinant to make them to employ C&D waste management measures. The interviewees agreed that they are not willing to pollute the environment intentionally; they generally would like to see a clean and sustainable world. However, this does not mean that they have a strong willingness to employ C&D waste management measures. They regarded that C&D waste management is more like company behaviour rather than their individual behaviour. In a real project, they decide whether to take C&D waste management actions mainly based on the project needs and requirements.

Governmental supervision is a significant factor that they are concerned with when deciding whether to employ C&D waste management measures. The five interviewees said there are local regulations requiring the contractors to move C&D waste away from the construction site and dispose of it at appointed districts. Generally, they will follow the requirements of the related regulations. However, as the majority of the produced C&D waste is soil, they usually sell it to the companies which trade in soil. Because the cities are experiencing fast urbanisation currently and there are many active construction sites in a particular city, there are demands for soil in other projects to make up levels of the construction sites. In this circumstance, soil is sold to the companies operating soil trades instead of delivering it to the governmental appointed discharging places. In many cases, the contractors may consume the soil themselves at their own sites. Two interviewees mentioned that they rarely send C&D waste to landfills or public disposal places. The way they dealt with the C&D waste with little recycling value is just burying it in the construction sites, and build public areas (e.g., community park) at the burying places. They admitted that such actions may cause soil pollution and other problems (e.g., ground settlement). Nevertheless, they said it is a very common phenomenon in practice because the government has no supervision on that. Therefore, it is suggested that the government can give more detailed specifications on C&D waste management in construction sites, and impose stricter supervision to increase the contractor's awareness. In addition, integrating C&D waste management requirements in contracts during the tender stage is also an effective solution (Tam et al., 2007a). The government can arrange more weights to C&D waste management in green building rating systems.

Together with governmental supervision, the interviewees agreed that the economic viability is a significant influential factor when they make C&D waste management decisions. One interviewee even stressed that if the profit of violating regulations is higher than its cost, then there is a big possibility that they will take such actions if they regard the consequence of such actions is not severe from their point of view and the company values. The example presented in the last paragraph is also an evidence of this statement. In addition to the lack of supervision, the economic benefit can be gained from not sending C&D waste to the appointed landfills. All of the five interviewees mentioned that continually earning money is the first priority in their projects, no matter on C&D waste management decisions or other kinds of decisions. This is echoed with the research conducted by Wu et al. (2015b) which indicated that the decision-makers of a project often choose economic benefit rather than environmental protection when conflict (i.e. time limitation, site constraint) occurs between them due to the company's benefit-earning nature. Tam (2008) also found that low financial incentive and increase in overhead cost were the major difficulties in implementing a waste-management-plan. Therefore, it is suggested that the government can provide attractive incentives to stimulate the contractors to employ proper C&D waste management in their projects. Otherwise, the government can increase the punishment level to those companies which violate the regulation requirements. Of course, the prerequisite of this measure is a good supervisory mechanism.

The insignificance of project constraints in making C&D waste management decisions was also confirmed from the interviews. The interviewees clarified that C&D waste management is only one aspect in a project of concern. Actually, C&D waste management does not require too much money compared with other expenses. Also, regular C&D waste management measures are not advanced technologies. The only problem that may be encountered is the lack of area to store C&D waste. However, as the projects are generally very large in the current stage of the industry market, and there are usually several development phases to develop real estate in a project, it is not too difficult to solve the problem of arranging C&D waste. The contractors care more about the quality of the buildings other than the quality of waste disposal. Thus the project constraints are usually not significant when making C&D waste management decisions.

Through the interviews with the professionals, the results derived from the SEM analysis are validated. It can be concluded that the government plays a very important role in promoting contractor’s C&D waste management behaviour. in the current situation of Mainland China, strict supervision and proper economic incentives are the most effective measures to make the contractors employ better C&D waste management.

6.6 Summary

This chapter described the results derived from the empirical analysis. The influences of background information variables in C&D waste management were tested. It is found that the adoption of C&D waste management measures has no relationship between personal background information factors. Using the structural equation modelling, confirmatory factor analysis and path analysis were conducted. The results from confirmatory factor analysis showed the model has good validity. The relationships between potential determinants and behaviour were further tested. The results showed that the individual's intention is not a significant factor that influences the contractor's C&D waste management behaviour. In addition, project constraints are not major considerations when contractors employ C&D waste management. Two significant determinants can influence the contractor's C&D waste management behaviour: governmental supervision and economic viability. Therefore, measures should be considered from these two aspects in order to stimulate the contractor to implement better C&D waste management behaviour.

CHAPTER 7 Conclusions

7.1 Introduction

This chapter presents the conclusions of this study. The research objectives are reviewed, followed by a general overview of the key findings derived from this research study. Significance and contributions of this study are also presented. Finally, the limitations and future research directions are suggested.

7.2 Review of the research objectives

The governmental reports and academic studies have showed that the amount of C&D waste was very large. Adverse environmental impacts can be produced if C&D waste inappropriately disposed. Nevertheless, C&D waste can also be utilised as a secondary resource if it gets proper treatment. Recently, plenty of strategies and technologies have been proposed to facilitate effective C&D waste management. However, the level of C&D waste management in Mainland China remains behindhand. It is, therefore, important to find out the determinants that affect the contractor's adoption of effective C&D waste management measures. According to the Theory of Planned Behaviour (TPB), individual's behavioural intention has a significant relationship to the corresponding behaviour. However, little research has been conducted to investigate the relationship of the contractor's C&D waste management intention and behaviour based on TPB. Therefore, the principal aim of this study is to investigate the determinants that affect contractor's C&D waste management behaviour.

In order to achieve above aim, four specific objectives were proposed to be achieved as follows:

1) To identify the potential critical factors that affect the contractor's behaviour of C&D waste management;
2) To develop measurement scales for investigating the contractor's C&D waste management behaviour and the potential determinants;
3) To explore the interrelationships between potential C&D waste management determinants and the contractor's actual behaviour;
4) To provide suggestions for promoting the implementation of effective C&D waste management in the current situation of Mainland China.

The first objective was achieved by literature review of A&B theories and C&D waste management studies. A focus group meeting was further conducted with experienced professionals. Potential determinants were derived from literature and discussed in the focus group meeting.

The second objective was achieved by literature review, a focus group meeting, and a pilot study. Firstly, the measurement scales were developed based on existing literature and discussed in the focus group meeting. Secondly, the preliminary questionnaire was tested using a pilot study.

The third and the fourth objectives were achieved by questionnaire survey and interviews with professionals. Statistical analysis was employed to explore the interrelationships of the constructs reflected by the collected data. A final model presenting the relationships was derived and further validated using interviews. Suggestions for promoting the implementation of effective C&D waste management were given based on the analysis results.

7.3 Major research findings

Through the literature review, eight constructs were proposed to formulate the preliminary theoretical model. Five constructs were proposed based on the classical A&B theory (i.e., TPB) including attitude towards behaviour (AB), subjective norm (SN), perceived behavioural control (PBC), behavioural intention (BI), and behaviour (B). The TPB was selected because it is the most popular theory in exploring the relationships of behavioural intention and behaviour. However, as the individual's perceived behaviour control may not exact, three other contextual constructs were introduced based on the current C&D waste management studies, including governmental supervision (GS), economic viability (EV), and project constraints (PC). These three constructs were considered because they are the most frequently discussed factors in the current C&D waste management research.

In order to test the relationships of potential determinants and the actual C&D waste management behaviour, a questionnaire was designed including eight scales for measuring the proposed constructs. The questionnaire was designed based on the literature review and a focus group meeting. A pilot study was conducted to improve the reliability and validity of the questionnaire.

After the data were collected, statistical analysis was conducted to investigate the relationships of potential influencing factors and actual C&D waste management behaviour. Non-parametric tests were firstly employed to explore whether personal characteristics have influence in behaviour. The results showed that the personal background information factors had no significant influence in C&D waste management behaviour. Then, the relationships of potential determinants and behaviour were tested using Structural Equation Modelling (SEM). The results showed that behavioural intention had no significance on C&D waste management behaviour. This might be because C&D waste management behaviour is a group behaviour at company level; the individual's intention has little effect on it. The results also indicated that the governmental supervision and economic viability were significant for determining C&D waste management behaviour; however, the construct of project constraints was found insignificant. In order to validate the analysis findings, a triangulation analysis was conducted. The participants from the industry affirmed the analysis findings.

7.4 Significance and contributions of this research study

This research study investigated the determinants of contractor's C&D waste management behaviour in the circumstance of Mainland China. The research findings are significant because the generally believed viewpoint, namely C&D waste management intention is an important determinant for making C&D waste management decisions, was denied in this study. Based on the research findings, economic viability and governmental supervision were the two important aspects for improving contractor's C&D waste management behaviour in the current situation of Mainland China. Policies and measures should be made from improving these two aspects other than focusing on improving contractor's C&D waste management intention.

This study also makes contributions from both academic and practical perspectives:

- From the academic perspective, firstly, this study is the first attempt to integrate contextual constructs into the classical A&B theory to investigate the determinants of C&D waste management. The research findings are believed to be of great significance for improving the effectiveness of C&D waste management in Mainland China. Secondly, measurement scales were originally developed for the constructs and Structural Equation Modelling (SEM) was used to test the potential determinants. The research findings can make contributions to the body of knowledge of C&D waste management. Furthermore, the developed model can assist in gaining a better understanding of the variables which affect the adoption of C&D waste management measures.

- In addition to the academic contributions, the research findings also have implications to the industry. Firstly, the research findings showed that the priority of construction company's profit is higher than the practitioner's intention in the implementation of real-life projects. Therefore, in the current situation of Mainland China, the priority should be given to improve company's visions rather than the staff's environmental awareness. Secondly, the findings of this study can serve as valuable references for planning C&D waste management in Mainland China. As economic viability and governmental supervision are the two significant determinants, it is implied that the government is the key for improving C&D waste management in current situation. The government should take responsibilities to propose policies and measures to increase the economic viability of implementing C&D waste management and to strengthen governmental supervision on C&D waste treatments.

7.5 Limitations and directions for future research

7.5.1 Limitations of this study

This research also has limitations; two major limitations are as follows:

- Firstly, the sample size of the SEM analysis is not ideally adequate. Though there are many different statements from scholars about sample size requirement when employing SEM, it is a consensus that the ideal ratio of one measurement item to response number is 1:10. The sample size used in this study was 207, just satisfies the minimum requirement.

- Secondly, the region of the respondents should be narrower. The respondents in this study were distributed in the whole Mainland China; however, different cities may have different requirements or policies on C&D waste management. For example, Shenzhen has a more complex regulation on C&D waste management while other cities may even have no specific regulation on C&D waste. In this circumstance, the opinions of the respondents may differ.

7.5.2 Future research directions

Notwithstanding the limitations indicated above, this study proposed a new platform for investigating the determinants of C&D waste management behaviour. The possible future research directions are proposed as follows:

- Implementing such research in a more specific region with a larger sample size. The research study was implemented focusing on the construction contractors in Mainland China. As the C&D waste management levels may be various in different cities, future research can be conducted focusing on one specific region. In addition, a larger sample size can make the analysis results more reliable.
- Making comparisons of C&D waste management determinants in different regions. As C&D waste management situations are various in different regions, making comparisons can assist in sharing successful experiences so as to increase the C&D waste management level.

APPENDICES

APPENDIX 1: FOCUS GROUP MEETING GUIDE

1. Please introduce your work experience (e.g., what is the rank of your company, how many years have you been engaged in the construction industry, what is your education level).
2. What C&D waste management strategies or technologies do you know to reduce, reuse, or recycle C&D waste?
3. What are the most important influencing factors when considering C&D waste management implementation?
4. What are the most common difficulties and obstacles when employing C&D waste management?
5. What suggestions would you provide to promote C&D waste management?

APPENDIX 2: QUESTIONNAIRE – IN CHINESE

建筑承包商对于建筑垃圾管理的态度与行为调查问卷

尊敬的参与者：

您好！我是香港理工大学建筑与房地产学系的博士生，目前正在进行“承包商对于建筑垃圾管理的态度与行为调查”这一课题的研究。

建设部于 2005 年出台的《城市建筑垃圾管理规定》指出：建筑垃圾是指建设单位、施工单位新建、改建、扩建和拆除各类建筑物、构筑物、管网等以及居民装饰装修房屋过程中所产生的弃土、弃料及其它废弃物。我国每年建筑垃圾产生量巨大，若乱抛乱弃，会造成严重的资源浪费和环境污染。通过实施有效的建筑垃圾管理，能够有效地减少资源消耗，降低环境污染。

本问卷的主要目的是识别承包商采取有效建筑垃圾管理行为的决定性因素及各因素与最终行为的内在联系。问卷共包括 9 个部分，共 51 个问题。所列问题没有标准答案，全部完成仅会使用 5 至 10 分钟的时间。本问卷所有问题都是采用匿名回答，对所得答复将严格保密。

如果您对本研究存在任何疑问或建议，欢迎与本人取得联系：zezhou.wu@

敬祝　　身体健康、工作顺利！

香港理工大学建筑及房地产学系

吴泽洲

第一部分：背景信息（共 9 题）

（本部分用于调查被访者的背景信息，请您将认为符合的选项标红。）

1. 您所从事的工作类型：

☐ 企业管理	☐ 项目管理
☐ 工程技术	☐ 成本控制
☐ 质量控制	☐ 现场施工
☐ 其他：________________	

2. 您的从业时间：

☐ 0-5 年	☐6-10 年
☐11-15 年	☐16 年及以上

3. 您的性别：

☐ 男	☐ 女

4. 您的最高学历：

☐ 博士	☐ 硕士
☐ 学士	☐ 大专及以下

5. 您参与过的项目个数：

☐1-5 个	☐6-10 个
☐ 11-20 个	☐ 21 个及以上

6. 您现在所在公司的承包资质：

☐ 特级	☐ 一级
☐ 二级	☐ 三级
☐ 其他：________________	

7. 您现在参与的项目类型：

☐ 住宅建筑	☐ 商业建筑
☐ 办公建筑	☐ 工业建筑
☐ 公共设施	☐ 其他：________________

8. 您现在参与项目的合同价格：

☐<1000 万元	☐1000≤合同价<5000 万元
☐5000≤合同价<1 亿元	☐ 1 亿元≤合同价<5 亿元
☐5 亿元≤合同价<10 亿元	☐≥10 亿元

9. 您现在参与项目的现场施工人员数量：

☐1-50 人	☐51-100 人
☐ 101-200 人	☐ 201 人及以上

第二部分：态度调查（共 5 题）

（本部分用于调查被访者对建筑垃圾管理的态度，请您将认为符合的选项标红。）

	非常不同意	不同意	中立	同意	非常同意
1. 实施有效的建筑垃圾管理能够改善环境质量。	1	2	3	4	5
2. 实施有效的建筑垃圾管理能够促进社会可持续发展。	1	2	3	4	5
3. 实施有效的建筑垃圾管理能够提升企业的品牌效益。	1	2	3	4	5
4. 实施有效的建筑垃圾管理能够提升项目的社会形象。	1	2	3	4	5
5. 实施有效的建筑垃圾管理是值得提倡的。	1	2	3	4	5

第三部分：主观规范调查（共 6 题）

（本部分用于调查对被访者有重要影响的群体对建筑垃圾管理的态度，请您将认为符合的选项标红。）

	非常不同意	不同意	中立	同意	非常同意
1. 我的项目领导期望我采取有效的建筑垃圾管理措施。	1	2	3	4	5
2. 我的同事期望我采取有效的建筑垃圾管理措施。	1	2	3	4	5
3. 我的家人及好友期望我采取有效的建筑垃圾管理措施。	1	2	3	4	5
4. 我的业主期望我采取有效的建筑垃圾管理措施。	1	2	3	4	5
5. 项目的潜在客户期望我采取有效的建筑垃圾管理措施。	1	2	3	4	5
6. 项目所处地区政府期望我采取有效的建筑垃圾管理措施。	1	2	3	4	5

第四部分：行为控制认知调查（共 5 题）

（本部分用于调查被访者所感知到的对建筑垃圾管理行为的自我控制能力，请您将认为符合的选项标红。）

	非常不同意	不同意	中立	同意	非常同意
1. 我有足够的机会去实施建筑垃圾管理。	1	2	3	4	5
2. 我能得到足够的支持去实施建筑垃圾管理。	1	2	3	4	5
3. 我有足够的时间去实施建筑垃圾管理。	1	2	3	4	5
4. 我有足够的空间去实施建筑垃圾管理。	1	2	3	4	5
5. 我有足够的经验去实施建筑垃圾管理。	1	2	3	4	5

第五部分：行为意向调查（共 4 题）

（本部分用于调查被访者对实施建筑垃圾管理行为的意向，请您将认为符合的选项标红。）

	非常不同意	不同意	中立	同意	非常同意
1. 我愿意在项目中采取避免建筑垃圾产生的相关措施。	1	2	3	4	5
2. 我愿意对项目产生的建筑垃圾进行回收利用。	1	2	3	4	5
3. *我愿意看到项目中有建筑垃圾乱抛乱弃的现象。*	1	2	3	4	5
4. 我愿意参加建筑垃圾管理培训。	1	2	3	4	5

第六部分：政府监管调查（共 4 题）

（本部分用于调查被访者所在地区政府对建筑垃圾管理的监管情况，请您将认为符合的选项标红。）

	非常不同意	不同意	中立	同意	非常同意
1. 政府有明确的法律条文对现场建筑垃圾的处理进行规范。	1	2	3	4	5
2. 政府有专门的行政部门对建筑垃圾的管理进行监管。	1	2	3	4	5
3. 政府有健全的监督体系对建筑垃圾的处理进行监督。	1	2	3	4	5
4. 政府有严厉的处罚措施杜绝建筑垃圾的乱排乱放行为。	1	2	3	4	5

第七部分：经济可行调查（共 5 题）

（本部分用于调查被访者对建筑垃圾管理的经济可行性进行评价，请您将认为符合的选项标红。）

	非常不同意	不同意	中立	同意	非常同意
1. 在施工现场实施建筑垃圾管理能够降低施工成本。	1	2	3	4	5
2. 减少建筑垃圾的排放能够降低施工成本。	1	2	3	4	5
3. 对建筑垃圾实施有效的回收利用能够给企业带来收益。	1	2	3	4	5
4. 政府目前所征收的建筑垃圾填埋费费率较高。	1	2	3	4	5
5. 政府有具有吸引力的激励措施鼓励建筑垃圾的有效处理。	1	2	3	4	5

第八部分：限制因素调查（共 6 题）

（本部分用于调查被访者在实际工程经验中所遇到的建筑垃圾管理限制因素，请您将认为符合的选项标红。）

	非常不同意	不同意	中立	同意	非常同意
1. 项目有足够的人员实施有效的建筑垃圾管理。	1	2	3	4	5
2. 项目有足够的资金实施有效的建筑垃圾管理。	1	2	3	4	5
3. 项目有足够的时间实施有效的建筑垃圾管理。	1	2	3	4	5
4. 项目有足够的施工场地实施有效的建筑垃圾管理。	1	2	3	4	5
5. 项目有足够的设备实施有效的建筑垃圾管理。	1	2	3	4	5
6. 现有的建筑垃圾回收利用市场成熟。	1	2	3	4	5

第九部分：行为调查（共 7 题）

（本部分用于调查被访者对于建筑垃圾管理所采取的行为，请您将认为符合的选项标红。）

	从未有过	偶尔	中立	经常	一直如此
1. 我曾经在经历的项目中通过有效的现场施工管理来减少建筑垃圾的产生。	1	2	3	4	5
2. 我曾经在经历的项目中通过合理的材料采购来减少建筑垃圾的产生。	1	2	3	4	5
3. 我曾经在经历的项目中通过使用先进的技术（如预制构件）来减少建筑垃圾的产生。	1	2	3	4	5
4. 我曾经在经历的项目中通过采取现场分类对产生的建筑垃圾分类处理。	1	2	3	4	5
5. 我曾经在经历的项目中对能够直接再利用的建筑垃圾实施再利用。	1	2	3	4	5
6. 我曾经在经历的项目中对可再生利用的建筑垃圾进行回收处理。	1	2	3	4	5
7. 我曾经在经历的项目中采取了其他措施对建筑垃圾实施有效管理。	1	2	3	4	5

如果您对本问卷有任何疑问或建议，请提出：

如果您想获得本研究的最终报告，请留下您的联系方式：

姓名： 公司： 地址： 电话： 邮箱：

问卷结束！

非常感谢您对本研究做出的重要贡献！

APPENDIX 3: QUESTIONNAIRE – IN ENGLISH

Questionnaire Survey

Investigation of Contractor's Attitude and Behaviour towards Construction and Demolition (C&D) Waste Management

Dear respondent:

I am a PhD student in the Department of Building and Real Estate in The Hong Kong Polytechnic University. You are cordially invited to participate in a research study, which is entitled 'Investigation of contractor's attitude and behaviour towards construction and demolition (C&D) waste management'.

In the 'Regulation of municipal construction and demolition waste management' issued by the China Ministry of Construction in 2005, it was defined that C&D waste includes the wasted soil, materials and other components that are generated from construction, renovation, extension and demolition activities of buildings, infrastructures and other projects. The annual generation of C&D waste is significant in China, if C&D waste is disposed of inappropriately, resource wastage and environmental pollution will be caused. Effective C&D waste management can aid in not only reducing the resource wastage but also mitigating the environmental pollution.

The purpose of this study is to investigate the determinants of the contractor's C&D waste management behaviour so as to explore their interrelationships. The questionnaire has 9 sections, including 51 questions. There are no standard answers to the questions, and it only takes you 5-10 minutes to complete the questionnaire. Individual details will not be disclosed and all responses will remain strictly confidential.

If you have any enquiries or suggestions about this research, please contact Mr. Zezhou Wu through the following email address: zezhou.wu@

Best wishes!

Zezhou Wu

Department of Building and Real Estate

Part I：Background Information (9 questions)

1. The working category:

☐Company management	☐Project management
☐Construction engineering	☐Cost control
☐Quality control	☐ On-site construction
☐Other: ___________	

2. The time you have joined in the construction industry:

☐0-5 years	☐6-10 years
☐11-15 years	☐16 years or above

3. Your gender:

☐Male	☐Female

4. The level of your education:

☐PhD	☐ Master
☐Bachelor	☐Senior high school or below

5. The number of projects you have participated in:

☐1 to 5	☐6 to 10
☐11 to 20	☐21 or above

6. The ranking of your company:

☐Premium	☐Rank 1
☐Rank 2	☐Rank 3
☐Other: ___________	

7. The type of your project:

☐Residential building	☐Commercial building
☐Office building	☐Industrial building
☐Infrastructure	☐Other: __________

8. The contract sum of your project:

☐ Sum ≤ 10 million RMB	☐ 10 million < sum ≤ 50 million RMB
☐50 million < sum ≤ 100 million RMB	☐100 million < sum ≤ 500 million RMB
☐500 million < sum ≤ 1 billion RMB	☐ Sum > 1 billion RMB

9. The number of on-site construction workers in your project:

☐1 to 50	☐51 to 100
☐101 to 200	☐201 or above

Part II: Attitude Investigation (5 questions)

	1-Strongly disagree 3-Neutral 5-Strongly agree				
	1	2	3	4	5
1. Effective C&D waste management can improve the environmental quality.	☐	☐	☐	☐	☐
2. Effective C&D waste management can promote the sustainability development of the society.	☐	☐	☐	☐	☐
3. Effective C&D waste management can improve the company’s brand benefit.	☐	☐	☐	☐	☐
4. Effective C&D waste management can improve the social image of the project.	☐	☐	☐	☐	☐
5. Effective C&D waste management is worthy to be advocated.	☐	☐	☐	☐	☐

Part III: Subjective Norm Investigation (6 questions)

	1-Strongly disagree 3-Neutral 5-Strongly agree				
	1	2	3	4	5
1. My project manager expects me to employ effective C&D waste management.	☐	☐	☐	☐	☐
2. My colleagues expect me to employ effective C&D waste management.	☐	☐	☐	☐	☐
3. My family and friends expect me to employ effective C&D waste management.	☐	☐	☐	☐	☐
4. My project owner expects me to employ effective C&D waste management.	☐	☐	☐	☐	☐
5. The potential customers expect me to employ effective C&D waste management.	☐	☐	☐	☐	☐
6. The local government expects me to employ effective C&D waste management.	☐	☐	☐	☐	☐

Part IV: Perceived Behavioural Control Investigation (5 questions)

	1-Strongly disagree 3-Neutral 5-Strongly agree				
	1	2	3	4	5
1. I have adequate opportunities to employ effective C&D waste management.	☐	☐	☐	☐	☐
2. I have adequate supports to employ effective C&D waste management.	☐	☐	☐	☐	☐
3. I have adequate time to employ effective C&D waste management.	☐	☐	☐	☐	☐
4. I have adequate space to employ effective C&D waste management.	☐	☐	☐	☐	☐
5. I have adequate experiences to employ effective C&D waste management.	☐	☐	☐	☐	☐

Part V: Behavioural Intention Investigation (4 questions)

	1-Strongly disagree 3-Neutral 5-Strongly agree				
	1	2	3	4	5
1. I intend to take actions to avoid C&D waste generation.	☐	☐	☐	☐	☐
2. I intend to take actions to reuse or recycle C&D waste.	☐	☐	☐	☐	☐
3. <u>*I intend to see the inappropriate dumping of C&D waste.*</u>	☐	☐	☐	☐	☐
4. I intend to attend trainings on C&D waste minimisation.	☐	☐	☐	☐	☐

Part VI: Governmental Supervision Investigation (4 questions)

	1-Strongly disagree 3-Neutral 5-Strongly agree				
	1	2	3	4	5
1. The government has complete and clear regulations on C&D waste management.	☐	☐	☐	☐	☐
2. The government has particular department(s) for C&D waste management.	☐	☐	☐	☐	☐
3. The government has a comprehensive supervision system for C&D waste management.	☐	☐	☐	☐	☐
4. The government imposes strict punishment to illegal C&D waste dumping.	☐	☐	☐	☐	☐

Part VII: Economic Viability Investigation (5 questions)

	1-Strongly disagree 3-Neutral 5-Strongly agree				
	1	2	3	4	5
1. On-site C&D waste management can reduce construction cost.	☐	☐	☐	☐	☐
2. Decreasing C&D waste can save construction cost.	☐	☐	☐	☐	☐
3. Effective C&D waste management can bring benefits to the company.	☐	☐	☐	☐	☐
4. The current fee for discharging C&D waste is high.	☐	☐	☐	☐	☐
5. The government has attractive policies to encourage minimising C&D waste.	☐	☐	☐	☐	☐

Part VIII: Project Constraint Investigation (6 questions)

	1-Strongly disagree 3-Neutral 5-Strongly agree				
	1	2	3	4	5
1. The project has enough workers for effective C&D waste management.	☐	☐	☐	☐	☐
2. The project has enough money for effective C&D waste management.	☐	☐	☐	☐	☐
3. The project has enough time for effective C&D waste management.	☐	☐	☐	☐	☐
4. The project has enough space for effective C&D waste management.	☐	☐	☐	☐	☐
5. The project has enough equipment for effective C&D waste management.	☐	☐	☐	☐	☐
6. The current C&D waste recycling market is mature.	☐	☐	☐	☐	☐

Part IX: Behaviour Investigation (7 questions)

	1-Never 3-Neutral 5-Always				
	1	2	3	4	5
1. I used to minimise C&D waste through appropriate on-site management.	☐	☐	☐	☐	☐
2. I used to minimise C&D waste through appropriate material procurement.	☐	☐	☐	☐	☐
3. I used to minimise C&D waste through advanced construction technologies.	☐	☐	☐	☐	☐
4. I used to minimise C&D waste through on-site sorting.	☐	☐	☐	☐	☐
5. I used to directly reuse C&D waste in my project.	☐	☐	☐	☐	☐
6. I used to recycle C&D waste in my project.	☐	☐	☐	☐	☐
7. I used to minimise C&D waste through other measures in my project.	☐	☐	☐	☐	☐

If you have any comments or suggestions concerning this questionnaire, please feel free to indicate:

If you want to receive a copy of the final report, please provide the following information:

Name:
Organisation:
Address:
Telephone No.:
Email:

END OF THE QUESTIONNAIRE!

THANK YOU VERY MUCH FOR YOUR PRECIOUS CONTRIBUTION!

APPENDIX 4: INTERVIEW GUIDE

1. Please introduce your work experience (e.g. what is the rank of your company, how many years have you engaged in the construction industry, what is your education level).
2. Which level of C&D waste minimisation do you focus more in your project, reduction, reuse, recycling, or others?
3. What C&D waste management strategies or technologies have you used to minimise C&D waste generation?
4. According to your experience, do you think the contractor's intention of C&D waste management is significant for adopting C&D waste minimisation measures? Why?
5. According to your experience, do you think economic viability is significant when considering C&D waste minimisation behaviour? Why?
6. According to your experience, do you think governmental supervision is significant when considering C&D waste minimisation behaviour? Why?
7. According to your experience, do you think project constraints are significant when considering C&D waste minimisation behaviour? Why?
8. What are the major difficulties and obstacles when implementing C&D waste management?
9. What suggestions would you provide to promote C&D waste management?

REFERENCES

Ajayi, S.O., Oyedele, L.O., Bilal, M., Akinade, O.O., Alaka, H.A., Owolabi, H.A., Kadiri, K.O., 2015. Waste effectiveness of the construction industry: Understanding the impediments and requisites for improvements. Resources, Conservation and Recycling 102, 101-112.

Ajzen, I., 1985. From Intentions to Actions: A Theory of Planned Behavior, in: Kuhl, J., Beckmann, J. (Eds.), Action Control. Springer Berlin Heidelberg, 11-39.

Ajzen, I., 1991. The theory of planned behavior. Organizational Behavior and Human Decision Processes 50 (2), 179-211.

Ajzen, I., 2006a. Attitude toward the behavior. <http://people.umass.edu/aizen/att.html> (9 January 2015).

Ajzen, I., 2006b. Intention. <http://people.umass.edu/aizen/int.html> (9 January 2015).

Ajzen, I., 2006c. Subjective norm <http://people.umass.edu/aizen/sn.html> (9 January 2015).

Ajzen, I., Driver, B.L., 1991. Prediction of leisure participation from behavioral, normative, and control beliefs: An application of the theory of planned behavior. Leisure Sciences 13 (3), 185-204.

Al-Sari, M.I., Al-Khatib, I.A., Avraamides, M., Fatta-Kassinos, D., 2012. A study on the attitudes and behavioural influence of construction waste management in occupied Palestinian territory. Waste Management &

Research 30 (2), 122-136.

Armitage, C.J., Conner, M., 2001. Efficacy of the theory of planned behaviour: A meta-analytic review. British Journal of Social Psychology 40, 471-499.

Baldwin, A., Poon, C.S., Shen, L.Y., Austin, S., Wong, I., 2009. Designing out waste in high-rise residential buildings: Analysis of precasting methods and traditional construction. Renewable Energy 34 (9), 2067-2073.

Bamberg, S., Ajzen, I., Schmidt, P., 2003. Choice of travel mode in the theory of planned behavior: The roles of past behavior, habit, and reasoned action. Basic and applied social psychology 25 (3), 175-187.

Beck, L., Ajzen, I., 1991. Predicting dishonest actions using the theory of planned behavior. Journal of research in personality 25 (3), 285-301.

Begum, R.A., Siwar, C., Pereira, J.J., Jaafar, A.H., 2009. Attitude and behavioral factors in waste management in the construction industry of Malaysia. Resources Conservation and Recycling 53 (6), 321-328.

Berdie, D.R., 1989. Reassessing the value of high response rates to mail surveys. Marketing Research 1 (3), 52-64.

Boynton, P.M., 2004. Hands-on guide to questionnaire research: Administering, analysing, and reporting your questionnaire. BMJ: British Medical Journal 328 (7452), 1372-1375.

Budd, R.J., North, D., Spencer, C., 1984. Understanding seat-belt use - A test of bentler and speckart extension of the theory of reasoned action. European Journal of Social Psychology 14 (1), 69-78.

Carmen Neipp, M., Jose Quiles, M., Leon, E., Tirado, S., Rodriguez-Marin, J., 2015. Applying the Theory of Planned Behavior: Which factors influence on doing physical exercise? Atencion Primaria 47 (5), 287-293.

Chang, M.K., 1998. Predicting unethical behavior: A comparison of the theory of reasoned action and the theory of planned behavior. Journal of business ethics 17 (16), 1825-1834.

Chen, M., Blanc, D., Gautier, M., Mehu, J., Gourdon, R., 2013. Environmental and technical assessments of the potential utilization of sewage sludge ashes (SSAs) as secondary raw materials in construction. Waste Management 33 (5), 1268-1275.

Chen, Z., Li, H., Wong, C.T.C., 2003. Webfill before landfill: an e-commerce model for waste exchange in Hong Kong. Construction Innovation: Information, Process, Management 3 (1), 27-43.

Cheng, C.-F., Chen, L.H., Chen, M.-Y., Lu, W.-C., 2012. Fan participation behaviour in baseball: An application of the theory of planned behaviour. International Journal of Sports Marketing & Sponsorship 14 (1), 22-33.

Chiang, Y.H., Chan, E.H.W., Lok, L.K.L., 2006. Prefabrication and barriers to entry - a case study of public housing and institutional buildings in Hong Kong. Habitat International 30 (3), 482-499.

Chow, L.K., 2005. Incorporating fuzzy membership functions and gap analysis concept intoperformance evaluation of engineering consultants: Hong Kong study. The University of Hong Kong, Hong Kong.

Chu, P.Y., Chiu, J.F., 2003. Factors influencing household waste recycling behavior: Test of an integrated Model1. Journal of Applied Social Psychology 33 (3), 604-626.

Cochran, K.M., Townsend, T.G., 2010. Estimating construction and demolition debris generation using a materials flow analysis approach. Waste Management 30 (11), 2247-2254.

Coelho, A., de Brito, J., 2013. Economic viability analysis of a construction and demolition waste recycling plant in Portugal - part I: location, materials, technology and economic analysis. Journal of Cleaner Production 39, 338-352.

Comrey, A.L., Lee, H.B., 2013. A first course in factor analysis. Hillsdale: Psychology Press.

Conner, M., Armitage, C.J., 1998. Extending the theory of planned behavior: A review and avenues for further research. Journal of Applied Social Psychology 28 (15), 1429-1464.

Conner, M., Norman, P., Bell, R., 2002. The theory of planned behavior and healthy eating. Health psychology 21 (2), 194.

Cordano, M., Frieze, I.H., 2000. Pollution reduction preferences of US environmental managers: Applying Ajzen's theory of planned behavior. Academy of Management journal 43 (4), 627-641.

Dahlén, L., Lagerkvist, A., 2010. Pay as you throw: Strengths and weaknesses of weight-based billing in household waste collection systems in Sweden.

Waste Management 30 (1), 23-31.

De Vaus, D.A., De Vaus, D., 2001. Research design in social research. London: Sage.

DeVellis, R.F., 2012. Scale development: Theory and applications. Newbury Park: Sage.

Dillman, D.A., 1978. Mail and telephone surveys: The total design method. New York: John Wiley & Sons.

Droba, D., 1931. Methods used for measuring public opinion. American Journal of Sociology, 410-423.

Fatta, D., Papadopoulos, A., Avramikos, E., Sgourou, E., Moustakas, K., Kourmoussis, F., Mentzis, A., Loizidou, M., 2003. Generation and management of construction and demolition waste in Greece - an existing challenge. Resources Conservation and Recycling 40 (1), 81-91.

Fishbein, M., 1967. Attitude and the prediction of behaviour. New York: John Wiley & Sons.

Fishbein, M., Ajzen, I., 1975. Belief, attitude, intention and behavior: An introduction to theory and research. Reading, MA: Addison-Wesley.

Fishbein, M., Ajzen, I., Hinkle, R., 1980. Predicting and understanding voting in American elections: Effects of external variables. Understanding attitudes and predicting social behavior, 173-195.

Formoso, C.T., Soibelman, L., De Cesare, C., Isatto, E.L., 2002. Material waste in building industry: Main causes and prevention. Journal of Construction

Engineering and Management 128 (4), 316-325.

Fowler, F., 1995. Improving survey questions: design and evaluation. Thousand Oaks, CA: Sage.

George, J.F., 2004. The theory of planned behavior and Internet purchasing. Internet research 14 (3), 198-212.

Godin, G., Kok, G., 1996. The theory of planned behavior: A review of its applications to health-related behaviors. American journal of health promotion 11 (2), 87-98.

Guagnano, G.A., Stern, P.C., Dietz, T., 1995. Influences on attitude-behavior relationships a natural experiment with curbside recycling. Environment and behavior 27 (5), 699-718.

Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E., Tatham, R.L., 2006. Multivariate data analysis. Upper Saddle River, NJ: Pearson Prentice Hall.

Han, H., Hsu, L.T.J., Sheu, C., 2010. Application of the theory of planned behavior to green hotel choice: Testing the effect of environmental friendly activities. Tourism Management 31 (3), 325-334.

Hao, J.L., Hills, M.J., Shen, L.Y., 2008. Managing construction waste on-site through system dynamics modelling: the case of Hong Kong. Engineering, Construction and Architectural Management 15 (2), 103-113.

Hashimoto, S., Tanikawa, H., Moriguchi, Y., 2009. Framework for estimating potential wastes and secondary resources accumulated within an economy - A case study of construction minerals in Japan. Waste Management 29

(11), 2859-2866.

Hassan, S.H., Aziz, H.A., Adlan, M.N., Johari, I., 2015. The causes of waste generated in Malaysian housing construction sites using site observations and interviews. International Journal of Environment and Waste Management 15 (4), 295-308.

Hauser, B.K., Koontz, T.M., Bruskotter, J.T., 2012. Volunteer participation in collaborative watershed partnerships: Insights from the Theory of Planned Behaviour. Journal of Environmental Planning and Management 55 (1), 77-94.

Hendricks, S.J.H., 1988. Preventive dental-health behavior intention prediction - The theory of reasoned action. Journal of Dental Research 67 (4), 784-784.

Henson, R.K., 2001. Understanding internal consistency reliability estimates: A conceptual primer on coefficient alpha. Measurement and evaluation in counseling and development 34 (3), 177.

HKEPD, 2013. Construction waste. <http://www.epd.gov.hk/epd/misc/cdm/introduction.htm#> (8 December 2013).

HKEPD, 2014. Monitoring of solid waste in Hong Kong - waste statistics for 2012. <https://www.wastereduction.gov.hk/en/materials/info/msw2012.pdf> (19 October 2014).

HKEPD, 2015. An overview on challenges for waste reduction and management in Hong Kong.

<http://www.epd.gov.hk/epd/english/environmentinhk/waste/waste_main content.html> (7 November 2015).

Hollnagel, E., 1993. Human reliability analysis: Context and control. London: Academic Press.

Hrubes, D., Ajzen, I., Daigle, J., 2001. Predicting hunting intentions and behavior: An application of the theory of planned behavior. Leisure Sciences 23 (3), 165-178.

Jones, R.E., 1989. Understanding paper recycling in an institutionally supportive setting: An application of the theory of reasoned action. Journal of Environmental Systems 19 (4), 307-321.

Kaplan, S., Manca, F., Nielsen, T.A.S., Prato, C.G., 2015. Intentions to use bike-sharing for holiday cycling: An application of the Theory of Planned Behavior. Tourism Management 47, 34-46.

Kim, J.-O., Mueller, C.W., 1978. Factor analysis: Statistical methods and practical issues. London: Sage.

Knoeri, C., Binder, C.R., Althaus, H.J., 2011. Decisions on recycling: Construction stakeholders' decisions regarding recycled mineral construction materials. Resources Conservation and Recycling 55 (11), 1039-1050.

Kokemuller, N., Media, D., 2015. The advantages of a focus group as a method for gathering data for customers. <http://smallbusiness.chron.com/advantages-focus-group-method-gathering-data-customers-17759.html> (16 March 2015).

Kourmpanis, B., Papadopoulos, A., Moustakas, K., Stylianou, M., Haralambous, K.J., Loizidou, M., 2008. Preliminary study for the management of construction and demolition waste. Waste Management & Research 26 (3), 267-275.

Lage, I.M., Abella, F.M., Herrero, C.V., Ordonez, J.L.P., 2010. Estimation of the annual production and composition of C&D Debris in Galicia (Spain). Waste Management 30 (4), 636-645.

Lau, H.H., Whyte, A., Law, P.L., 2008. Composition and characteristics of construction waste generated by residential housing project. International Journal of Environmental Research 2 (3), 261-268.

Lee, K.L.G., 2009. Sustainable urban renewal model for a high density city: Hong Kong. The Hong Kong Polytechnic University.

Li, J., Tam, V.W.Y., Zuo, J., Zhu, J., 2015. Designers' attitude and behaviour towards construction waste minimization by design: A study in Shenzhen, China. Resources, Conservation and Recycling 105, Part A, 29-35.

Li, M., Yang, J., 2014. Critical factors for waste management in office building retrofit projects in Australia. Resources, Conservation and Recycling 93, 85-98.

Lingard, H., Graham, P., Smithers, G., 2000. Employee perceptions of the solid waste management system operating in a large Australian contracting organization: implications for company policy implementation. Construction Management and Economics 18 (4), 383-393.

Liska, A.E., 1984. A Critical-examination of the causal-structure of the Fishbein-Ajzen Attitude-Behavior Model. Social Psychology Quarterly 47 (1), 61-74.

Llatas, C., 2011. A model for quantifying construction waste in projects according to the European waste list. Waste Management 31 (6), 1261-1276.

Loken, B., 1983. The theory of reasoned action - Examination of the sufficiency assumption for a television viewing behavior. Advances in Consumer Research 10, 100-105.

Lu, W.S., Yuan, H.P., 2010. Exploring critical success factors for waste management in construction projects of China. Resources Conservation and Recycling 55 (2), 201-208.

Lu, W.S., Yuan, H.P., 2011. A framework for understanding waste management studies in construction. Waste Management 31 (6), 1252-1260.

Lu, W.S., Yuan, H.P., Li, J.R., Hao, J.J.L., Mi, X.M., Ding, Z.K., 2011. An empirical investigation of construction and demolition waste generation rates in Shenzhen city, South China. Waste Management 31 (4), 680-687.

Lynne, G.D., Casey, C.F., Hodges, A., Rahmani, M., 1995. Conservation technology adoption decisions and the theory of planned behavior. Journal of economic psychology 16 (4), 581-598.

Manstead, A.S.R., Proffitt, C., Smart, J.L., 1983. Predicting and understanding mothers infant-feeding intentions and behavior - Testing the theory of reasoned action. Journal of Personality and Social Psychology 44 (4), 657-

671.

McBean, E.A., Fortin, M.H.P., 1993. A forecast model of refuse tonnage with recapture and uncertainty bounds. Waste Management & Research 11 (5), 373-385.

Mendis, D., Hewage, K.N., Wrzesniewski, J., 2013. Reduction of construction wastes by improving construction contract management: a multinational evaluation. Waste Management & Research 31 (10), 1062-1069.

Moan, I.S., Rise, J., 2005. Quitting smoking: Applying an extended version of the theory of planned behavior to predict intention and behavior. Journal of Applied Biobehavioral Research 10 (1), 39-68.

MOC, 2013. Regulation of Municipal Construction and Demolition Waste Managment. <http://baike.baidu.com/view/436142.htm#1> (19 Augstust 2013).

Nelson, A., Modeste, N.N., Marshak, H.H., Hopp, J.W., 2014. Using the theory of planned behavior to predict infant restraint use in Saudi Arabia. Saudi Medical Journal 35 (9), 959-966.

Nitivattananon, V., Borongan, G., 2007. Construction and demolition waste management: current practices in Asia, Proceedings of the International Conference on Sustainable Solid Waste Management, 5-7.

Norman, P., Armitage, C.J., Quigley, C., 2007. The theory of planned behavior and binge drinking: Assessing the impact of binge drinker prototypes. Addictive Behaviors 32 (9), 1753-1768.

Novick, G., 2008. Is there a bias against telephone interviews in qualitative research? Research in nursing & health 31 (4), 391-398.

Opdenakker, R., 2006. Advantages and disadvantages of four interview techniques in qualitative research. <http://www.qualitative-research.net/index.php/fqs/article/view/175/392> (14 November 2015).

Osmani, M., Glass, J., Price, A.D.F., 2008. Architects' perspectives on construction waste reduction by design. Waste Management 28 (7), 1147-1158.

Ouyang, J.L., Lu, M.J., Li, B., Wang, C.Y., Hokao, K., 2011. Economic analysis of upgrading aging residential buildings in China based on dynamic energy consumption and energy price in a market economy. Energy Policy 39 (9), 4902-4910.

Pakpour, A.H., Zeidi, I.M., Emamjomeh, M.M., Asefzadeh, S., Pearson, H., 2014. Household waste behaviours among a community sample in Iran: An application of the theory of planned behaviour. Waste Management 34 (6), 980-986.

Pallant, J., 2007. SPSS survival manual: A step-by-step guide to data analysis using SPSS version 15. Maidenhead, Berkshire, England: McGraw-Hill Education.

Peng, C.L., Scorpio, D.E., Kibert, C.J., 1997. Strategies for successful construction and demolition waste recycling operations. Construction Management and Economics 15 (1), 49-58.

Poon, C.S., 1997. Management and recycling of demolition waste in Hong Kong.

Waste Management & Research 15 (6), 561-572.

Poon, C.S., Yu, A.T.W., Ng, L.H., 2001. On-site sorting of construction and demolition waste in Hong Kong. Resources, Conservation and Recycling 32 (2), 157-172.

Poon, C.S., Yu, A.T.W., See, S.C., Cheung, E., 2004. Minimizing demolition wastes in Hong Kong public housing projects. Construction Management and Economics 22 (8), 799-805.

Quested, T.E., Marsh, E., Stunell, D., Parry, A.D., 2013. Spaghetti soup: The complex world of food waste behaviours. Resources, Conservation and Recycling 79, 43-51.

Rodriguez, G., Alegre, F.J., Martinez, G., 2007. The contribution of environmental management systems to the management of construction and demolition waste: The case of Autonomous Community of Madrid (Spain). Resources Conservation and Recycling 50 (3), 334-349.

Russo, R., 2004. Statistics for the behavioural sciences: An introduction. New York: Psychology Press.

Salant, P., Dillman, I., Don, A., 1994. How to conduct your own survey. New York: John Wiley & Sons.

Schifter, D.E., Ajzen, I., 1985. Intention, perceived control, and weight loss: An application of the theory of planned behavior. Journal of Personality and Social Psychology 49 (3), 843.

Sejwacz, D., Ajzen, I., Fishbein, M., 1980. Predicting and understanding weight loss: Intentions, behaviors, and outcomes. Understanding attitudes and predicting social behavior, 101-112.

Shen, L.Y., Tam, V.W.Y., Tam, C.M., Drew, D., 2004. Mapping approach for examining waste management on construction sites. Journal of Construction Engineering and Management 130 (4), 472-481.

Sheppard, B.H., Hartwick, J., Warshaw, P.R., 1988. The theory of reasoned action: A meta-analysis of past research with recommendations for modifications and future research. Journal of Consumer Research, 325-343.

Shi, J.G., Xu, Y.Z., 2006. Estimation and forecasting of concrete debris amount in China. Resources Conservation and Recycling 49 (2), 147-158.

Shimp, T.A., Kavas, A., 1984. The theory of reasoned action applied to coupon usage. Journal of Consumer Research 11 (3), 795-809.

Sito, P., 2014. China to lead growth in construction spending in Asia. <http://www.scmp.com/property/international/article/1494304/china-lead-growth-construction-spending-asia> (24 August 2014).

Solis-Guzman, J., Marrero, M., Montes-Delgado, M.V., Ramirez-De-Arellano, A., 2009. A Spanish model for quantification and management of construction waste. Waste Management 29 (9), 2542-2548.

Sun, M., Geelhoed, E., Caleb-Solly, P., Morrell, A., 2015. Knowledge and attitudes of small builders toward sustainable homes in the UK. Journal of Green Building 10 (2), 215-233.

Tam, V.W.Y., 2008. On the effectiveness in implementing a waste-management-plan method in construction. Waste Management 28 (6), 1072-1080.

Tam, V.W.Y., Shen, L.Y., Tam, C.M., 2007a. Assessing the levels of material wastage affected by sub-contracting relationships and projects types with their correlations. Building and Environment 42 (3), 1471-1477.

Tam, V.W.Y., Tam, C.M., 2006. A review on the viable technology for construction waste recycling. Resources Conservation and Recycling 47 (3), 209-221.

Tam, V.W.Y., Tam, C.M., Zeng, S.X., Ng, W.C.Y., 2007b. Towards adoption of prefabrication in construction. Building and Environment 42 (10), 3642-3654.

Udawatta, N., Zuo, J., Chiveralls, K., Zillante, G., 2015. Attitudinal and behavioural approaches to improving waste management on construction projects in Australia: Benefits and limitations. International Journal of Construction Management 15 (2), 137-147.

USEPA, 2013a. Basic information. <http://www.epa.gov/osw/nonhaz/industrial/cd/basic.htm> (19 August 2013).

USEPA, 2013b. Construction & demolition materials. <http://www.epa.gov/osw/nonhaz/industrial/cd/index.htm> (19 August 2013).

USEPA, 2013c. Estimating 2003 building-related construction and demolition materials amounts. <http://www.epa.gov/wastes/conserve/imr/cdm/pubs/cd-meas.pdf> (19

August 2013).

Van Teijlingen, E., Hundley, V., 2001. The importance of pilot studies. Social research update (35), 1-4.

Wang, J., Li, Z., Tam, V.W.Y., 2015. Identifying best design strategies for construction waste minimization. Journal of Cleaner Production 92, 237-247.

Wang, J., Ritchie, B.W., 2012. Understanding accommodation managers' crisis planning intention: An application of the theory of planned behaviour. Tourism Management 33 (5), 1057-1067.

Wikipedi, 2015. 2015 Shenzhen landslide. <https://en.wikipedia.org/wiki/2015_Shenzhen_landslide> (20 January 2016).

Wimalasena, B.A.D.S., Ruwanpura, J.Y., Hettiaratchi, J.P.A., 2010. Modeling construction waste generation towards sustainability, Construction Research Congress 2010: Innovation for Reshaping Construction Practice, May 8, 2010 - May 10, 2010. American Society of Civil Engineers, Banff, AB, Canada, 1498-1507.

Wong, E.O.W., Yip, R.C.P., 2004. Promoting sustainable construction waste management in Hong Kong. Construction Management and Economics 22 (6), 563-566.

Wu, M., 2010. Questionnaire statistical analysis practice: SPSS operation and application. Chongqing: Chongqing University Press.

Wu, Z., 2012. Research on construction and demolition waste quantification and management strategies. Chongqing University.

Wu, Z., Fan, H., Liu, G., 2015a. Forecasting construction and demolition waste using gene expression programming. Journal of Computing in Civil Engineering 29 (5), 04014059.

Wu, Z., Shen, L., Yu, A.T.W., Zhang, X., 2015b. A comparative analysis of waste management requirements between five green building rating systems for new residential buildings. Journal of Cleaner Production (in press).

Wu, Z., Xiang, R., Liu, G., 2011. Minimization Management of Construction and Demolition Waste under Systemic View. Construction Economy 2, 101-104.

Wu, Z., Yu, A.T.W., Shen, L., Liu, G., 2014. Quantifying construction and demolition waste: An analytical review. Waste Management 34 (9), 1683-1692.

Wu, Z., Yu, A.T.W., Wei, Y., 2015c. Predicting Contractor's Behavior Toward Construction and Demolition Waste Management, Proceedings of the 19th International Symposium on Advancement of Construction Management and Real Estate. Springer, 869-875.

Xu, W., Zhou, M., Zhou, W., 2015. Construction waste a growing problem for China. <http://usa.chinadaily.com.cn/epaper/2015-12/25/content_22841451.htm> (25 December 2015).

Yang, Z., Becerik-Gerber, B., Mino, L., 2013. A study on student perceptions of higher education classrooms: Impact of classroom attributes on student satisfaction and performance. Building and Environment 70, 171-188.

Ye, G., Yuan, H.P., Shen, L.Y., Wang, H.X., 2012. Simulating effects of management measures on the improvement of the environmental performance of construction waste management. Resources Conservation and Recycling 62, 56-63.

Yeung, F.Y., 2007. Developing a partnering performance index (PPI) for construction projects: a Fuzzy Set Theory approach. The Hong Kong Polytechnic University.

Yost, P.A., Halstead, J.M., 1996. A methodology for quantifying the volume of construction waste. Waste Management & Research 14 (5), 453-461.

Young, R.A., Kent, A.T., 1985. Using the theory of reasoned action to improve the understanding of recreation behavior. Journal of Leisure Research 17 (2), 90-106.

Yuan, H.P., Shen, L.Y., 2011. Trend of the research on construction and demolition waste management. Waste Management 31 (4), 670-679.

Zhang, X., Wu, Z., Feng, Y., Xu, P., 2014. "Turning green into gold": A framework for energy performance contracting (EPC) in China's real estate industry. Journal of Cleaner Production (in press).

Zhao, W., Leeftink, R.B., Rotter, V.S., 2010. Evaluation of the economic viability for the recycling of construction and demolition waste in China-The case of Chongqing. Resources Conservation and Recycling 54 (6), 377-389.