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PUBLIC POLICY RESEARCH FUNDING SCHEME

FINAL REPORT

Project Title:

(English) **Strategies and Measures for Construction and Demolition Waste Management of Refurbishing/Renovating Existing Buildings in Hong Kong**

(Chinese) 香港既有建築修繕/改造中的建築垃圾管理策略及措施研究

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Executive Summary (in English)

Part A - Abstract

The construction industry is the major source of solid waste in Hong Kong. The capacity of landfills will reach saturation in 2020s. Renovation and refurbishment projects contribute 10 to 20% of the construction and demolition waste. There are over 5,000 buildings in Hong Kong that are over 30 years old and may require extensive refurbishment under the Mandatory Building Scheme. Besides, most new owners/tenants will renovate their premises before moving in. There is an urgent need to explore strategies and measure for developing effective construction and demolition waste management of refurbishment/renovation projects in Hong Kong. This study aimed to investigate the generating process of refurbishment and renovation waste in order to identify the types and estimate the amount of refurbishment and renovation waste; to identify the best practices promoting and the perceived barriers to refurbishment and renovation waste management in Hong Kong; and develop effective strategies and measures for minimizing and managing refurbishment and renovation waste particularly for the private sector.

Literature review, semi-structured interviews, site observations and document reviews were used to collect data for analysis. The research was carried out in five stages: (i) Research Design, (ii) Data Collection, (iii) Data Analysis, (iv) Strategy Development, and (v) Dissemination of Research Findings.

Key Research Findings

Six strategies and measures for management of refurbishment and renovation wastes were derived from research findings, which was presented to building professionals, contractors, recycling contractor, scholars and government officials in a focus group meeting to collect their comments. The six strategies and measures were refined according to their comments, which are (a) Pre-refurbishment Audit, (b) Development of Recycling Market, (c) Sea Reclamation, (d) Incineration, (e) Incentive and (f) Education and Research.

Part B – Layman Summary on Policy Implications and Recommendations

The world is facing the problems of depletion of natural resources and environmental pollution. Construction industry disposed an average of about **4,000 tonnes** of construction and demolition waste at landfills per day in 2017. **10 to 20%** of the waste comes from refurbishment and renovation of existing buildings. Parts of the waste such as metal, timber and glass can be recycled and manufactured into useful products. Reuse and recycling can save natural resources and reduce pollution. The research team have carried detail investigation on the processes of refurbishment/renovation projects to identify the difficulties in reducing waste generated from refurbishment and renovation. The research arrived at six potential strategies and measures to reduce refurbishment/renovation waste. After consultation with building professionals, building contractor, recycling contractors, scholars and government officials, the six proposals were refined and recommended to the Government for promoting effective refurbishment/renovation waste management in Hong Kong. The proposed strategies and the benefits to the society are listed as follows:

a) Pre-refurbishment Audit

The aim of pre-refurbishment audit is to retrieve reusable/recyclable building materials from the building during dismantling work. The contractor will check and record down what type and anticipated quantity of building materials that can be recovered for reuse/recycling before commencement of renovation work. The contractor will then dismantle the existing finishes and fittings step by step in order to sort out the items that are planned to be reused/recycled. The recyclable items will be sold to recycling contractors. The saving in cost will be shared between the contractor and the workers. If the amount of sorted recyclable materials is less than the planned, the contractor will be penalized. Pre-refurbishment audit can create incentive for contractors to sort out the recyclable waste, thus reducing consumption of natural resources and amount of waste to be disposed at landfills.

Government can develop guidelines for carrying out pre-refurbishment audit and take the lead to include pre-refurbishment audit in public projects to set up an example for private projects to follow.

b) Development of Recycling Market

Concrete, timber, metal and glass wastes generated from refurbishment and renovation work can be recycled for use. However, the local recycle market is immature lacking the technologies and market to facilitate the development of recycling market. Currently only metal can be sold for recycling. Others will be disposed of as their sale values are low and difficult to be cleaned for recycling. Government should study how to facilitate the development of local recycling business such as allotting research funding to universities or other organizations for developing innovative technologies to cleanse or prepare concrete, timber and glass (in addition to metal) suitable for recycling. Government can consider establishing a labelling system standardizing the quality of products manufactured from recycling materials, which can provide confidence on the qualities of recycled products to potential buyers.

c) Sea Reclamation

The non-decomposable components of refurbishment/renovation waste such as crushed concrete can be used as filling materials in reclamation. The Lantau Tomorrow Project will create a third core business district covering 1,700 hectares of artificial islands through massive land reclamation near Kau Yi Chau and Hei Ling Chau of the eastern waters of Lantau Island. The filling material, sea sand will be bought from Mainland. The cost of sea sand is very expensive, which is estimated to be more than 160 billion dollars. Inert waste from refurbishment/renovation projects can be utilized in reclamation project for constructing urban open areas and recreational facilities, thus reducing construction cost. However, construction sites are usually too congested to carry out labour and time consuming waste sorting. Contractors are reluctant to carry out on-site sorting due to high operating cost and may causing delay to the project. Government can create more off-site public sorting facilities preferably near landfills or consider providing financial and technical support to private-operated sorting facilities.

d) Incineration

Incineration is a reliable technology that can reduce the volume of solid waste by combustion and generate electricity at the same time. The volume of refurbishment/renovation waste can be reduced by incineration, which occupies less landfill spaces. Alternatively, the ash can be used as a cement additive or as concrete aggregate in road construction. Metal can be recovered from ashes for recycling. Government should consider to develop long-term incineration plan and extend the list of incinerable materials to cover refurbishment/renovation waste as well as offering financial incentive to contractors who sort out the combustible waste to incinerators.

e) Incentive

Good reputation is a valuable asset of a company and can act as an effective advertisement to the public. Government can improve waste management in refurbishment and renovation projects by introducing an annual “Sustainable Refurbishment and Renovation Award” to contractors who have successfully achieved in reducing refurbishment/renovation waste to a specified level.

f) Education and Research

Government can assist contractor associations to train up skillful recycler workers. The public should be educated the importance of building maintenance, and the advantages of recycling and incinerating refurbishment/renovation waste in protecting our environment making it a safe and healthy place to live in for us and our generations after. Government should set aside funding for carrying out research to explore or improve the technologies of recycling construction waste. The funding is recommended to be open for academia and public application.

Executive Summary (in Chinese)

第一部分 – 研究摘要

建造業是香港固體廢物的主要來源。垃圾堆填區的容量將在 10 年內達到飽和狀態。翻新和裝修項目佔整體拆建廢料的 10%至 20%。香港現時擁有超過 5,000 座已擁有 30 年曆史的樓宇。惟根據屋宇署的強制性驗樓計劃，這類建築可能需要進行大規模翻新及改造。此外，大多數新業主或租客在入伙新居之前都會對其房屋進行翻新或裝修。因此，為了發展香港現時翻新及裝修（翻修）項目的有效拆建廢料管理，有關策略和措施的研究已是迫在眉睫。這項研究旨在調查翻修廢物的產生過程，以便判斷翻修廢物的類型並估計其數量；找出推廣香港翻修廢物管理的最佳做法，以及實踐翻修廢物管理時所遇到的障礙；最後，製定相關的戰略和措施，以減少和管理在私人市場產生的翻修廢物。

本研究使用文獻綜述，半結構化訪談，現場觀察和文獻綜述來收集數據以便進行分析。該研究分五個階段進行：（i）研究設計，（ii）數據收集，（iii）數據分析，（iv）策略制定和（v）宣傳研究結果。

主要研究結果

這次研究結果總結出了用於管理翻修廢物的六種策略和措施，並在焦點小組會議上咨詢了建築專業人士，承建商，回收承建商，學者和政府官員對這些策略和措施的意見。其後，根據他們的意見完善了這六項策略和措施，分別是（a）翻新前審查，（b）發展市場，（c）填海，（d）焚化，（e）激勵和（f）教育和研究。

第二部分 - 政策概述和相關政策建議

世界正面臨自然資源枯竭和環境污染的問題。 2017 年，建築行業平均每天在垃圾堆填區棄置約 **4000 公噸**拆建廢料。**10%至 20%**的廢料來自對現有建築物的翻新。這些廢料的一部分，例如金屬，木材和玻璃，可以回收再利用，製成有用的產品。這樣可以節省自然資源並減少環境污染。研究團隊對翻修項目的施工過程進行了詳細的調查，以確定減少翻修廢物的困難。研究得出了六種潛在的策略和措施，以減少翻修廢物的棄置。經與建築專業人士，承建商，回收承建商，學者和政府官員協商後，研究團隊對這六項建議進行了完善，並向以此向政府進諫，務求促進香港有效的翻修廢物管理。建議的策略和對社會的好處如下：

a) 翻新前審查

翻新前審查的目的是在拆除工作時從建築物中檢索可再利用/回收的建築材料。承建商將在翻修工程開始之前檢查並記錄可再利用/回收的建築材料的類型和預期數量。然後，承

建商將逐步拆除現有的飾面和配件，並篩選出計劃再利用/回收的材料。可回收材料將出售給回收承建商。因此節省的成本將由承建商和工人共同分享。如果實際可回收材料的數量少於預期數量，承建商將受到處罰。翻新前的審查可以促使承建商篩選出可再利用/回收的廢物，從而減少自然資源的消耗及減少垃圾堆填場的處置量。政府可以協助製定翻新前審查的指南，並率先將翻新前審查納入公營項目，以作為後續私人項目的參考。

b) 發展回收市場

翻修工程產生的碎石料，木材，金屬和玻璃廢料可以回收及再利用。 但是，本地的回收市場還不成熟，缺乏促進回收市場發展的技術和市場。 目前只有金屬能出售及進行回收。其他的廢料將被棄置，因為它們的商業價值低並且難以清潔以作回收。 政府應研究如何促進本地回收業務的發展，例如向大學或其他組織分配研究資金，以開發創新技術來清潔或製備適合回收的混凝土，木材和玻璃（金屬除外）。 政府可以考慮建立一個標籤制度，以標準化由回收材料製成的產品的質量，這可以增加潛在購買者對回收產品質量的信心。

c) 填海

一些不可分解的翻修廢料，例如碎混凝土，可以用作填海工程的填充材料。 “明日大嶼”計劃通過填海，在大嶼山東部水域附近的交椅洲和喜靈洲興建一個覆蓋 1,700 公頃的人工島作為第三個核心商業區。 海砂作為填充材料將會從內地購買。但是海砂的成本非常昂貴，預計超過 1600 億港幣。翻修項目產生的廢物可用於填海工程從而降低建設成本。惰性翻修廢物可用於填充公眾休憩區域和娛樂設施。然而，建築工地通常過於擁擠，以至於無法進行需要大量勞動力和費時的廢物分類。由於高昂的運營成本以及可能導致工程延誤，承建商通常不願進行現場廢物分揀。政府可以在垃圾堆填場附近建立更多的公營廢物分類設施，或者考慮為私營分類設施提供財務和技術支援。

d) 焚化

焚化是一項非常可靠的技術，它可以透過燃燒減少固體廢物體積的同時發電。 焚化可減少翻修廢物的數量以減少佔用垃圾堆填區的空間。 除此之外，爐灰可以用作水泥添加劑或用作道路建設中的混凝土骨料。 與此同時，承建商可以從爐灰中回收金屬進行回收。政府應考慮制定長期焚燒計劃，並擴大可焚化材料的清單以涵蓋翻修廢物，並向對可焚燒廢物進行分類的承包商提供經濟激勵。

e) 激勵

良好的聲譽是企業寶貴的資產，它可以作為面對公眾最有效的廣告。 政府可以透過向成功減少翻修廢物至指定水平的承建商頒發年度“可持續翻新和裝修獎”，從而改善翻修項目中的廢物管理。

f) 教育與研究

政府可協助承建商協會培訓熟手的回收工人，亦可教育市民有關建築物維護的重要性以及回收和焚化翻修廢物在保護環境方面的優勢，提供我們和我們子孫後代安全健康生活的地方。 政府可撥出資金進行研究，以探索或改善現時建築垃圾的回收及再利用技術。 建議將撥款開放給學術界和公眾使用。

Chapter 1 Introduction

Hong Kong is one of the world's leading business centers. The population is more than 7.4 millions living in about 1,107 square kilometers with a high population density of 6,830 people per square kilometer (Information Services Department, 2017). As the city continues to expand, enormous amounts of natural resources were consumed by the construction industry and generating a significant quantity of C&D waste from both new construction and renovation contributing to environmental pollution. Reduction of construction and demolition (C&D) waste to landfill remains a seemingly insurmountable challenge. Several schemes and policies have already been introduced to promote more effective waste management, but there is still much that can be done to reduce the amount of waste being sent to the landfills. Exporting C&D waste to mainland China is undermined due to imposed tax and complicated procedures to obtain permits in transporting these materials. Furthermore, the existing recycling industry in Hong Kong is immature due to high capital cost and low profit. There has been increased pressure to resolve the increasing C&D waste problem through exploring more sustainable waste management practices.

The majority of the academic papers in C&D waste management focus mainly on new building construction without addressing specifically renovation and refurbishment (R&R) waste (Sáez et al., 2017). The findings of this study will help formulating corresponding R&R waste management policies to overcoming the barriers of low financial incentive due to the increasing overhead costs in waste reduction, which will eventually promote construction practitioners' attitudes and behavior towards proactive waste management. This study offers insights to establish strategies and measures to minimize R&R waste. For instance, providing appropriate on-site sorting can promote reuse and recycling of R&R waste in the private sector. The proposed strategies and measures arising from this study can help contractors to implement proper waste management plans as well as assisting professionals (particularly the BEAM Plus consultants and assessors) to carry out site inspections regularly for effective R&R waste reduction.

1.1 Background

Hong Kong is a city under constant expansions and improvements in buildings, bridges, railways, and other construction projects. In 2017, there are more than 42,000 existing buildings in Hong Kong. The majority of buildings have been in existence for more than 30 years. The number of residential and composite buildings aged 50 years and above are over 5,000 (Hong Kong Government, 2017). According to the Mandatory Building Inspection Scheme (MBIS), these buildings need to be demolished or renovated due to inadequate and improper maintenance which may leads to urban decay. Consequently, the forthcoming R&R projects will generate large amounts of construction waste in the building industry. Moreover, renovating existing buildings instead of redevelopment has become a popular alternative to maximize resource efficiency (Caccavelli & Gugerli, 2002). In order to achieve low-carbon living in the future, two objectives of Policy Address 2017 and 2018 focused on promoting the green culture of “Use less, Waste less” and “Dump Less, Save More, respectively (Hong Kong Government, 2017). The implementation of Construction and Demolition Waste Charging Scheme was imposed in 2005 (EPD, 2020), which had created the necessary financial incentives to reducing construction waste. The Environmental Protection Department (EPD) studies the long-term feasibility of controlling waste disposal by developing local recycling industry (Hong Kong Government, 2019).

In 2017, about 1.54 million tonnes of C&D waste was generated in Hong Kong, which had decreased by 4.9% comparing to 2016 (1.62 million tonnes) in total C&D generation. However, the percentage of disposed C&D waste at landfills increased from 6 % in 2016 to 7% in 2017(EPD, 2018). In recent years, reusing inert C&D waste has slightly increased by 2% amounting to 92% in 2017 (EPD, 2018). In order to reach world of sustainability, it is important to encourage building owners, designers and contractors who are involved in private R&R projects to adopt sustainable building design to facilitate R&R waste management.

1.2 Problem Statement

The majority of buildings over 30 years old need to be demolished or renovated. It is anticipated that considerable numbers of R&R project will commence in the near future. Large amounts of R&R waste will be produced. C&D waste is defined as waste, which generate from construction, renovation and demolition activities (Yuan et al., 2011). It is mainly composed of concrete, asphalt, wood, metals, gypsum wallboard, and roofing (Nitivattananon and Borongan, 2007). R&R waste is generally a hybrid of C&D waste, which is derived from improving and repairing of existing structures (Public Works and Government Services Canada, 2013).

Hong Kong, like other metropolitan cities, is facing a shortage of space for public fill and landfill capacity for C&D waste. Our landfills are expected to be saturated in the early 2020s, and public fill capacity will be depleted in the near future. In 2017, mixed construction waste has already accounted for about 27% of the total waste intake at the three existing landfills (EPD, 2018a). More public fill areas will be diverted to landfills if lacking effective waste reduction measures. In view of the shortage of landfills and reclamation sites, and the increasing numbers of aged buildings that require refurbishment in the next two decades, there is an urgent need to study the problems generated by R&R waste and derive solutions for these problems. The effectiveness of the current strategies and measures for reducing C&D waste should be evaluated covering the environmental, social and economic aspects (Yuan and Shen, 2011; Yuan, 2013 a & b).

1.3 Aim of the Study

This study aims to investigate thoroughly the current waste management practices for R&R works, to identify barriers and existing best practices in reducing R&R waste, and recommend strategies and measures to minimize the R&R waste particularly for the private sector.

1.4 Objectives of the Study

The specific objectives to achieve the research aim are as follows:

(1) To examine the type and amount of waste generated, and how waste is created during refurbishment/renovation work of existing buildings in Hong Kong;

(2) To identify the best practices promoting, and the perceived barriers hindering the management of waste reduction on refurbishment/renovation projects specifically in Hong Kong; and

(3) To develop effective strategies and measures likely to minimize and manage the C&D waste generated by refurbishment/renovation projects.

1.5 Research Methodology

Desktop study, semi-structured interviews, site observations and document reviews were used as the primary data collection methods to achieve the objectives of this research. The research was carried out in five stages: (a) Research Design, (b) Data Collection, (c) Data Analysis, (d) Strategy Development, and (e) Dissemination of Research Findings. Figure 1.5.1. illustrates the research processes to achieve the objectives and develop strategies.

Semi-structured interviews and site visits were conducted to supplement thematic analysis and content analysis were applied to analyze the collected data from interviews, site observations and documents provided by the participants in this research project. As for refinement and confirmation of the strategies and measures for C&D waste management and reduction, an in-depth focus group meeting was organized after data analysis in order to obtain views and insights on the preliminary strategies and measures from the building professionals.

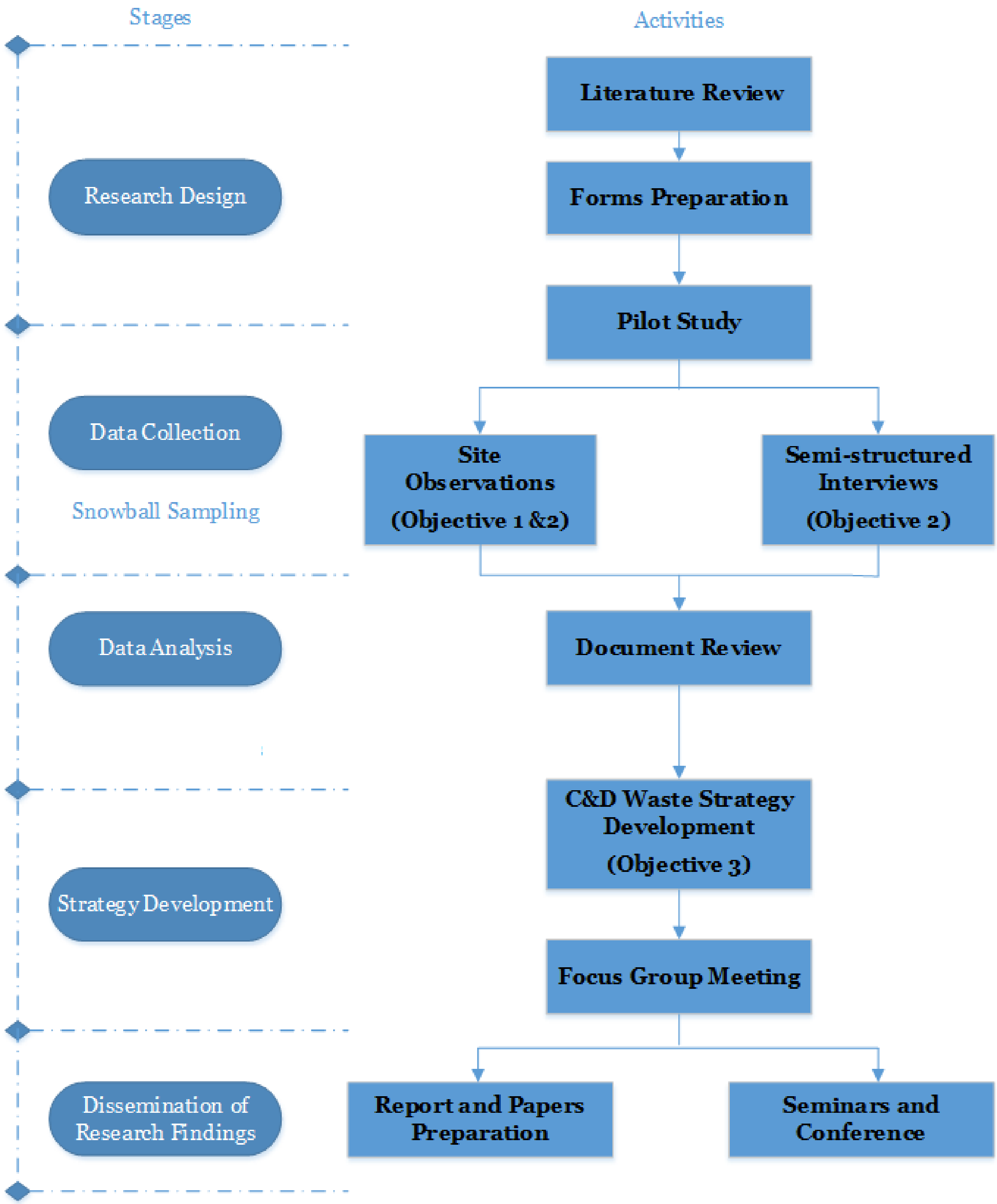

Figure 1.1 Research Framework

1.5.1 Research Design (Desktop Study)

The desktop study was carried out, which comprised three sub-processes as follows:

i. Literature review

At the early stage of the study, the objective of desktop study was to establish a theoretical foundation for the proposed research. Extensive literature review was conducted. Previous and related works in this topic were identified through content analysis of published papers, reports and books. All relevant study carried out by the PI and research staff were naturally included.

ii. Form Preparation

Interview guides and site observation forms were drafted based on literature review. Seven R&R projects were selected from acquainted owners or contractors ensuring consent to access relevant document could be obtained. The seven R&R projects covered different types of buildings including two public housing estates, one private single-block residential building, one government quarter, one institutional building, one religion building and one hospital building. The Waste Management Plans of these projects were analyzed to identify various types of R&R waste and the generation processes. The findings helped to refine the interview guidelines and site observation forms.

iii. Pilot Study

A pilot study of semi-structured interview was carried out with university academic staff to test the reliability and validity of the interview guides, which was finalized in this stage.

1.5.2 Data Collection

There are two processes in this stage for achieving Objective 1 and 2, which are (i) Semi-structured Interview and (ii) Site Observation.

i. Semi-structured Interview

A semi-structured interview is suitable to explore attitudes, values, beliefs and motives (Richardson et al., 1965; Smith, 1975). Semi-structured interviews with open-ended questions were conducted with developers, clients, designers, contractors, sub-contractors and scholars to collect comments from different stakeholders relating to R&R waste management based on the interview guidelines at Appendix A. The first part of interview was based on a set of established questions regarding to the basic information of the interviewed organizations, the undergoing R&R project, the implementation of waste management plan and different stakeholders were invited to share their recommendations on R&R waste reduction for Hong Kong. Permissions from interviewees were sought to access their relevant documents relating to waste management plan, records of the quantity and type of generated R&R waste, and R&R waste reduction practices. Considering the nature and characteristics of the industry structure, the snowball sampling process was deployed for data collection (Salganik and Heckathorn, 2004). The interviewees were asked to recommend other related/acquainted organizations (developers/clients, building designers, contractors, etc.) that were involved in R&R projects for further interviews until this snowball sampling discontinued.

ii. Site Observation

Site observation study was carried out aiming to identify the types of R&R waste generated, the generation processes, waste management practices on site, best practices to reduce R&R waste, and barriers to achieve effective waste management. Photographs were taken to record the site conditions, limitations in waste reduction arising from site condition, and best practices in R&R waste management. Site visits covered different types of buildings, which includes religious building, public residential housing, hospital, single residential building, government quarter, and educational institution.

1.5.3. Data Analysis

The collected data were subject to qualitative analysis by applying thematic analysis. Thematic analysis is one of the most common forms of analysis in qualitative research. It emphasizes **pinpoint**, examining and recording **patterns (or themes)** within data. Themes, which are recurring across data sets, are important to the description of a phenomenon and associated with a specific research question. Thematic analysis allows categories/codes to emerge from data (Saldana, 2009) and interpretation of themes supported by data (Guest, 2012).

Content analysis was used to quantify patterns in the transcribed interview scripts. Content analysis is a research method for the study of documents and communication artifacts, which can be **texts, pictures, audio or video**.

1.5.4. Strategy Development

1.5.4.1 R&R Waste Strategies Development

Waste management strategies and measures for R&R projects in Hong Kong were developed from reviewing the findings of desktop study, site observation, semi-structured interviews, oversea C&D/R&R waste management policies, and relevant documentations from the studied R&R projects. This stage covers Objective 3.

1.5.4.2. Focus Group Meeting

A focus group meeting of about 10 participants from building professionals (developers/clients, building designers, engineers, surveyors, contractors/subcontractors and end-users) and three scholars from academia was held. Participants were selected by convenient sampling from the PI's established network of contacts who were experienced in C&D waste management. The research team briefed the participants about the research findings and presented the list of proposed R&R waste management strategies for further discussion. Questions and responses were thoroughly understood and validated by repeating and rephrasing them, and picking non-verbal cues from participants. The discussion was recorded, transcribed and studied to identify core themes using thematic analysis (Morse, 1994). The research team would analyze the findings from focus group meeting in details and revise the proposed strategies and measures for R&R waste management accordingly.

1.6 Dissemination of Research Findings

The research findings will be summarized in two papers and will submit to international refereed journals for publication. A seminar will also held in due course (tentatively in May 2020) when the Novel Coronavirus epidemic has been declined.

Chapter 2 Refurbishment & Renovation – Definitions, Benefits and Barriers

As most of the research on waste management were conducted on new constructions, this chapter focused on differentiating R&R waste from C&D waste. The term "R&R waste" was defined. The benefits of refurbishing and renovating existing buildings in lieu of redevelopment were discussed with barriers to implementing R&R waste reduction and management were identified.

2.1 Definition of Refurbishment and Renovation

Shah (2012) categorized refurbishment into light touch, medium intervention, extensive intervention and comprehensive demolition and rebuild. In addition, Thorpe (2010) asserted that refurbishment could be in form of a holistic dwelling approach or a work-by-work regime to minimize the disturbance brought by refurbishment. The terms "refurbishment" and "renovation" are always interchangeable, however, they are slightly different relating to the purpose of activities.

Refurbishment is defined as the process of improving a building by decorating and cleaning it while adding new furniture, equipment, etc. It involves work such as repairing, painting and cleaning, undertaken to make a building look new again. Renovation is the process of improving a broken, damaged, or outdated structure. Renovations apply typically to residential units and buildings. In addition, renovation can refer to making something new, or bringing something back to life.

2.2 Types of R&R Projects

There are three main purposes for refurbishing and renovating existing buildings. Firstly, the R&R work changes the original function of the building, such as converting a historical building to a museum. Secondly, the building capacity is upgraded, for instance by adding extra floors to the original buildings. Thirdly, the performance of aged buildings can be upgraded with a fresh appearance by revitalization.

Furthermore, R&R Project types can be categorized according to the extent of works (Alfrendo, 2016), which refers to minor, medium and majors scale as shown in Table 2.1.

Table 2.1 Categorized R&R project types according to the extent of work.

	Minor	Medium	Major
Purpose	• Extend economic life	• Renew building structure and services to present day standards	• To secure the long-term benefits of existing building planning
Payback Period	• Normally 5 years	• Typically 10years	• At least 15 years
Scope of Work	• Often carried out in an occupied building, • Phasing working with a clear program is necessary • Confine to redecoration and repair work • Minimal alterations to building services	• Fittings, finishes and elements of building services will be replaced or upgraded by advance technologies • Limited structural alterations	• Meet modern expectations for specification and performance standards • All fittings, finishes and services will be replaced • May involve structural alterations

2.3 Definition of C&D and R&R Waste

According to Environmental Protection Department (EPD, 2018a), C&D waste is any substances which is produced from construction and then discarded, regardless of whether it has been processed or stored. It includes surplus materials generated from site clearance, excavation, construction, refurbishment, renovation, demolition and road works. R&R waste is a hybrid of C&D waste from improvements and repairs to existing structures (Public Works and Government Services Canada, 2013). It is mainly composed of concrete, asphalt, wood, metals, gypsum wallboard, furniture, electrical appliances and roofing (Nitivattananon and Borongan, 2007).

There are two types of construction waste, which are inert and non-inert construction waste. Non-inert construction waste accounts for about 10% of the total construction waste (EPD, 2018s) and usually includes bamboo, timber, vegetation, packaging waste and other organic materials. Some of non-inert waste can be recycled while others are disposed of in landfills. In contrast, inert waste is also known as public fill in Hong Kong including construction debris, rubble, earth, bitumen, cement and concrete, which can be used for land formation. Materials such as concrete and asphalt can be recovered for construction use.

2.4 Types of Waste Generated During R&R of Existing Buildings

This section introduces different types of C&D wastes from overseas official websites. Since R&R works are mostly a combination of new construction and demolition work (Coelho and Brito, 2011a), the classification of C&D waste from the official websites can be applied to R&R waste.

2.4.1 C&D Waste Classification in United States

The Environmental Protection Agency (EPA) of United States (US) supervises C&D waste management. According to the EPA official website, C&D waste is generated when new building and civil-engineering structures are built, and existing buildings and civil-engineering structures are renovated or demolished (including deconstruction activities) (EPA, 2019). Figure 2.1. illustrates the compositions of C&D materials, which are mainly concrete, wood, asphalt, gypsum, metals, bricks, glass, plastics, salvaged building components, trees, stumps, earth, and rocks (EPA, 2015).

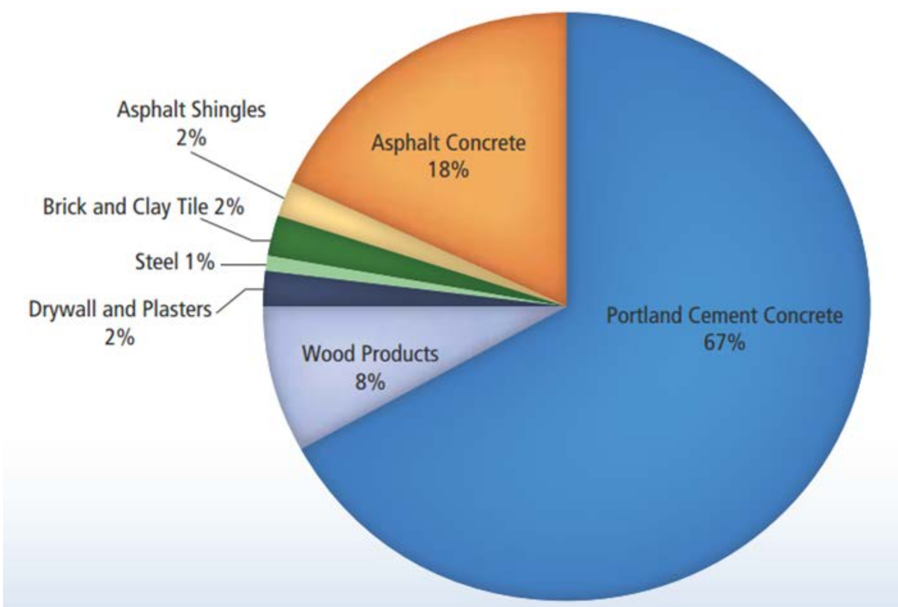

Figure 2.1 C&D waste composition in the United States, 2013 (EPA, 2015)

2.4.2 C&D Waste Classification in European Union

According to the European Commission (EC), C&D waste is regarded as 'one of the heaviest and most voluminous waste streams' in the European Union (EU) (EC, 2016). It was reported that C&D waste represents approximately 25-30% of all EU waste (EC, 2016). Compositions of C&D waste include concrete, bricks, gypsum, wood, glass, metals, plastic, solvents, asbestos and excavated soil, many of which can be recycled (EC, 2016).

2.4.3 C&D Waste Classification in Japan

The Japanese official websites do not classify C&D waste. Instead, the Japan Ministry of the Environment (JME) enacted a 'Construction Material Recycling Law' on May, 2000, which helped to maintain a very high rate of recycling (as shown in Figure 2.2.). This law requires contractors to sort and recycle the C&D waste. In addition, some specific construction materials, such as concrete, asphalt/concrete and wood building materials, etc., are recommended to be reused.

2.4.4 C&D Waste Classification in Singapore

The Singapore Building & Construction Authority (BCA) has defined C&D waste as the material resulting from the construction, alteration or demolition of buildings and other structures. It consists of a mixture of hardcore (concrete, masonry, bricks, tiles), reinforcement bars, dry walls, wood, plastic, glass, scrap iron and other metals, etc. (BCA, 2008). Different from Hong Kong, the earth excavated during foundation work is not included in "C&D waste" in Singapore. Steel re-bars, wood and glass waste are excluded from construction debris, and accounted under separate item headings called "Ferrous Metals", "Wood" and "Glass" respectively.

2.4.5 R&R Waste Classification in Canada

Metro Vancouver Regional District (MVRD) of Canada states that renovation wastes are responsible for 25 per cent of material generated from the building sector in Metro Vancouver. It identifies that the R&R wastes are usually generated from two phases, which are demolition and new construction. Table 2.2. lists the items that can be reused and/or recycled from demolition and renovation projects (Metro Vancouver, 2019).

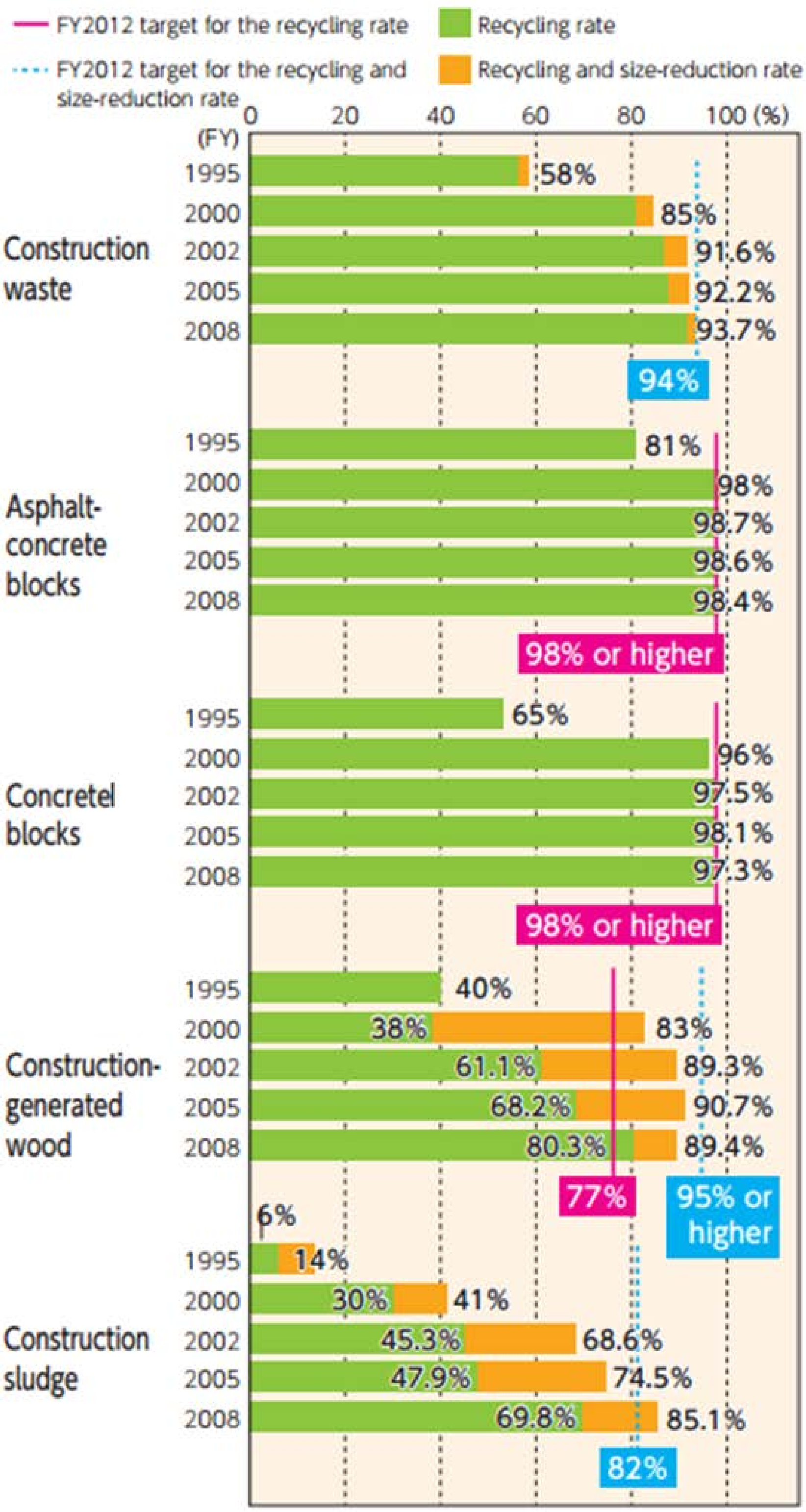

Figure 2.2 Construction waste recycling rate in Japan (JME, 2014)

Table 2.2 Reusable and recyclable items from renovation projects

Salvageable Building Materials	Recyclable Demolition Materials
Heavy timbers	Cinder blocks
Dimensional lumber	Structural concrete
Steel beams & studs	Asphalt pavement
Wainscoting	Dimensional lumber
Insulation	Metal piping
Siding	Gypsum wallboard
Heating ducts	Electrical cable
Electrical equipment	Aluminum siding
Bricks & blocks	Metal window frames
Light fixtures	Rebar
Plumbing fittings	Cement based stucco
Interior doors & frames	Metal deck railings

(Metro Vancouver, 2019)

2.4.6 Types of R&R wastes classification from academic papers

Summarizing from literature review on refurbishment and renovation topics "Concrete/Mortar", "Wood/Timber" "Iron/Steel" and "Glass" are the most common construction waste in R&R projects. Table 2.3 tabulates the findings from literature review.

Table 2.3 General Refurbishment and Renovation Construction Waste Type

	Bergsdal et al., 2007	Thorpe, 2010	Hardie et al., 2011	Coelho & Brito, 2011b	Appleby, 2011	Tischer, 2013	Mália et al., 2013	Ren, 2013	Balba et al., 2013	Hosseini, 2015	Lu et al., 2015	Villoria Sáez et al., 2016	Ghose et al., 2017	Yu et al., 2018	Tallini & Cedola, 2018
Inert Renovation Waste															
Brick/Tile	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
Bituminous mixtures						✓	✓	✓	✓	✓	✓				
Concrete/Mortar	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lime Sand		✓												✓	
Non-Inert Renovation Waste															
Wood/Timber	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Gypsum/Plaster	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓		
Composite board														✓	
Plastic/Rubber		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓			
Paper/cardboard				✓		✓		✓		✓		✓			
Iron/Steel	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓		✓
Aluminum alloy		✓	✓			✓						✓	✓	✓	✓
Glass	✓	✓	✓			✓	✓	✓	✓		✓	✓	✓	✓	✓
Insulation materials	✓	✓			✓	✓	✓				✓	✓	✓		
Asbestos	✓					✓					✓				

2.5 Quantification Methods of R&R Wastes

The quantification methodologies for C&D waste can be applied to the R&R wastes due to the similarity in nature. Wu et al. (2014) conducted a systematic review for the existing C&D waste quantification methods and concluded that no single quantification method could fulfill all the scenarios. Quantification methodology should be appropriately selected according to actual quantification objectives and site conditions.

2.5.1 Site Observation

Among the existing waste quantification methodologies, the most direct and simple one is to obtain construction waste generation information through site observations. For example, Mokhtar et al. (2016) calculated volume of refurbishment waste from eight residential sites based on the number of loads trip for waste disposal and the bin load volume. Lu et al. (2011) investigated the C&D waste generation rate in Shenzhen by weighing each bucket of the generated waste and recorded the collected data in inventory forms. In Malaysia Lau et al. (2008) estimated the C&D waste amount according to the shapes of the waste piled on site. Kartam et al. (2004) estimated from truck load records from landfills in Kuwait. This quantification methodology was also used by Nagapan et al. (2013), Mokhtar et al. (2010), Kofoworola and Gheewala (2009), Kelly and Hanahoe (2008), Begum et al. (2006), Bossink and Formoso et al. (2002) and Brouwers (1996).

Site observation can be classified into direct and indirect measurement (Wu et al., 2014). Direct measurement of C&D waste can provide the most practical waste generation rates, which is the fundamental information for C&D waste quantification. Support from the contractors is essential and observation process is time, money and time consuming. In indirect measurement, the quantities and composition of the C&D waste were estimated by visual observations and from truckload records (Poon et al, 2004b). Indirect measurement can only provide an approximate amount of the generated C&D waste.

2.5.2 Generation Rate Calculation (GRC) method

Based on the waste generation information collected from site observations, it is recommended to use Generation Rate Calculation (GRC) method, which is the most common construction waste quantification methodology used by academia. The principle of GRC is to find out the common unit of C&D waste generation for a particular site or construction activity, such as kilogram per meter square (kg/m2), volume per meter square (m3/m2) or kilogram per thousand dollars (kg/$1000), etc. and applied for calculating C&D waste generation rate.

The area-based calculation, which is based on C&D waste generation rate per renovation area, is popularly applied in GRC methodology to estimate all types of C&D waste. For example, Lage et al. (2010) utilized the surface areas of new buildings, renovations and demolitions in Galicia to estimate the regional C&D waste generation. The GRC methodology has also been applied by other researchers like Hoglmeier et al. (2013), Li et al. (2013), and Mália et al. (2013), Coelho and de Brito (2011a), De Melo et al. (2011), Zhao et al. (2010), Banias et al. (2010).

2.6 Benefits of Sustainable R&R

The construction industry is accused of polluting our environment in terms of air, water, noise, light and waste (Ding, 2008). The construction industry should look for new ways for avoiding, minimizing, reusing, recycling and handling C&D waste (Alarcon, 1997; Conventry et al., 2001; Baldwin et al., 2009). Refurbishing and renovating existing buildings in lieu of redevelopment can contribute to conserve our environment offering benefits in three major aspects.

2.6.1 Social benefits: maintaining health and comfort to the building occupants

As Hong Kong residents spend around 85% of their time indoors, the indoor environmental conditions have a significant impact on the quality of life (HKGBC, 2016). Buildings should be able to provide a safe, healthy and comfortable indoor environment. Poor indoor building environments can reduce productivity and endanger occupants' health (Wydon, 2004). The design, construction, development, management, operation and maintenance of buildings should seek to provide a good quality indoor environment that optimizes energy use and reduces waste (Gelfand and Duncan, 2012). R&R work can restore the optimum condition of a building. As the nature of work and types of waste generated in C&D and R&R projects are similar, the principles of sustainable R&R work are similar to the principles applied in sustainable building design. This is particularly important when the R&R work is carried out in occupied buildings.

2.6.2 Economic returns for green buildings

Building refurbishment and upgrading (including maintenance, repair, restoration and alternation/additional works) are major activities of construction industry. Recently, building owners and developers have realized the potential economic value of the refurbishing and reuse of the vast stock of old, redundant and obsolete buildings (Lam, 2016). According to Gorse and Highfield (2009), revitalizing aged buildings can provide high quality modern accommodation more quickly than new construction, and often with a lower cost. R&R work can shorten the construction period by half or even one quarter, and 50-80 per cent saving in construction cost as compared to constructing a new building. R&R work offer considerable economic benefits to the owners and developers.

2.6.3 Environmental benefits

In the past 40 years, massive worldwide energy consumption resulting in global warming has been a major global concern (Hansen et al., 1997). One of the ways to reduce energy consumption is to recycling and reuse of existing resources as an alternative of replacement can reduce energy consumption. Refurbishment and renovation can retain most of the existing structure and fabric, thus avoiding the need to extract raw materials for new construction and achieve energy saving even for major R&R work (Gorse and Highfield, 2009).

2.7 Barriers Hindering the Management of Waste Reduction on R&R projects

Sanvido and Riggs (1991) identified four constraints in R&R waste management, which were time, space, information, and environment. Section 2.7.1 to 2.7.5 summarize the barriers in implementing R&R waste management identified from literature review and further elaborate the four constraints.

2.7.1 Characteristics of construction industry

Due to limited land supply, the areas of construction sites are limited. Furthermore, clients tend to impose a tight construction period for greater financial return. Lack of available space and restricted construction period are limiting factors of on-site sorting in the waste stream (Poon et al., 2004c; Shen et al., 2004; Kartam et al., 2004; Formoso et al., 2002). It is important to recognize the unique outcomes of these restrictions in R&R waste management and to allocate available resources to overcome the fundamental causes in a long-term perspective (Nam and Tatum, 1988). In view of the tight construction schedule, contractors prefer replacement by new materials instead of reuse/recycling, which is more labour and time-consuming, in building refurbishments and renovations (Hosseini, 2015). Moreover, a highly effective waste disposal logistics are crucial in a restricted site (Lipsmeier and Ghabel, 1999). However, R&R projects usually involves several subcontractors or trade contractors, which are usually small and medium sized companies lacking the resources to carry out effective waste management. The fragmented nature of R&R work make it difficult to standardize the C&D waste management (Li, 2012; Dulung and Pheng, 2005; Holm, 2000).

2.7.2 Buildings in occupation

According to the Hong Kong Mandatory Building Inspection Scheme (HKMBIS), comprehensive refurbishment is mandatory for buildings over 30 years. The aim of the scheme is to uplift the safety condition of these buildings and safeguard public health. It is common that the building is still occupied during the process of R&R work that may cause nuisance to occupants. Cooperation of occupants in facilitating the R&R is the crucial factor of successfully implementing a sustainable waste management (Ng et al., 2014). Therefore, it is vital to collect the occupants' expectations and requirements in the early stage of the R&R project for subsequent decision-making process (Burton, 2012). Furthermore, it is always difficult for occupants to arrive at common consensus in sustainable R&R waste management (Living Cities, 2010). A simple action by providing different barrels for domestic and construction waste can help occupants and workers in onsite waste sorting.

2.7.3 Construction practitioners' attitudes towards reuse and recycle

Working practices and attitudes of on-site workers may militate against reuse and recycling in refurbishment projects (Teo and Loosemore, 2001). R&R waste is often a composite construction waste making it complicated to be assessed and consequently difficult to be reused or recycled (Sezer, 2017) that may deter workers in waste sorting. Therefore, it is important to create incentive by rewarding workers to carry out on-site sorting (Joshi and Sanjay, 2004).Users always concern quality, appearance and cost of the material. Recovering old materials is time-consuming and expensive, which may not concur with clients' expectations and requirements (Hosseini, 2015). This is particularly for the case of old residential buildings that are constructed with cheap, low quality, and hazardous materials making reuse and recycling not an environmental friendly option (Sezer, 2015).

2.7.4 Lack of economic incentive

The financial benefits of R&R waste management may not be attractive as compared with new construction projects. Small to medium sized R&R projects generate only small amount of wastes and recyclable materials, which cannot economically substantiate recycling facilities, comparing to large R&R projects (Seydel et al., 2002; Hosseini, 2015). Figure 2.3 and 2.4 show the types of waste generated from new construction and R&R projects. New construction project can perform better in waste separating because small amount of mixed waste is produced. Contractors need to allocate more resources to sort the mixed waste in R&R projects imposing pressure and difficulties to project management.

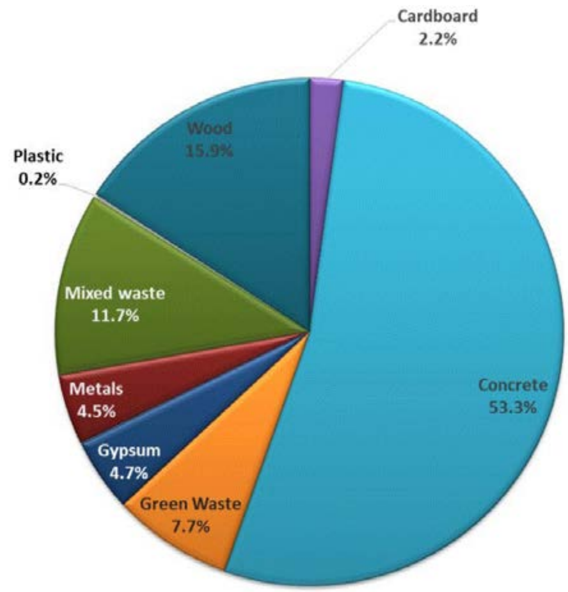

Figure 2.3 Classification of C&D wastes in new construction projects at UBC (Hosseini, 2015)

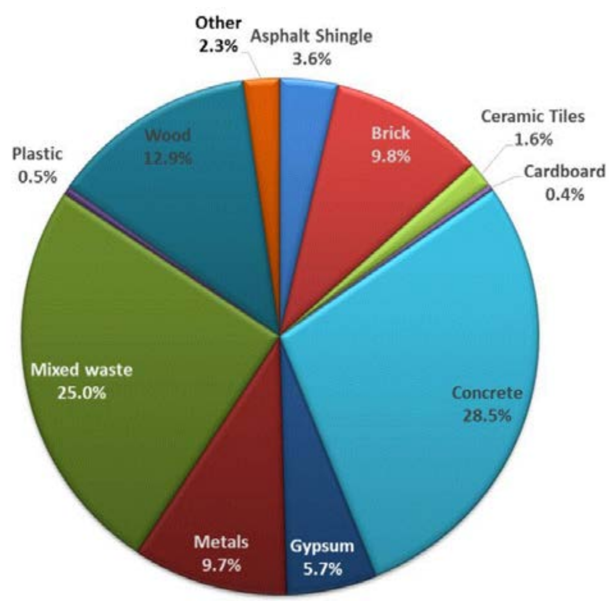

Figure 2.4 Classification of R&R wastes in refurbishment projects at UBC (Hosseini, 2015)

2.7.5 Changing conditions and unpredictable factors

Due to limitation in available information of the construction site such as discovering of hazardous material, post-war bombs and historical artifacts, R&R project cost and period are assessed in the design stage according to the type and age of the building, which frequently result in time and cost overrun (Arain, 2005; Mitropoulos and Howell, 2002; McKim et al. 2000). These unforeseen conditions may generate extra construction waste affecting waste management, as efficient coordination among various stakeholders is required to maintain a stable progress (Ali et al., 2010). Due to these uncertainties, waste management for R&R projects adopt a different process and is less regulated as compared to new construction (Li and Yang, 2014). A flexible and changeable waste management practice is required to fulfill the various unpredictable conditions.

Chapter 3 Review on Overseas Policies and Strategies in R&R Waste Management

3.1 The Importance of R&R Waste Management

C&D waste generation can impose adverse effects to the environment, health and safety and even profitability of enterprises (Poon et al, 2003; Esin and Cosgun 2007; Yuan and Shen, 2011; Adjei et al., 2013). A number of factors including economic conditions and growth levels, market conditions, population size and density, relevant laws, source reduction initiatives, geographic location, and climatic conditions influence C&D waste generation. (Public Works and Government Services Canada, 2013). Ineffective C&D waste management can lead to (a) saturated landfill, (b) increase in illegal dumping, and (c) generating social opposition to environment degradation caused by demolition (Hao et al., 2007; Lu and Yan, 2007). The major impact is consuming large amount of valuable land resources for waste disposal, which causes environmental problems and wasting large amount of public money in treating waste from landfills (Yuan et al., 2011). There is an urgent need to manage C&D waste in order to reduce its negative impacts on the environment (Ajayi et al., 2017; Yuan et al., 2011). Both governments and private sectors have the responsibilities to solve these problems. Governments must develop policies and strategies to optimize the economics and social impacts of waste while private sector must develop operational practices to comply with such interventions (Adjei et al., 2013).

3.2 Influencing Factors of Sustainable C&D Waste Management

Calvo et al. (2014) and Manowong (2012) had identified four influencing factors of sustainable C&D waste management, which are (i) market-based economic aspect, (ii) environmental aspect, (iii) legal aspect, and (iv) social aspect. Market-based instruments include tax, government subsidizes and other economic incentives. Environmental aspect involves environmental standards and culture. Legal aspect covers laws and regulations, implementation of R&R waste management policy and quality standard. Social aspect concerns about public health and safety, and social education. Tam (2008) concluded from his research that the percentage of reused and recycled C&D waste reflected the effectiveness of C&D waste management to certain extent as illustrated in Figure 3.1. A study on the overseas and local policies cum strategies in C&D waste management can shed light on developing policies and strategies in R&R waste management in Hong Kong.

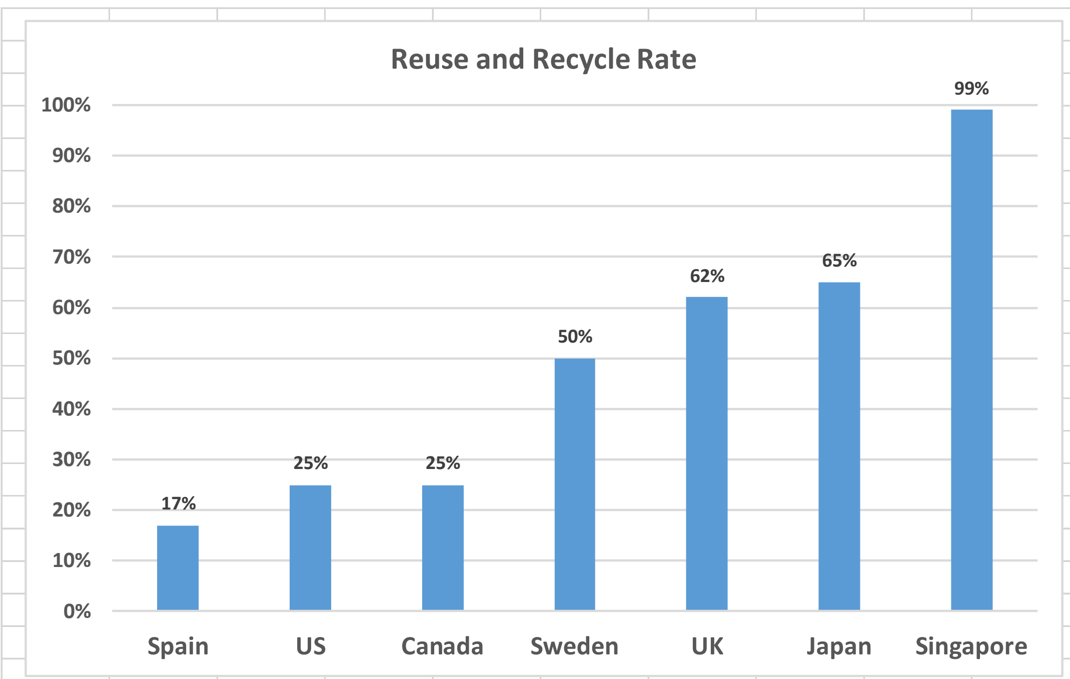

Figure 3.1 Comparison of C&D waste reuse and recycle in various countries (Tam, 2008)

3.3 Overseas Policies and Strategies in R&R Waste Management

European Union (EU) waste management legislations, and C&D waste management strategies of seven countries covering Europe, North America and Asia were studied to identify their factors of success and reasons for failure.

3.3.1 European Union (EU)

Europe has generated around 890 million tonnes of C&D waste per year and only 50% is recycled, which is far from the target rate of 70% by 2020 as stipulated in Waste Framework Directory 2008/98/EC (EC, 2019a). C&D waste management has been incorporated into European and International laws in order to promote the culture of reuse and recycling (Sakai et al., 2011). The principles of European Union Waste Management Legislation and Policy (EUWMLP) can be categorized into four areas, which are (a) prevention through minimizing waste, (b) precautionary measures to safeguard environment, (c) polluters-to-pay, and (d) the proximity and self-sufficiency for waste disposal (Nowak et al., 2009; Pongrácz, and Pohjola, 2004). The adoption of the first Sustainable Development Strategy (SDS) in 2001led to the introduction of the 3R principles (Reduce, Reuse and Recycle) in waste management (Sakai, et al., 2011), which formed the basis of Waste Hierarchy (WH) (Nash, 2009). WH focuses on reducing the environmental impacts of waste generation and management by encouraging life cycle thinking (Adjei et al., 2013), which involves a wealth of waste management practices tied to policies, institutional settings, financial mechanisms, technology selection, and stakeholder participation (Pires et al., 2011). The Waste Framework Directive (2008/98/EC) enables member states to set up Extended Producer Reasonability (EPR) schemes: an efficient resource management tool to enforce producers taking over the responsibility for the end of life management of their used products (EXPRA, 2019).The EU waste management legislations form the basis of waste management policies and strategies in EU countries. The legislations are summarized in Table 3.1., which is based on Adjei et al. research (2013).

Table 3.1 Summary of waste management legislations of EU

Legislative Area • laws and ordinances relating to avoid, recycle, transport, treat and dispose different kind of wastes (Adjei et al., 2013) • sustainable actions to improve quality of life for both current and future generations (Ledoux et al., 2005; Pires et al., 2011)	***Community Strategy for Waste Management***	• expanding focus of waste management policy from *environmental protection* to *social* and *economic* concerns • aims to (a) reduce waste generation, and (b) increase in energy and materials recovery
	Waste Framework Directive (WFD) 2008/98/EC	Requires EU members to draw up: • regulations on the collection, transport, recovery and disposal of waste • waste management plans • establish separate collection system by 2015
	Landfill Directive	Supplements WFD by (Adjei et al., 2013): • specifying uniform technical standards at community level • setting out requirements for the location, management, engineering, closure and monitoring for landfills
	Council Decision 03/33/E	• establishes criteria and procedures for the acceptance of waste at landfills
	Integrated Pollution Prevention and Control Directive (IPPCD)	• requires operators of industrial and waste installations to obtain an environmental permit
	Packaging and Packaging Waste	• sets the target for the management of packaging waste
	Hazardous Waste Directive	• Sets the requirements for managing waste containing hazardous substances

3.3.2 Spain

Spain has similar situation of Hong Kong that has a high volume of C&D waste generation but a low recycling rate of 17% (Calvo et al., 2014). The first national plan on C&D waste was announced only in 2001 (ES, 2001). Royal Decree (Spanish Government-Ministry of the Presidency 2008) implemented the principle of producer responsibility - Extended Producer Responsibility (EPR), which governed waste prevention and responsibility among the participants in the production and management of C&D waste. It also incorporated the obligation to introduce waste management plans, and requirement of a construction permit that laid down the control on waste quantities and treatment cost prior to commencement of construction work in 2008 (Calvo et al., 2014). Law 22/2011 of Waste and Contaminated Soil setup specific measures in terms of 3R regulation for achieving three main objectives: inert waste recovery, eradication of illegal landfills, and promoting demand for the recycling of C&D wastes, particularly for recycled aggregate (Calvo et al., 2014). However, there are still outstanding issues such as the prevention of pollution caused by landfills and the creation of green economy (Yuan et al., 2012). Spain adopted "Council Directive 1999/31/EC 26 April 1999" on landfill of waste (EUR-Lex, 2019) but impose no additional measures on landfill ban (CEWEP, 2017). Construction companies have no incentives to engage in waste management as well as Spanish government lacks effective regulation and economic incentives to reduce the amount of C&D waste and increase reuse/recycle rate (Calvo et al., 2014). Market-based instruments such as taxes, subsidies and other incentives are more effective than laws in promoting environmental innovation but are not well developed in Spain (Calvo et al., 2014; Kemp and Pontoglio, 2011). Although BREEAM ES has been developed and delivered by the Instituto Tecnológico de Galicia, which focuses on the assessment and certification of master planning, new construction, renovation/refurbishment and in-use building life cycle stages (BREEAM, 2019a), its effectiveness is impeded by the deficiencies in waste management policies.

3.3.3 United States

C&D waste in the United States contributes to about 300 million metric tons of waste annually (USEPA, 2015; USEPA, 2019a). The reuse and recycling rate is about 25% (Calvo et al., 2014). Realizing that public policies could play a major role in advancing C&D waste reduction and recovery, the U.S. Environmental Protection Agency (USEPA) has developed technical criteria in "40 CFR Part 257-Criteria for Classification of Solid Waste Disposal Facilities and Practices" for industrial landfills (LII, 2019; USEPA, 2019a &b). Reducing and recycling C&D waste have the benefits of conserving landfill space, reducing the environmental impact of producing new materials, creating new jobs, and reducing overall building project expenses by minimizing purchase and disposal costs (USEPA, 2019b). The significant role of C&D waste management is moving towards more "sustainable materials management (SMM)", which is a systemic approach to using and reusing materials in a more productive manner over their entire life cycles, thus reducing discharge to landfills (Tolaymat, 2018; USEPA, 2019c). Builders, construction teams and design practitioners can divert C&D waste from disposal by buying used and recycled products, practicing source reduction, preserving existing structures, as well as salvaging and reusing existing materials (USEPA, 2019b). C&D waste recovery is a promising avenue of economic, environmental, and social benefit (USEPA, 2019c). USEPA has been promoting the following "best practices" for reducing, reusing, and recycling C&D waste (USEPA, 2019b):

(a) Designing for Adaptability, Disassembly and Reuse Strategies (DADR)

A building should be designed using simple open-span structural systems, standard and modular building components; durable recoverable materials for reuse and recycle; and removable mechanical fastener e.g. bolts, screws and nails; and minimizing usage of different types of materials. Connections should be visible and accessible. Planning the movement and safety of workers to carry out building adaptation, future repair and disassembly should be considered in advance. A Disassembly Plan with key information (e.g., as built drawings, materials, key components, structural properties and repair access and contact information) of a building is recommended for demolition/renovation projects.

(b) Source Reduction

Reducing life-cycle material use, energy use and waste generation should be considered in the design stage trying to preserve existing building components by repairing rather than replacement.

(c) Deconstructing Buildings

Design building using specialty materials with high resale value for items such as hardwood flooring, multi-paned windows, architectural moldings, unique doors and plumbing/electrical material fixtures. High-quality brick-laid construction with low-quality mortar allows for relatively easy break-up and cleaning. Partial deconstruction should be considered in case a building do not meet one or more of these criteria.

USA adopted the BREEAM and LEED green building rating systems. The BREEAM USA In-Use version 6 support owners, managers and occupiers of existing buildings to measure their sustainability performance and gain information to drive improvements in a cost-effective manner. Leadership in Energy and Environmental Design® (LEED) provides independent verification of a building's green features and encourages the design, construction, operations and maintenance of resource-efficient, high-performing, healthy, cost-effective buildings (LEED, 2019). State and local governments are responsible for coordinating different websites of waste exchange (for example the Associated General Contractors of America, Construction and Demolition Recycling Association) with buyers and sellers looking for reusable and recyclable C&D waste (USEPA, 2019b).

3.3.4 Canada

The Canadian construction industry is generating nine million tons of C&D waste annually accounting for 20 to 50% of the total municipal solid waste, which is composed mainly of wood products, asphalt, drywall, concrete and masonry (CCA, 1991). There is evident that 75% of the C&D waste has a residue value and can be reused, recycled or recovered (Yeheyis et al., 2013). The reuse and recycling rate is about 25% (Calvo et al., 2014). The main causes of C&D waste generation are: (a) faulty design, (b) unexpected changes in building design, (c) improper procurement and planning, (d) inefficient material handling and (e) residue of raw materials that can be managed by improving building design and site practice (Bossink and Brouwers, 1996). The construction waste management sector in Canada is regulated by regulatory frameworks and building rating systems (Yeheyis et al., 2013). A levy was introduced on the disposal of waste materials at licensed landfills under the Finance Act 1996 (Practical Law, 2019). Ontario Ministry of the Environment (MOE) passed the Waste Reduction Action Plan (WRAP) covering the 3Rs principles (Reduce, Reuse and Recycle) to ensure that municipalities as well as industrial, commercial and institutional sectors develop strategies to reduce at least 50% of waste being sent to landfill by 2000 as compared to 1987 (Sonnevera International, 2006). WRAP 102/94 requires building and business owners to conduct and update annually waste audits, develop and implement waste reduction plans (Yeheyis et al., 2013). Source separation for certain C&D waste generated from buildings larger than 2,000 m^2 is mandatory under WRAP 103/94 (Sonnevera International, 2006). Solid Waste Resource Management Regulations of Nova Scotia authorizes the Resource and Recovery Fund Board (RRFB) to provide funding to construction projects that reduce, divert or recycle C&D waste. A comprehensive list of C&D waste including asphalt paving, porcelain and ceramic are banned by Halifax Regional Municipality under the By-Law L-200. The By-Law also requires all C&D waste to be delivered to a certified C&D Processing Facility or Transfer Station, of which 75% must be recycled (Jeffrey, 2011). The Canada Green Building Council

(CaGBC) works to change industry standards, develop better design practices and guidelines, advocate for green buildings, and develop educational tools for implementing sustainable design and construction practices (Brydon, 2011). CaGBC supplement the US LEED rating systems with Canadian construction practices, regulations and climates (Yeheyis et al., 2013). LEED Canada CS applies to new construction and major renovations of commercial and institutional buildings (CaGBC, 2019). The review report on waste management in Canada was prepared in 2014 for the In 2014 Canadian Council of Ministers of Environment had reviewed the waste management practices in Canada and criticized that current regulations were overly prescriptive and not able to create innovation in reducing waste upstream (Giroux, 2014).

The Public Works and Government Services of Canada invited proposals for managing construction, C&D and R&R waste in Canada under the tender "Characterization and Management of Construction and Demolition Waste in Canada (K2AA0-13-0025)" (PWGSC, 2013). The proposal aimed to improve the knowledge of: (a) linkages between C&D/R&R waste and substances of interest; (b) current management approaches and best practices for these wastes; (c) Canada's infrastructure and existing secondary markets for C&D waste material; (d) opportunities for improvement that may exist to support the environmentally sound management of C&D/R&R waste; and (e) enhanced resource recovery and economic growth through the creation of green jobs.

3.3.5 Sweden

Sweden has established an effective waste management system achieving reuse and recycling 50% of C&D waste (EC, 2019b). The Ministry of the Environment is responsible for formulating national policies on environmental issues, which has established the Swedish Environmental Protection Agency for promoting environmental policies, implementing environmental regulations and issuing guidelines for compliance (Legislative Council Secretariat, 2014). The amount of C&D waste generated in 2012 had decreased by 18% to 9.4 million tonnes comparing to 2010 with recycling rate meeting the EU 70% recycling target (EC, 2019a). The major legislations for waste management are laid down in Swedish Environmental Code "Miljöbalken" (SFS 1998:808) Chapter 15, Ordinance on Waste (SFS 2011:927) and Environmental Code - Chapter 2 (EC-2), which are transposed from WFD 2008/98/EC (Arm et al., 2014). The Ordinance (2001:512) on the Landfill of Waste requires C&D waste to be treated before disposing and bans disposing unsorted combustible waste at landfills (EC, 2019b; SEPA, 2019). Furthermore, the project operator is required to verify that the C&D waste can be disposed of at the landfill (SEPA, 2019). Building Code (SFS 2010:900) requires submission an inspection plan to local authorities prior to commencement of construction projects containing an inventory of anticipated hazardous and non-hazardous C&D waste. The inspection plan should include information on waste sorting, precautionary actions to prevent environmental and health risks, and the final disposal of the C&D waste. There is no specific regulation on waste management for renovation projects, which are expected to comply with the requirements of C&D waste management (EC, 2019b). Ordinance on Environmental Assessment SFS 2013:251 requires contractors to obtain a permit for managing, processing and recycling of C&D waste (EC, 2019b). The landfill tax, which was introduced on 1 Jan 2000, reflected the demand for landfill (Legislative Council Secretariat, 2014). Sweden's Waste Plan 2012-2017 (SWP 12-17) targets to increase reuse, recycling rate of non-hazardous C&D waste to 70% by weight in 2020. Law on landfill tax SFS 1999:673 allows refunding contractor based on the amount of C&D waste that is not disposed and subsequently reused or recycled (EC, 2019b). The Sweden Green Building Council has developed and delivered the BREAAM SE and LEED 2000, which focus on the assessment and certification of new construction and building refurbishment (BREEAM, 2019b, EC, 2019b).

3.3.6 United Kingdom (UK)

The construction industry of UK generated 89.9 million tonnes of C&D waste in 2008 contributing to 35% of the total waste generated, of which about 62% of the C&D waste was reused or recycled (Defra, 2011). Based on EU Directives, the UK Governments developed policies and strategies to optimize the economic impact and reduce the social impacts of C&D waste, and implementations to enforce businesses sector to develop operational practices aligning with such interventions (Adjei et al., 2013). Waste regulations were reformed to minimize and divert C&D waste from landfills, which had assisted compliant business in reducing construction costs and paved the drawing-up of the Site Waste Management Plans (SWMP) Regulations (Adjei et al., 2013). SWMP requires demolition project valued £300,000 or more to prepare a waste management plan including the expected levels of waste and prioritizing waste management through the waste hierarchy (Adjei et al., 2013; Envirowise, 2008). The Land Tax Regulations 1996 and later the Landfill (England and Wales) Regulation 2002 (Landfill 2002) have created an incentive for construction industry to reduce C&D waste leading to significant investment in recovery systems (Davenport, 2003; Seely, 2009; Adjei et al., 2013). The Waste (England and Wales) (Amendment) Regulations 2012 enforce waste separation to ensure that waste undergoes recovery operations in accordance with the Directive and to facilitate or improve C&D waste recovery whenever it is "technically, environmentally and economically practicable" (Defra, 2012). Schedule 10 of the Environmental Permitting (England and Wales) Amendment Regulations (EPR-10) aims to alleviate the adverse environmental impact caused by landfills. Schedule 9 of the Environmental Permitting (England and Wales) covers waste management, responsibilities of stakeholders and licensing control of waste disposal. The Packaging (Extended Producer Responsibility) Bill 2017-19 (PEPRB), which required producers of packaging products to assume responsibility for the collection, transportation, recycling, disposal, treatment and recovery of those product, was introduced to the Parliament on 13 June 2018 with an aim to solve the excessive packaging waste (UK Parliament, 2018). BREEAM UK comprises a number of schemes covering the life cycle stages of master planning, new construction of buildings and infrastructure assets, and R&R work (BREEAM, 2019a). The BREEAM Refurbishment and Fit Out Standard (RFO) focuses on accrediting building renovation work (BREEAM, 2019b).

3.3.7 Japan

In land-scarce Japan, up to 80% of garbage is incinerated, while a small percentage (about 1% of council waste) ends up in landfills (Onishimay, 2005; Sturmer, 2018). Municipal and construction waste are recycled at high rate (Choi et al., 2009). C&D waste generation accounts for approximately 20% of all industrial waste (Ogushi and Kandlikar, 2007). As Japan is facing the problem of saturated landfills, illegal dumping due to increasing generation of C&D waste is getting serious, which accounts for 70% of illegal dumping (Ogushi and Kandlikar, 2007). In 1991, Japanese government established the Recycling Law to encourage the reuse and recycling of construction byproducts, which included demolished concrete, soil, asphalt concrete, and wood (Nitivattananon and Borongan, 2007). After sorting of C&D waste, reusable and recyclable waste will be sold as resources, the remaining are pulverized and sent to landfills or incinerators depending on nature of waste (Tsoi et al., 2009). Basic Environment Act 1993 (BEA 1993) forms the backbone of environmental policies and legal system for establishing a sound material-cycle society in Japan. Based on the Basic Environmental Law, the Basic Environment Plan (BEP) was drawn up in December 1994, which outlines the general direction of Japan's environmental policies (MOE, 2019a).

Yumeshima in Osaka is a reclaimed island of about 390 hectares. The land is divided into four main sections: Section 1to house the Mega-solar Power System, Section 2 is an integrated resort, Section 3 is the site of World Expo and Section 4 is a container terminal (Osaka Port & Harbor Bureau (2019) (Figure 3.2 and 3.3). Sand, soil, dredged soil and general waste was used as the filling materials of Yumeshima Island. The “sandwich” method is applied in reclaiming Section I. General waste was used as landfill materials after the reclaimed land had reached the sea level. A 50cm thick normal soil was spread on the waste layer after the general waste had reached 3m in thickness. The “sandwich” method can optimize decomposition of waste into soil, prevent waste scattering, reduce contaminated water exudation and maintain hygiene. Section 2 and 3 were reclaimed by marine sand, inert C&D waste, excavated soil from civil engineering projects and dredged soil from rivers and harbors. Normal mountain soil and inert waste generated from construction work sites were used as landfill materials in Section 4. A soft alluvial clay layer had formed from the seabed to a depth of approximately 20 meters underneath the Yumeshima Island. The seabed cannot be used as foundation base for urban facilities unless being strengthened. In order to make the reclaimed land ready for use, Osaka government constructed reclamation seawalls in 1977 and improved its ground foundation in 1994 (Barry, 2013).

Figure 3.2 Yumeshima Island

(Source: https://www.city.osaka.lg.jp/contents/wdu020/port/information/development_02.html)

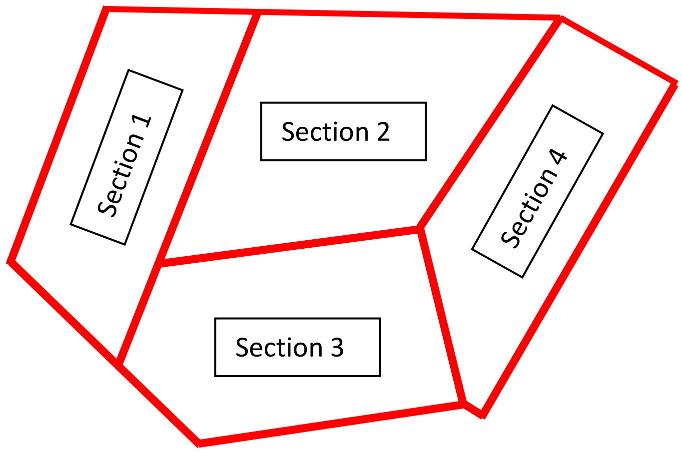

Figure 3.3 Plan View of Yumeshima Island

In order to address C&D waste issue, the Construction Material Recycling Law (CMRL) that aligned with the 3Rs principles was enacted in May 2000 aiming at recycling and reuse of construction by-products to ensure efficient use of resources. Japan has achieved a reuse and recycling rate of 65% in 2000 (Tam, 2008). CMRL targeted 95% recycling rate of specified construction materials by 2010 (MOE, 2019b). Contractors are required to carry out waste sorting and recycling of specified C&D wastes under CMRL, such as concrete, asphalt and wood. CMRL also applies to renovation project of contract sum exceeds 100 million yen (HKD 715m). A Work Plan (WP) for sorting C&D/R&R waste should be submitted for approval seven days prior to commencement of work. A registration system of demolition contractors has been introduced to ensure appropriate demolition works. CMRL also stipulates the work procedures as summarized in Figure 3.3.3 (MOE, 2014). Japan has developed the Comprehensive Assessment for Built Environment Efficiency (CASBEE) as the assessment tool for construction (housing and buildings), urban (town development) and city management, which is collectively known as the CASBEE Family. Japanese Ministry of Land, Infrastructure and Transportation (MLIT) had assisted in developing CASBEE in 2001(Endo et al., 2007). Under CASBEE, CASBEE for Renovation (CASBEE-RN) is designed to evaluate the performance of existing buildings based on specifications for renovation and the predicted performance (CABEE, 2019; Endo et al., 2007).

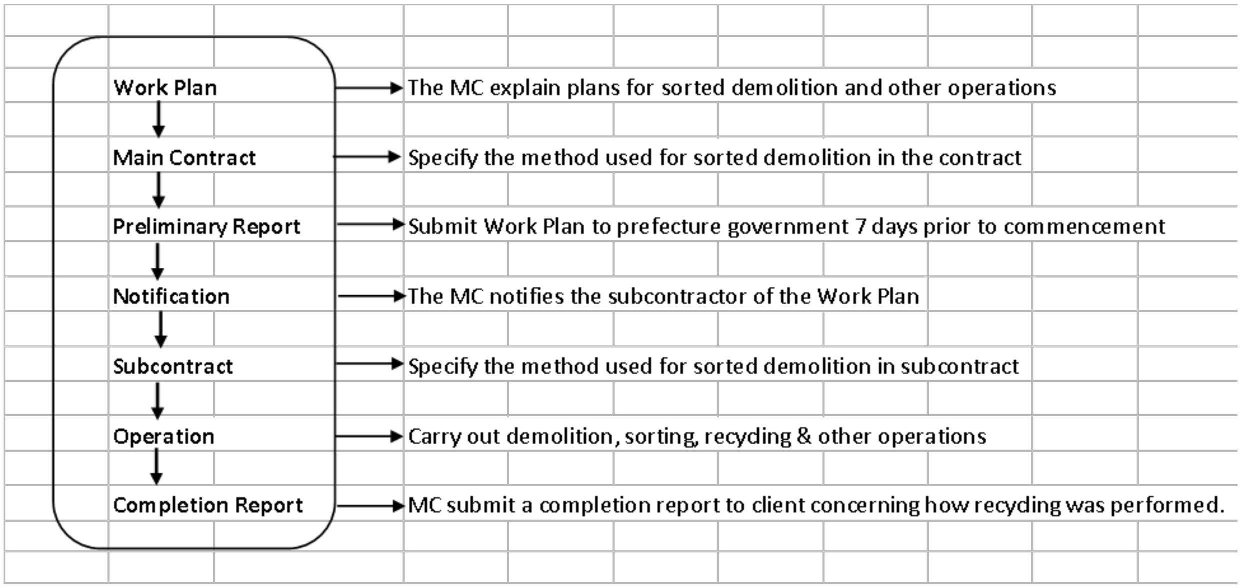

Figure 3.4 Flowchart of sorted C&D waste and recycling

3.3.8 Singapore

(The content is abstracted from the BCA website of Singapore Government (BCA, 2019) unless specified)

Singapore is aspired to be a leading global city in environmental sustainability focusing on improving energy efficiency requirements in buildings and has adopted a more holistic approach to encourage environmental friendliness in buildings without compromising environmental quality and comfort. Singapore has been very successful in reducing C&D waste with a high recycling rate of 99% (Tam, 2008). The Building and Construction Authority (BCA) under the Ministry of National Development advocates the development of an excellent built environment for Singapore. The vision of BCA is to develop “a future-ready built environment for Singapore” in partnership with stakeholders and the community. Demolition Protocol governs C&D waste management, which is a set of procedures aiming to produce cleaner C&D waste to a quality acceptable for waste recyclers in manufacturing high-quality recycled concrete aggregates by implementing Pre-demolition Audit (PDA), Sequential Demolition (SD), and Onsite Sorting (Chew, 2010). To safeguard public health and environment, all general waste disposal (including C&D waste) facilities must either obtain their license or submit an exemption declaration to National Environment Agency (NEA) since 1 August 2017 (NEA, 2019).

Semakau landfill is Singapore's and the world's first offshore landfill, which has 350 hectares environmentally friendly waste disposal plant with a handling capacity of 63 million cubic meters of waste. It operated on 1 April 1999 and is expected to last until 2045 or beyond. Semakau landfill will be turned into an eco-park after cessation of operation. The landfill was created by reclaiming land between two small islands located 8 kilometers off the coast of Singapore. An impermeable membrane and clay layer surrounds the entire reclamation area in order to prevent leakage of any harmful chemical substances to the sea. The fill material is mainly composed of ash from incineration. The ash waste transported by covered barges every night and compacted within the impermeable membrane in order to prevent blowing in the air. Any leachate produced is processed at a leachate treatment plant and regular water testing is conducted to ensure the integrity of the impermeable liners. Semakau landfill construction is carried out in two phases. The area of Phase I is divided into eleven 'cells' for Phase I, which are lined with thick plastic and clay to prevent any harmful material from seeping into the sea. Phase II is not yet developed (Clean Green Singapore, 2012). Figure 3.5 shows the site design.

Figure 3.5 Aerial view of Semakau landfill

(Source: https://www.nea.gov.sg/our-services/waste-management/waste-management-infrastructure/semakau-landfill)

BCA has established Control Act and implemented through Building Control (Environmental Sustainability) Regulations (BCES) requiring a minimum environmental sustainability standard that is equivalent to the Green Mark Certified Level for new buildings and R&R works covering a gross floor area of 2000m^2 or more. The building professionals are required to assess the renovation work in compliance with the respective environmental standards based on the Code for Environmental Sustainability for Buildings (1st, 2nd and 3rd Edition) (CESB), and Addendum to Code (1st, 2nd and 3rd Edition) with respect to the first submission date for Urban Redevelopment Authority (URA) planning permission. The $100 and $50 Million Green Mark Incentive Schemes (GMIS) for Existing Buildings provide cash incentive to clients and contractors who have renovated existing buildings to meet a significant improvement in the building energy efficiency and satisfied reduction requirement in material resource usage. BCA will approve the applications for GMIS based on BCA Green Mark Scheme (GMS). GMIS was launched in January 2005 covering new and existing residential/non-residential buildings, which had facilitated reduction in energy, water and material resource usage.

3.4 Analysis of C&D Waste Management Policies and Strategies in Oversea Countries

Table 3.2 summarizes the major policies and strategies of C&D waste management in the above countries. All the studied countries except Spain have developed market-based economy promoting reuse and recycle of C&D waste. There is no landfill ban legislation in Spain leading to a low incentive in preventing landfill pollution and developing a green economy in C&D waste management.

Table 3.2 Comparison of C&D waste management policies in oversea countries

Country (Recycling Rate)	**Market-based economic**	**Environmental**	**Legal**	**Social**	**Assessment**
Spain (17%)	*Not well developed; Creation of green economy - weak*	*Not comprehensive; Prevention of landfill pollution - weak*	Directive 1999/31/EC; *No landfill ban implemented*	Not specific	BREEAM ES
US (25%)	SMM; DADR; Deconstruction; Waste exchange websites	SMM	40 CFR Part 257	SMM; DADR	BREEAM USA; LEED
Canada (25%)	RRFB; K2AA0-13-0025	K2AA0-13-0025	Finance Act 1996; WRAP By-Law L-200	K2AA0-13-0025	CaGCB; LEED Canada CS
Sweden (50%)	SFS 2010:900; SFS 1999:673	SFS 2011:927; EC-2; SFS 2010:900	2001:512; SFS 2010:900; SFS 2013: 251	Not specific	BREAAM SE; LEED 2000
UK (62%)	Land Tax Regulation 1996	ERP 2012; PEPRB; ERP-10	SWMP; Land Tax Regulation 1996; Landfill 2002	EPR-9	BREEAM UK - RFO
Japan (65%)	Recycling Law - Reuse/Recycling; Incineration	BEP; CMRL	Recycling Law; BEA 1993; CMRL;	3R Principles	CASBEE - RN
Singapore (99%)	GMIS	NEA – licensing; PDA; SD; Onsite Sorting	Demolition Protocol; BCES; CESB	BCA	GMS

Calvo et al. (2014) studied the C&D waste management policy and strategies in Spain and identified the main barriers for C&D waste management in Spain are related to political, social, economic and technical aspects as summarized in Table 3.3. The lack of effective regulation is not the root cause but relationship between environmental innovation and policy is important. Tam (2008) conducted a questionnaire survey and structure interviews to investigate the effectiveness of the existing implementation of the waste management policy in the Hong Kong construction industry, which also had a low recycling rate of 48% (LegCo, 2013). ‘‘Low financial incentive’’ and ‘‘increase in overhead cost to perform reuse and recycle’’ are considered as the major barriers to the implementation of C&D waste reduction. Market-based instruments (taxes, subsidies and other incentives) are considered to be more effective than laws in promoting environmental innovation (Kemp and Pontoglio, 2011).

Table 3.3 Main barriers for C&D waste management in Spain

Political barrier	• Insufficient data on recovery and recycling rates of C&D • Government lack control over C&D waste management plans • Legislation independent and highly dispersed at regional level
Social barrier	• Lack of coordination between the agents involved in C&D waste management • Lack of initiatives and awareness programs • Unclear responsibility of the 3Rs regulation
Economic barrier	• No specific allocations for C&D management in contract and technical specification • High costs of managing C&D waste and the imprecision of current legislation
Technical barrier	• Technical standards do not make provision for the use of recycled material • No legislation to regulate installations for the treatment of C&D waste

The effect of economic incentive/benefit is reflected in the high recycling rate of US, Canada, Sweden, UK, Japan and Singapore. More jobs are created in US through reducing and recycling C&D waste. The overall building project expenses can be reduced by avoiding purchase and disposal costs. The funding provided by The Resource and Recovery Fund Board of Canada for reducing, diverting or recycling C&D waste creates an economic incentive to the construction industry. Law on landfill tax SFS 1999:673 of Sweden allow for refunding C&D waste that is reused or recycled. The Landfill (England and Wales) Regulation 2002 have created an incentive for construction industry to reduce C&D waste and facilitated UK in successfully developing C&D waste recovery systems. The mandatory C&D waste sorting and recycling for large renovation projects (under the Construction Material Recycling Law) has greatly reduced C&D waste generation. The cash incentive provided by GMIS for Existing Buildings has greatly enhanced achieving a significant improvement in reducing material resource usage and C&D waste in building renovation. Enforcement of legislations and creating financial incentive in reducing C&D waste are considered the top influential factors in waste management. Others best practices in waste management are pre-demolition audit, developing a mature recycling market, incineration, land reclamation, and building accreditation based on building assessment systems.

Chapter 4 Review on Current Statutory and Administrative C&D Waste Management Measures in Hong Kong

4.1 C&D Waste Management Polices in Hong Kong

Academic paper, relevant publications from government departments, bureaus and HK-BEAM form the primary and secondary sources of literature review on the current C&D waste management policies and measures of Hong Kong. The followings are highlights of the policies and measures.

4.1.1 Waste management plan (WMP)

All public and government funded construction projects are required to conduct Waste Management Plan (WMP) before commencement of construction work. Site staff need to carry out monthly review on the implementation of WMP. WMP stipulate site inspections to be carried out on regular basis to ensure C&D waste management measures complies with WMP. Site inspection report should be prepared in a way that can arouse environmental protection and consider reducing of C&D waste (Poon et al., 2004a).

Tam's investigation (2008) on the effectiveness of the WMP implementation reviewed that government received inconsistent feedback from the construction industry during the trial period of WMP implementation. The merits of WMP are the stipulations of 'Propose methods for on-site reuse of materials' and 'Propose methods for reducing waste'. The major barriers are 'Low financial incentive' and 'Increase in overhead cost'.

4.1.2 Construction waste disposal charging scheme (CWDCS)

Construction Waste Disposal Charging Scheme (CWDCS) was enacted in January 2005 (EPD, 2016). Construction waste producers (construction contractors, renovation contractors or premise owners) need to obtain a dumping license from Fill Management Division of Civil Engineering Development Department (CEDD) for disposing C&D waste at landfills and public fill reception facilities (PFRF), and pay for the C&D waste disposal charge (Yeung, 2008; EPD, 2016). Hao et al. (2008) conducted a survey to examine the effectiveness of the CWDCS in 2006, one year after enforcement. The full year daily records of C&D waste disposal at Tseung Kwan O and Tuen Mun landfills and PFRF revealed that C&D waste disposal had been reduced by approximately 60%and 23% at landfills and PFRF, respectively, which reflected the effectiveness of CWDCS. Four years later, Hao et al. (2011) conducted another research to evaluate the effectiveness of the CWDCS again and discovered that only 49% of the construction practitioners carried out onsite waste sorting. Poon et al. (2013) and Yu et al. (2013) carried out structured questionnaire survey and interviews with experienced professionals to investigate the changes in contractor behavior and perceptions after three years implementation of CWDCS. . The research findings also revealed there was ‘a significant reduction of C&D waste in the first 3 years (2006–2008) of CWDCS implementation but could not sustain. The main reason was that the landfill disposal charge was becoming insignificant as compared to project sums, which could not create incentive for contractors to reduce C&D waste disposal. The construction waste disposal charges was increased from $100 to 175 per tonne in April 2017.

Lu et al. (2015) investigated construction stakeholders’ willingness to pay (WTP) for effective C&D waste management using a questionnaire survey in February 2014. The results showed that ‘the average maximum WTP were HKD 232/t and 120/t respectively for landfill disposal and PFRF, respectively; and HKD 186/t for off-site sorting facility (OSF) disposal, which were all higher than the existing CWDCS charges (HKD 125/t for landfills, HKD 27/t for PFRF and HKD 100/t for OSF disposal). This reflects that the current C&D waste disposal charges under CWDCS are not high enough to create incentive for the building industry to reduce C&D waste. It is suggested that government should introduce incremental charges for sustaining improvements in C&D waste reduction.

4.1.3 Development of a Mature Waste Recycling Market

In order to promote the C&D waste management intentions of construction stakeholders, it is essential for establishing a mature recycling market. Currently, a large amount C&D waste including recyclable materials are disposed as the recycling industry in Hong is under developed. Wong and Yip (2004) has conducted a survey to collect comments from local project participants towards C&D waste management. 29% of the interviewees worried about the quality of the recycled building materials (15% opined that recycled products might have a lower quality , 4% worried about the reliability, and 10% had no confidence that the ability of the recycled materials could meet specifications). Hong Kong needs to develop a mature waste recycling market to provide outlets for the sorted recyclable C&D waste (Poon et al., 2004b). The recycled products must be of high quality. The crushed concrete sorted from C&D waste can be used to manufacture high quality concrete products (Poon, 2007) complying the recently modified specifications of recycled aggregates in European countries, Japan and some states in US. The manufacturing process can be audited by Hong Kong Quality Assurance Agency to ensure the products meeting international standards. Government can take the lead by requiring public project to implement recycling of C&D waste. The C&D waste can be used to produce non-structural products such as partition walls, road dividers, bridge fencing, noise barriers, and paving blocks in the beginning. Ling et al. (2013) suggested to develop a reliable recycling market for glass aggregates.

4.2 Status Quo of C&D Waste Reduction Strategies and Measures in Hong Kong

4.2.1 Proper design

To avoid waste generation by reducing waste at source is the best practice in C&D waste management (Peng et al., 1997). Proper design is an effective measure for reducing C&D waste (Baldwin et al., 2009; Baldwin et al., 2008; Li et al., 2015; Poon, 2007; Poon et al., 2004a; Wang et al., 2014; Zhang et al., 2012). Study revealed that large amount of C&D waste is generated from faulty design. The design specifications are inconsistent with the actual dimensions of building materials, which resulting in large amount of cut-offs during construction (Poon et al., 2004a). This can be avoided if designers can spend some time to study the technical information of the materials prior to design. Baldwin et al., (2008 and 2009) applied modeling information flows in the design process to evaluate the design solutions when seeking to reduce C&D waste in high-rise residential buildings.

Poon (2007) proposed other measures to avoid C&D waste generation, which were dimensional coordination and standardization, minimizing the use of temporary works, avoiding late design modifications, and providing more detailed designs. Poon et al. (2003) and Zhang et al. (2012) studied the low-waste building technologies and suggested to apply designs of thinner internal walls and floor slabs, smaller foundation size, reusing excavated spoils as back-fill material to balance cut and fill, modular building components and prefabrication, hanging cradles, and using recyclable aggregates and asphalt in buildings. However, the importance of proper design has not been widely acknowledged by the designers.

4.2.2 Building information modeling (BIM)

Building Information Modeling (BIM) is an intelligent 3D model-based process that gives building designers the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure by superimpose multi-disciplinary information into one digital building model (AUTODESK, 2020). Cheng and Ma (2013) developed a BIM-based system for estimating and planning demolition and renovation waste, which could efficiently manage the C&D waste generation through clash detection, quantity take-off, planning of construction activities, site utilization planning, and prefabrication in order to avoid design problems, changes, and rework. The operation flowchart is shown in Figure 4.1. BIM can achieve the following functions:

i. Provide detailed volume information of each element category,
ii. Provide detailed volume information of each material type,
iii. Estimate total inert and non-inert demolition and renovation waste volumes,
iv. Estimate demolition and renovation waste disposal charging fee,
v. Estimate total number of pick-up trucks for demolition and renovation waste.

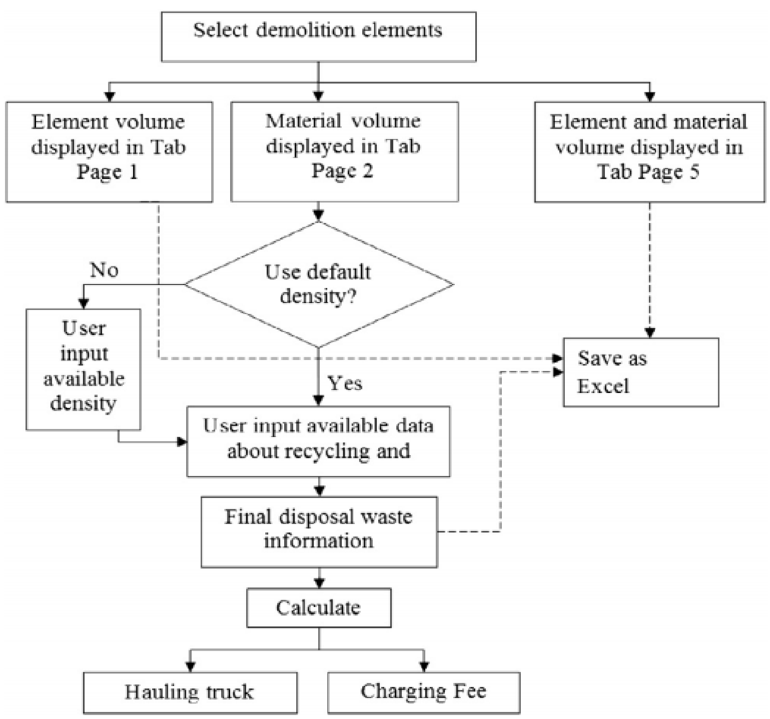

Figure 4.1 System operation flowchart (Cheng and Ma, 2013)

Liu et al. (2015) conducted a questionnaire survey and follow-up interviews with the architectural professionals in UK. A'BIM-aided construction waste minimization framework' was proposed based on the feedback. A cost-benefit analysis of demolition waste management was developed from BIM and used to analyze the disposal routes of demolition waste according to their characteristics (Hamidi et al., 2014; Park et al., 2014). C&D waste could be reduced by 4.3 to 15.2% through a BIM-based design validation process (Won et al. (2016).

4.2.3 Education and training

Williams (2014) claimed that education is important to the general waste management. Human behavior is an important factor of C&D waste management(Yuan and Shen, 2011). Change in the attitude of construction industry towards C&D waste management is more effective than improvements in building technology (Wong and Yip, 2004; Yuan and Shen, 2011; Ling and Leo, 2000). Education in waste management is crucial (Williams, 2014). Frontline staff including contractors, subcontractors and workers should be trained to follow the waste management procedures throughout the construction processes (Poon et al., 2004c).

4.2.4 Minimized use of timber from non-sustainable sources

Timber is a sustainable and the largest biotic fraction of construction material (Márton et al., 2014). UK has launched a quality standard for recycled wood (Wrap, 2012), which aims to support the sustainable wood-trade market and reduce timber waste. Exploring sustainable sources are essential to improve the sustainability of using timber in construction. Due to lack of local supply Hong Kong has to import timber from mainland or overseas. The construction industry can minimize the environmental impact of transportation by importing timber from nearby regions such as Asia and Oceania regions (Li et al., 2018).

4.2.5 Selective demolition

Selective demolition is an effective strategy for facilitating C&D waste reuse and recycling (Poon, 1997; Poon et al., 2004b). Selective demolition is 'principally' carry out the construction processes in a reveres manner, requiring a concise sorting of the different material according to respective categories before and during the demolition process so as to prevent contaminating inert or recyclable parts with wood, paper, cardboard, plastics and metals (Lauritezen and Hahn, 1992).

Selective demolition is usually carried out in the following procedures (Poon, 1997): (a) removal of remains and non-fixtures; (b) stripping, comprising internal clearing, removal of doors, windows, roof components, installation, water, air conditioning, electrical wiring and equipment, leaving only the building shell structure; and (c) demolition of the building shell. A picture was further given by Poon et al. (2004b) to illustrate the sequence of selective demolition process, as shown in Figure 4.2.

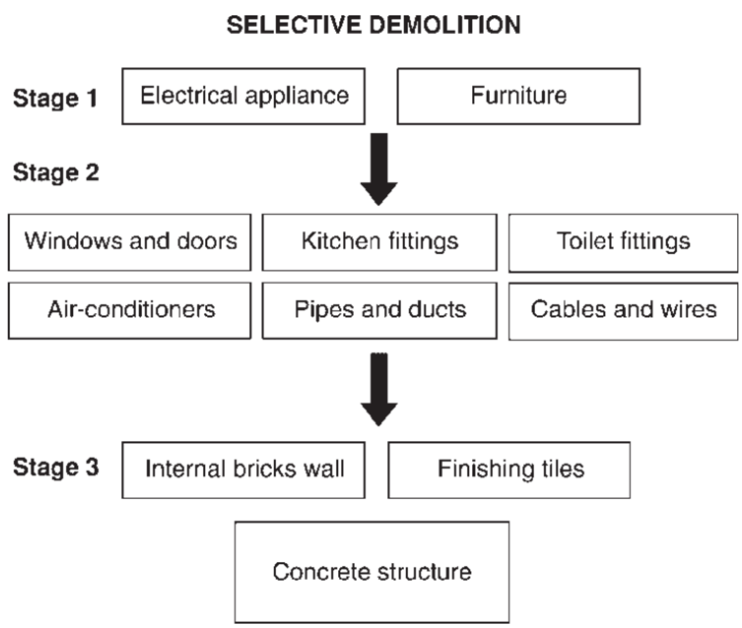

Figure 4.2 Sequence of selective demolition process (Poon et al., 2004b)

Selective demolition is remarked as a labor intensive and time-consuming activity, because almost all removal works are primarily carried out by hand. Lauritezen and Hahn (1992) estimated that the overall cost for the demolition work will be increased by 10~20% if selective demolition is implemented. Dantata et al. (2005) conducted an analysis of cost and duration for selective demolition of residential buildings. The study showed that the cost of selective demolition is 17% to 25% higher than the traditional demolition. In Hong Kong, contractors often development new project with fast demolition rate and rapid site clearance. In addition, special measures for sorting may be not possible due to time constraint and other site related factors (e.g. space limitations). Therefore, a major part of the reusable demolition materials could not be reclaimed (Poon, 1997).

In order to make contractors more willing to carry out selective demotion, there is a need to develop recycling markets to provide outlets for the collected recyclables (Poon et al., 2004b).

4.2.6 Waste sorting

Waste sorting is a prerequisite for successful waste reusing or recycling (Dupre, 2014; Vegas et al., 2015). Sorting C&D waste can be carried out (a) on-site or (b) off-site (Brunner and Stampfli, 1993; Lu and Yuan, 2012; Poon et al., 2001) responding to different site situations.

4.2.6.1 On-site sorting

On-site sorting is rated as an effective waste reduction strategy by many green building assessment systems (Wu et al., 2016). Poon et al. (2001) studied on-site sorting of C&D waste of different site conditions. The findings are summarized in Table 4.1. *Alternative 1* is suitable for large-scale projects where two refuse chutes can be set up for collecting inert and non-inert C&D waste separately. *Alternative 2*, which has only one refuse chute, is applied in small-scale projects with restricted site condition. Inert and non-inert C&D waste are collected separately at different days. *Alternative 3* with only one refuse chute deals with small-restricted site and manual sorting is required at specified area. The efficiency of onsite waste sorting and preference of application are in descending order from *Alternative 1 to 3*.

Although a high tipping fee is imposed, contractors have little incentive to perform on-site waste sorting due to time and labor-demanding. It is recommended to include onsite sorting in contractual requirements or make it mandatory.

Table 4.1 Three waste sorting alternatives at building construction sites

Alternative 1	(1) Two refuse chutes for each block: one for inert waste and the other for non-inert waste. (2) Separate collection of inert waste and non-inert waste from the refuse chutes. (3) Inert waste and non-inert waste are cleared by different trucks and disposed of at public filling area and landfills separately.
Alternative 2	(1) One refuse chute for each block. (2) Only one type of waste (inert or non-inert) will be collected and removed within a period of time (e.g. every 1 or 2 days).
Alternative 3	(1) One refuse chute for each block. (2) A sizable area for waste storage on the ground level. (3) Manual sorting of waste at the arranged area. (4) Separate removal of sorted wastes.

(Poon et al., 2001)

4.2.6.2 0ff-site sorting

Off-site sorting is carried out when the site conditions such as area is too limited to perform on-site sorting. Figure 4.3 is a flowchart of off-site sorting. The mixed C&D waste will be transported to an off-site sorting area where inert and non-inert waste were sorted. Inert materials will be sent to the public fill reception facilities while non-inert waste will be disposed at landfill. Lu and Yuan (2012) conducted two empirical case studies at Tuen Mun on off-site sorting facility. Since the introduction of off-site sorting facilities a total volume of 5.11 million tons of C&D waste was sorted from 2006 to 2012 contributing to a significant reduction of C&D waste disposal to landfills. The success of the off-site sorting program is attributed to 'sustaining policy support from the Hong Kong government', 'good policy execution', and 'implementing high disposal charges and the trip-ticket system'.

The effectiveness of off-site sorting can be improved by setting up off-site sorting facilities in more convenient locations, implementing effective measurements of the proportion of inert materials, prevention of noise and dust nuisance to neighborhoods and developing local recycling industry.

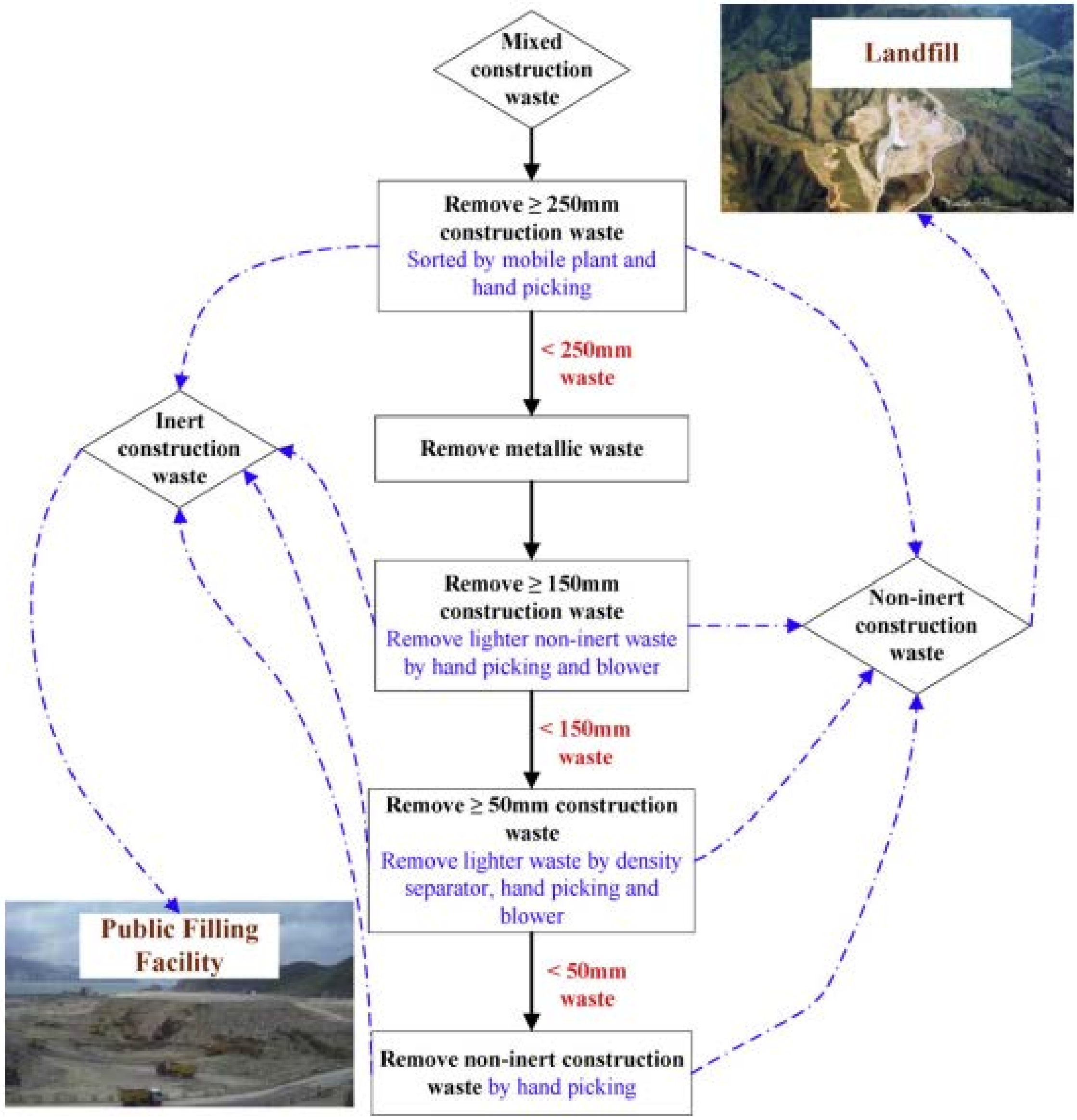

Figure 4.3 Flowchart of off-site construction waste sorting in Hong Kong (Lu and Yuan, 2012)

4.2.7 Integrated GPS and GIS technology

The purpose of integrating Global Position System (GPS) and Geographical Information System (GIS) technology is to transfer real-time location information of construction material and equipment (M&E) being used at a construction work. Li et al. (2005) introduced an integrated GPS and GIS technology for reducing the C&D waste. The conceptual model of GPS-and-GIS-integrated for M&E management system is shown in Figure 4.4. Long et al. (2009) and Su et al.

(2012) applied this technology to manage hazardous waste and material layout evaluation in renovation projects. Recently, Wu et al. (2016) applied this technology to demolition waste management. The GPS-and-GIS-integrated technology can help to improve efficiency and profits by providing real-time vehicle locations and status reports, navigation assistance, drive speed and heading information, and collect route history. Experimental results indicated that the proposed system can minimize the amount of on-site waste generation.

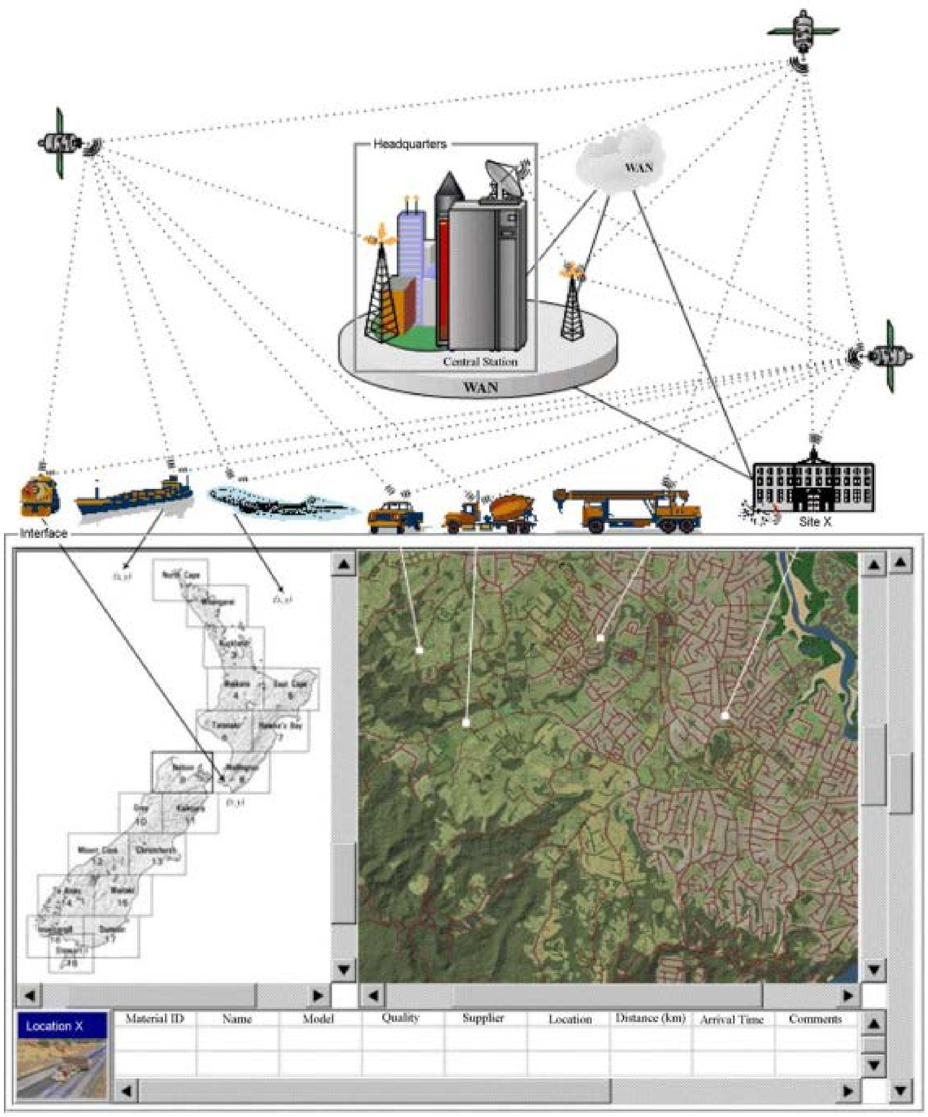

Figure 4.4 A conceptual model of GPS-and-GIS-integrated M&E management system (Li et al., 2005)

4.2.8 Incentive Reward Program

Admiration and financial reward can create incentive for construction workers to participate in C&D waste minimization (Warren, 1989; Kulatunga et al. 2006). Financial incentive program is an important measure to motivate workers, and proved to be effective in improving quality, and reducing project time and cost (Laufer and Jenkins, 1982). C&D waste management can be improved by rewarding workers according to the amounts and values of the wastes they have saved. Chen et al. (2002) introduced a group-based incentive reward program (IRP), which combined with an application of bar-code system, to meet the demand of on-site construction material management. A storage keeper is responsible to bookkeeping all the building materials which will be used in a construction project. Bar codes are printed on each item, or package (Figure. 4.5). The contractor's quantity surveyor will prepare an estimation on the amount of materials to be used prior to commencement of work. An identification card is issued to the group leader of each working group (Figure 4.6) of the project who is responsible for withdrawing all the materials needed by his group from the storage keeper. The group leader must return any unused materials to the storage keeper for record updating upon completion of work. The primary function of the bar-code system is to provide instant and up-to-date information on the quantities of materials withdrawn from the storage keeper by the group leaders. The storage keeper will scan the bar code and the label card of the team leader upon withdrawal and return of materials. The material-flow records will be used to calculate the exact amount of saving or over-consumption of building materials upon completion of the project. The contractor will be rewarded or penalized according to the saving or over-consumption. In the group-based IRP, members of the group will be equally rewarded or penalized.

Figure 4.5 Sample bar-codes for construction materials (Chen et al., 2002)

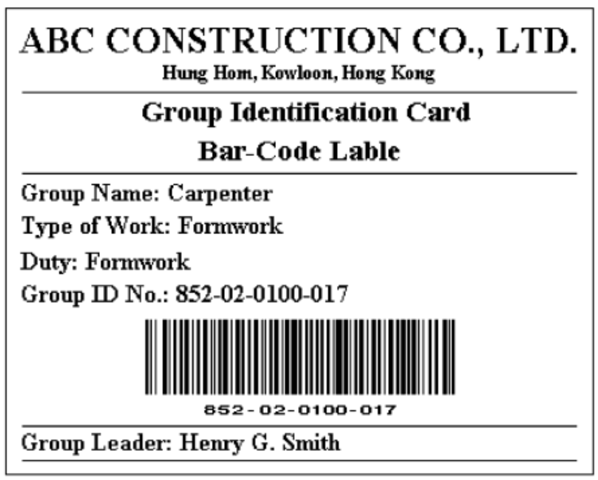

Figure 4.6 ID Card for the Carpenter group (Chen et al., 2002)

4.2.9 Online waste exchange

Middleton and Stenburg (1972) applied the concept of exchanging information of industrial residues to reducing waste volume. Commercial websites for trading waste material and equipment and professional websites for information exchange have set up subsequently due to development of effective multi-media communication. However, the websites for waste exchange are not widely accepted in the construction industry because: (a) contractors are not keen in C&D waste reduction; (b) profit gained from waste exchange is limited; (c) lacking a central platform coordinating different waste exchange websites, and (d) websites are not user-friendly (Chen et al., 2003). Chen et al. (2003) proposed an e-commerce model, which was named 'Web-fill' to solve the problems. Web-fill aimed to creating a convenient communication platform for contractors, developers, recyclers and local authorities for instant exchange their waste data. It can also help the local authorities to oversee the C&D waste management performance of developers and contractors at post-construction stage. The targeted users are contractors who generate C&D waste, landfill disposers who sort recyclable materials from C&D waste for sale, recyclers who buy recyclable C&D waste and sell to manufacturers who recycle C&D waste. The model was further improved in another research project published by Chen et al. (2006) improved the Web-fill system as presented in Figure 4.7. Web-fill system has the following advantages:

i. Contractors can use the Web-fill system to compensate the construction cost by finding buyer for their residual construction materials; purchasing residual, used materials and equipment from other contractors; buying inexpensive recovered materials from manufacturers; or dealing with recyclers.
ii. Manufacturers buy cheaper raw and processed materials or second-handed equipment at cheaper cost from contractors; and sell their recycled products on the Web-fill system.
iii. Recyclers can either sell second-hand materials to contractors and manufacturers on the Web-fill system or buy cheap materials from contractors.
iv. Landfill disposers can dispose of the C&D waste by selling recyclable or recoverable materials to manufacturers and recyclers at low prices or giving away free of charge through the Web-fill system in order to reduce the waste disposal charge of public filling facilities.

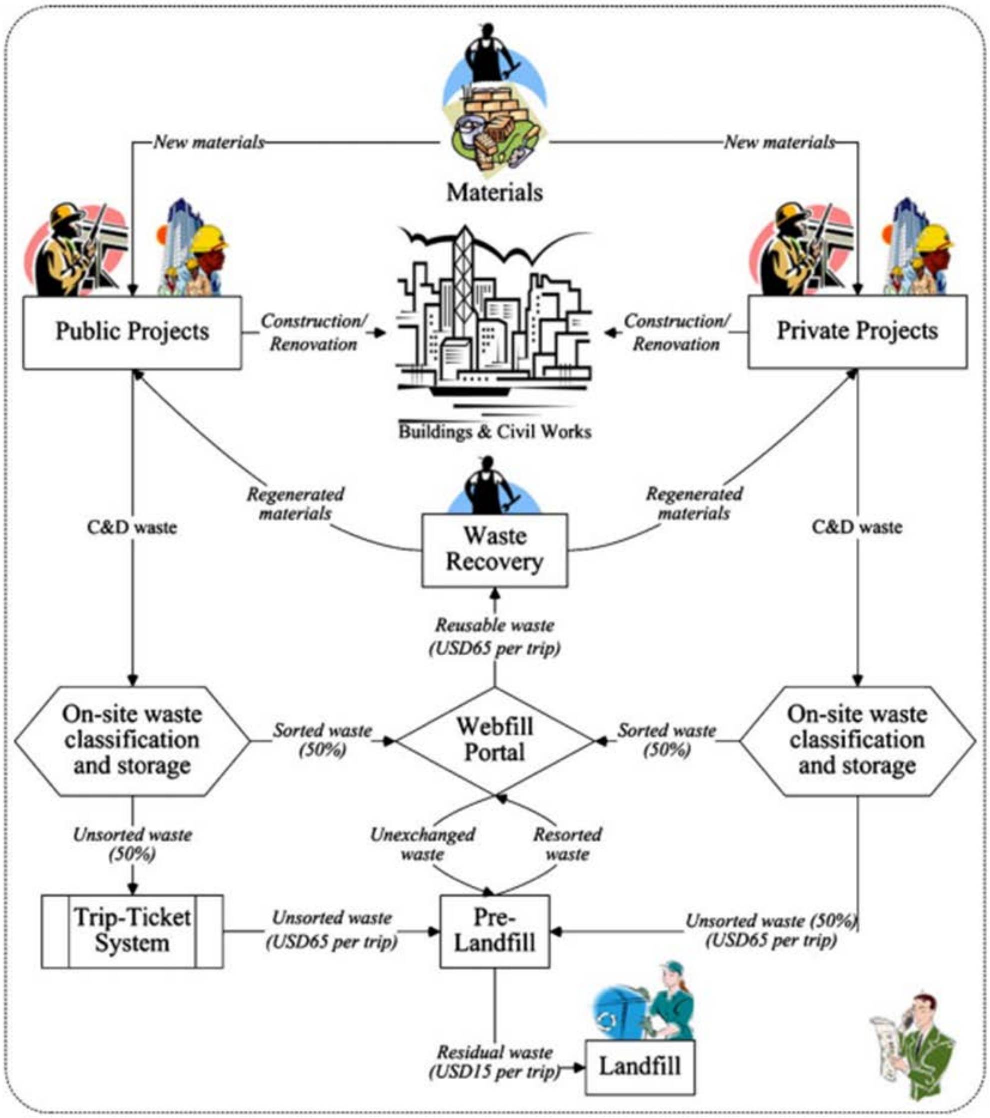

Figure 4.7 Design of the Web-fill system (Chen et al., 2006)

4.2.10 Use of prefabrication

Prefabrication is defined as 'a manufacturing process, generally taking place at a specialized off-site facility where various materials are joined to form a component, which is a part of the final installation' (Tatum et al., 1987). Various forms of prefabricated components have been applied in the construction industry. According to Tam et al. (2007b, c), those components can be generally classified into three categories: (a) semi-prefabricated non-structural elements, such as windows, ceiling, facades, and partition walls; (b) comprehensive prefabricated units containing structural prefabricated elements, such as columns, beams, floor or roof sheathing, slabs, load-bearing walls, and staircases, most of which are completed in the factory prior to assembly; (c) and modular buildings that are wholly completed off-site as a one-stop system.

Tam et al. (2007c) conducted a feasibility analysis of prefabricated construction activities by comparing the wastage levels between conventional and prefabrication constructions. It was found that prefabrication could reduce construction waste generation by up to 100% (reduce 84.7% of waste with the remaining 15.3% to be reused or recycled). Jaillon et al. (2009) estimated that the average wastage reduction level was about 52% by applying prefabrication in high-rise construction. The prefabrication technology can reduce around 60% of C&D waste during the life cycle of a building (Pons and Wadel, 2011) reflecting prefabrication technology is not limited to only improving buildability, quality and efficiency, but also reducing construction waste (Chiang et al., 2006) by reducing the amount of on-site wet-trade work (Li et al., 2014). Lu and Yuan (2013) conducted three case studies to analyze the waste reduction potential of using prefabricated building components in Hong Kong from the upstream manufacturing factories in the Pearl River Delta Region (PRDR) of Mainland China to delivering across the border to construction sites in Hong Kong. The maximum waste generation rate in the upstream processes of off-site prefabrication is 2% by weight, which proves that prefabrication technology is more environmental friendly than the conventional cast in-situ construction method.

Although the research findings suggested that prefabrication could bring significant benefits to the Hong Kong construction industry, concerns were also proposed about its application in dense urban environments. However, implementing prefabrication technology to replace cast in-situ construction has several limitations, which are (a) high investment cost is required to manufacture a series of steel moldings, which is the major barrier; (b) the delivery cost of prefabricated components from Guangdong Province is more expensive comparing to conventional construction; (c) prefabrication causes more environmental pollution during manufacturing and transportation; and (d) fabrication requires less on-site workers that may increase the unemployment rate in building industry (Jaillon and Poon, 2008).

4.2.11 Use of Machinery Sprayed Plaster

Machinery Sprayed Plaster (MSP) replaces the traditional cement mortar in some refurbishment and renovation projects. The major difference is that the MSP is pre-mixed and applied by mechanized plaster sprayer instead of mixing and applying traditional plastering by hand. Applying MSP has the benefits of high productivity, low labour demand and less waste generation (Poon et al., 2008) and can enable a worker to skim a wall 5 times faster than using a hand float would (Emma, 2015). Most importantly, surplus MSP retain its applicability provided the plaster is kept moist thus reducing wastage.

4.2.12 Use of Non-timber hoarding

Timber hoarding, which is the commonly used in Hong Kong construction industry, is difficult to be reused and recycled generating a significant amount of timber waste (EPD, 2017). Steel hoarding is an environmental friendly alternative due to its durability and reuse value. Water-filled hoarding systems, which is suitable to be applied in small to medium sized construction sites is another alternative particularly for R&R projects. It is easy to be dismantled and redeployed to other locations with less time and cost.

4.2.13 Use of Aluminum formwork and steel false-work

Comparing with traditional timber formwork, aluminum formwork can be erected and strike off in a shorter time reducing the floor cycle to four days (Poon et al., 2008). Although it is more expensive than steel and timber by 35% and 20%, respectively, its merits of lightweight and recyclability can facilitate workers to work on it independently and generate less waste (C&SD, 2019).

4.3 Overview of Building Environment Assessment Method (BEAM) Plus

Green Building Rating Systems (GBRSs) plays an important role in promoting sustainable construction. Different countries have their own GBRS, such as the Leadership in Energy and Environmental Design (LEED) of US, the Building Research Establishment Environmental Assessment Method (BREEAM) of UK, Green Globes Certification of Canada, BCA Green Mark of Singapore, and Assessment Standard for Green Building (GB/T50378-2014) of Mainland China.

The Hong Kong Green Building Council (HKGBC) was established in 2009 and strived to promote the standards and developments of sustainable buildings in Hong Kong. BEAM Plus, which is recognized and certified by HKGBC, is the Hong Kong’s leading initiative to offer independent assessments of building sustainability performance relating to the planning, design, construction, commissioning, management, operation and maintenance of a building. 'BEAM Plus for New Buildings (NB) Version 1.1' and 'BEAM Plus for Existing Buildings (EB) Version 1.1' were launched in 2010 and revised to versions 1.2 in January 2013. 'BEAM Plus Interiors' was launched in 2013. 'BEAM Plus for Existing Buildings is updated to version 2.0 in 2015 (HKGBC, 2020).

4.3.1 Waste management requirements in BEAM Plus Existing Buildings

BEAM Plus EB Version 2.0 encourage owners of existing buildings to adopt green building management and upgrade the building services systems. There are two schemes under BEAM Plus EB Version 2.0, which are the Comprehensive Scheme (EBCS) and Selective Scheme (EBSS). In the EBCS certificate can be awarded by two approaches, which are one-step assessment and stepwise assessment. One-step assessment is primarily designed for assessing new buildings. Stepwise assessment is for upgrading existing buildings to achieve BEAM Plus certification, which can deliver clients with an intermediate result from a preliminary assessment on various aspects of the proposed building improvement. This can offers greater flexibility in managing project budgets and time constraints. The 'Plan-Do-Check-Act' approach is adopted for the continual improvement of the buildings in EBCS. The 'Better than yesterday' principle is adopted in the EBSS to assess the improvements carried out in aged buildings through building management. In EBSS, each aspect is assessed on an individual basis. It has a lower threshold than the EBCS without prerequisites. The requirements of C&D waste management in the two schemes are different as explained in Table 4.2.

Table 4.2 Differences between Waste Management Aspects of BEAM Plus EBCS and EBSS

Contents	Comprehensive Scheme	Credit	Selective Scheme	Credit
Prerequisite	• Waste Recycling Facilities • Materials Purchasing Plan	/ /	N/A	/
Selection of Materials	• Materials Purchasing Practices • Use of Certified Green Products • Ozone Depleting Substances	5+1B 2B 3	• Materials Purchasing Plan • Materials Purchasing Practices • Ozone Depleting Substances	3 20 4
Waste Management and Reduction	• Waste Management Plan • Recycling Facilities for Different Waste Streams • Food Waste Management • Waste Treatment Equipment • Action to Waste Reduction	1 4 1+1B 1 B 3+2B	• Waste Management Plan • Basic Waste Recycling Facilities • Recycling Facilities for Different Waste Streams • Food Waste Management • Action to Waste Reduction	3 3 6 4 7
Innovations and Additions	N/A	/	• Achievement of Wastewi$e Certificate • Educational and Promotional Program • Innovative Techniques/ Performance Enhancements	1 2 2B
		18+7B		53+2B

*B=Bonus

In BEAM Plus EBCS, the performance aspects are grouped into the six categories: (i) Management; (ii) Site Aspects; (iii) Materials and Waste Aspects; (iv) Energy Use; (v) Water Use; and (vi) Indoor Environmental Quality. The requirements regarding to C&D waste management are listed in the category of Materials and Waste Aspects (MWA). Two main contents are included in MWA: (i) Selection of Materials; and (ii) Waste Management and Reduction. 'Waste Recycling Facilities (WRF)' is a prerequisite in MWA, which aims to conserve nonrenewable resources by promoting recycling of waste materials. There is no specific requirement on C&D waste management in Selection of Materials. In the Waste Management and Reduction, a waste management plan for sorting, recycling and disposal of waste is suggested. In the Waste Management and Reduction, a waste management plan is suggested to be developed for sorting, recycling and disposal of waste. Waste stream audit and waste/recycling records will be assessed. Conclusively, BEAM Plus EBCS focus on household waste, food waste and WEEE rather than C&D waste.

The categories of performance assessment are the same in BEAM Plus EBSS in the Selective Scheme. The requirements of C&D waste management are also laid down in Materials and Waste Aspects. Three main contents are included, which are (a) Selection of Materials; (b) Waste Management and Reduction; and (c) Innovations and Additions. There is no prerequisite in the

Materials and Waste Aspects for BEAM Plus EBSS. More credits can be attained than in BEAM Plus EBCS. For example, the credits for the requirement of 'Materials Purchasing Practices' are 20. BEAM Plus EBCS focus on household waste, food waste and WEEE. The recommended waste reduction measures in BEAM Plus EBSS are different from BEAM Plus EBCS. Continual Improvement and Dissemination and Feedback is included in addition to Waste Management Plan and Waste/Recycling Records. Furthermore, Innovations and Additions concerning materials and waste are integrated into Materials and Waste Aspects in BEAM Plus EBSS.

4.3.2 Waste management requirements in BEAM Plus Interiors

In BEAM Plus Interiors Version 1.0 (BEAM Plus IN), the assessment aspects are grouped into the following categories: 1) Green Building Attributes; 2) Management; 3) Materials Aspects; 4) Energy Use; 5) Water Use; 6) Indoor Environmental Quality; and 7) Innovations. The requirements relating to C&D waste management are specified in the category of Materials Aspects (MA).

Table 4.3 Waste Management Aspects in BEAM Plus Interior

Content	Requirement	Credit
Prerequisite	• Use of Non-CFC Based Refrigerants • Minimum Waste Recycling Facilities • Timber Used for Temporary Works	/ / /
Material Aspect	• Waste Recycling Facilities • Interior Components Reuse • Furniture and Partitions • Modular Design Materials • Designed for Disassembly • Sustainable Flooring Products • Sustainable Ceiling Products • Sustainable Wall and Door Products • Zero PVC • Ozone Depleting Substances • Demolition and Construction Waste Reduction	2 3 3 1 1 4 4 4 1 1 2
		26

From Table 4.3, it can be seen that there are three prerequisites in the waste management aspects, two of the prerequisites are related to C&D waste management, namely 'Minimum Waste

Recycling Facilities' and 'Timber Used for Temporary Works'. BEAM Plus IN focus on reducing non-inert waste, for example, the collection of paper, plastic and metal waste is required in the Minimum Waste Recycling Facilities. In addition, timber used in temporary works is suggested to be selected from sustainable forestry or reused timber. Other requirements including reusing directly interior components, such as walls, glazing, doors, ceilings, flooring, furniture and partitions; applying modular design materials and disassembly design for effective separation and collection; and using renewable products for ceiling, wall, and door. Best practices in reducing C&D waste relating to sorting, recycling, and disposal are encouraged.

4.4 Summary of Current C&D Waste Management Policies and Measures in Hong Kong

Chapter 4 presents the current statutory and administrative of C&D waste management policies and measures in Hong Kong. Literature review includes academic papers, governmental and industrial association websites, and BEAM Plus.

From the academic papers, there are three C&D waste management policies in Hong Kong, which are 'Waste Management Plan', 'Construction Waste Disposal Charging Scheme' and 'Development of Waste Recycling Market'. C&D waste management policies are implemented through ten measures relating to 'Proper Design', 'Waste Sorting', 'Selective Demolition', 'Use of Prefabrication', 'Online Waste Exchange', 'Incentive Reward Program', 'Integrated GPS and GIS Technology', 'Building Information Modeling', 'Education and Training' and 'Implementation of BEAM Plus'. The perceived benefits and limitations of these policies and measures are summarized in Table 4.4.

Table 4.4 Advantages and potential limitations of presented policies and measures

Policy/measure	Advantages	Potential limitations
Waste Management Plan	Waste management plans are generally required before the commencement of construction projects.	Lacking enforcement of actual implementation
Construction Waste Disposal Charging Scheme	Financial incentives for performing C&D waste management C&D waste are classified into inert and non-inert categories in order to encourage sorting.	The current disposal charges are low compared with other countries limiting the incentives for better waste management.
Development of A Mature Waste Recycling Market	A mature recycling market will increase the willingness of construction stakeholders to sort, reuse or recycle materials.	Potential worries about the quality of recycled materials; Lack of quality specifications; Lack of sufficient support from government to the recycling industry.
Proper Design	Proper design can greatly reduce the generation amount of the C&D waste due to less rework and effective material control	The design aiming for waste reduction is not user-friendly to the end use. Especially for building maintenance
Building Information Modeling	The BIM technology has been used in Hong Kong.	More modules need to be developed for C&D waste management; Increase of cost for establishment.
Education and Training	Hong Kong government has held workshops and trainings for increasing safety awareness.	Lack of emphasis from government and other construction stakeholders; Increase of cost.
Minimized use of timber from non-sustainable sources	Support sustainable wood-trade market Reduce wood going to landfill. Improve the sustainability performance of using wood	Lack of sustainable wood resources in Hong Kong Logistic of wood may not be sustainable
Selective Demolition	Benefit-earning from selling sorted valuable materials; Cost-saving from disposal at public fills rather than landfilling; Recommendations from government and green building rating tools.	Space demanding; Time demanding; Cost demanding; Labor demanding; Lack of a mature recycling market; Lack of coordination in contract arrangement.
Waste Sorting	On-site sorting: Profit-earning from selling sorted valuable materials; Cost-saving from disposal at public fills rather than landfilling; Recommendations from government and green building rating tools.	On-site sorting: Space demanding; Time demanding; Cost demanding; Labor demanding; Lack of a mature recycling market to absorb the sorted materials.

	Off-site sorting: Lower cost than landfilling disposal.	Off-site sorting: Double handling as a high percentage of waste received need to go the landfills eventually; Need proper locations of the off-site sorting facilities in order to reduce transportation cost; Potential generation of noise and dust at the off-site sorting facilities.
Integrated GPS and GIS Technology	The GPS and GIS technologies are mature.	Lack of GIS information; Lack of successful practices; Increase of cost.
Incentive Reward Program	Waste reduction intentions of construction workers can be stimulated.	Lack of benchmarks to evaluate material savings; Lack of awareness from project managers or developers.
Online Waste Exchange	Techniques for developing an online waste platform are mature.	Lack of promotion from the government and related organizations.
Use of Prefabrication	The technology has been mature; Hong Kong government has promoted the implementation of this technology.	Higher initial and transportation costs; Last minutes design changes limit its use.
Use of Machinery Sprayed Plaster	High productivity, Low labor demand Less waste generated	Cost demanding; Extra training is necessary for workers
Use of Non-timber hoarding	More environmentally friendly and durable over a long period	Need extra space for hoarding storage
Use of Aluminum formwork and steel false-work	Lightweight and recycling potential	Cost demanding;
Implementation of BEAM Plus	Several C&D waste minimization measures have been recommended by government and BEAM Plus for proper design.	No minimum requirement on MA Credits in BEAM Plus and credits for C&D waste management BEAM Plus are not compulsory.

Chapter 5 Research Findings

5.1 Results of Interviews

Interview is an effective way to gather interviewees' opinion responding to a subject or described phenomena (Kvale, 1983). The most common type is face-to-face interview (Opdenakker, 2006). Interviewees are asked open-ended questions in a semi-structured interview, which have the advantages of: (a) exploring the perceptions and opinions of the interviewees while enabling probing for more information and clarifying answers; (b) using a standardized questions for different sample group to convey equivalence of meaning; (c) the differences in answers reflect the differences in view from a diverse group of interviewees with different backgrounds and disciplines; and (d) the open-ended questions allow interviewees to give unstructured as well as spontaneous responses to the research topic (Abrahamson, 1983; Barriball, 1994; Denzin, 1989; Gordon, 1975; Mann, 1985; Smith, 1975; Reja et al.).

In this research study, structured questions were drafted based on the findings of literature review and desktop study (Appendix A). Interviewees were invited to express their views relating to: (a) differences and similarities in renovation of residential and commercial projects; (b) reuse and recycling of C&D/R&R wastes; (c) the waste management plan; (d) difficulties and barriers in implementing waste management; (e) effectiveness of different strategies and technologies of C&D/R&R waste management; and (f) recommendations to motivate waste recycling and reuse. Real estate investor, designer/consultant, building contractor/sub-contractor, recycling contractor, government officials and related stakeholders who were engaged in building demolition and renovation projects were invited for interview. Consultants were invited to share their experiences in waste management and methodology of estimating the quantity of C&D/R&R waste generation. A copy of the interview questions for consultants is listed in Appendix A. The interviewees were asked to share their waste management plans, records of C&D/R&R projects, documents and experiences relating to implementing waste management. They were also requested to recommend other personnel who were engaged in building refurbishment for future interviews whenever possible at the end of interviews. Considering the nature and characteristics of the industry structure, this snowball sampling process was deployed for data collection (Salganik and Heckathorn, 2004) until no further respondents could be identified.

Semi-structured interviews were conducted from March to August 2019. Ten interviewees were selected from different disciplines as listed below. Table 5.1 summarized the comments from interviewees listed below:

- LINK REIT - real estate investor (LINK)
- Swire Properties Ltd. - Real Estate Investor (Swire)
- P&T Architects and Engineers Ltd. – designer and consultant (P&T-AE)
- YSK2 Engineering Co. Ltd. - demolition contractor (YSK2)
- Chun Wo Construction Ltd. – main contractor (CW)
- Hong Dau Construction Co. Ltd. – contractor (HDCC)
- P&T Construction Co. Ltd. – contractor (P&T-CC)
- On Fat Lung Innovative Resource Ltd. - recycling company (OFLI),
- Civil Engineering and Development Department (CEDD)
- Environmental and Protection Department (EPD)

Table 5.1 Summary of Semi-Structured Interviews

	LINK	**HDCC**	**YSK2**	**P&T CC**	**P&T AE**	**Swire**	**OFL**	**CEDD/EPD**
1. Waste generation on renovation of residential vs. non-residential buildings	-	No significant differences	More varieties & larger amount for R&R	Larger amount for R&R	More furniture for R&R	No significant difference	-	-
2. Common types of R&R/C&D waste	Floor **tiles**, glass, concrete, partition boards, Bricks & plastic	PVC pipes, bamboo scaffolding, concrete, plastic & surplus materials	Furniture & paper	Brick, concrete, plastering, **tiles**, wood & packaging	Concrete. Bricks, **tiles**, wood & sanitary ware	Floor & wall **tiles**, timber, metal & packaging	-	-
3. Top 3 types pf R&R/C&D waste in quantity	Floor tiles, glass & concrete	Plastic, bamboo scaffolding & concrete	Furniture, wardrobe & paper	Decoration, Plastering tiles & furniture	Inert waste, wood & sanitary ware	Furniture. Plaster board, packaging	-	-
4. Reusable/recyclable R&R/C&D waste	Metal	Bamboo & metal	-	-	-	Plastic & timber board, concrete aggregate	Metal, rubber, glass, asphalt	-
5. Waste Management Plan implementation	LEED	MB MSS	-	-	-	BEAM Plus, BIM model	-	-
6. Barriers to recycling • Lack of govt. support	-	-	Agree	-	-	Agree	Agree	-
• Govt. lack of long-term planning	-	-	Agree	-	-	Agree	Agree	-
• Lack of public incentive	-	-	Agree	-	Agree	Agree	Agree	-
• Limited storage & sorting spaces	Agree	-	Agree	Agree	Agree		Agree	Agree
• High cost/low profit	Agree	-	Agree	Agree	Agree	Agree	Agree	Agree
• Time-consuming	Agree	-	-	-	Agree	Agree	Agree	-

5.1.1 Types and amount of waste generated by R&R projects

The types of waste generated from renovations of residential and non-residential buildings are similar except R&R waste generated from residential buildings is larger in quantity and has more varieties. Swire stated that the amount of C&D/R&R waste generated was directly proportional to the construction cost. The volume of waste generated could be estimated from waste management fee and crosschecked by trip ticketing system. Renovations of project sum less than 10 million without major demolition work generate 3 to 5 tons of non-inert waste. From their records, renovating a 20,000 square feet commercial building generated only 4 to 5 tons of non-inert waste apart from furniture. According to P&T-CC, the three main types of C&D waste from residential buildings are furniture, wardrobe and paper contributing 5 to 10% of the generated waste. Almost all the waste is dumped to landfills. R&R waste was estimated to contribute an average of 10 - 20% of the overall C&D waste. HDCC added that the amount of C&D waste generated from demolition was about twice the volume of R&R waste generated from the same building. According to EPD (2017), 18 million tons of inert C&D waste was generated annually, of which 1.8 to 3.6 million tons was R&R waste. 4.6 million tons of the inert waste was used for reclamation and the remaining was stored in fill bank. Non-inert waste is composed mainly of timber, metal, plastic and pallet. The common types of waste generated from demolition and renovation projects are similar, which consist mainly of wall and floor tiles, bricks, concrete, wood, glass, PVC pipes, sanitary wares, packaging, and surplus materials. The largest quantity of R&R waste is timber waste generated from discarded furniture. Due to lack of onsite sorting spaces, majority of the construction waste generated from private projects is mixed waste and will be dumped to landfill. Currently only metal waste has recycle value. Metal (including copper wiring) can be recycled while bridge deck, steel and bamboo scaffoldings to be reused. Steel scaffolding can be reused as its life span is ten years, which is eight years longer than bamboo scaffolding. However, the cost of steel scaffolding is four to five times of bamboo scaffolding. HDCC has successfully reduced the cost of steel scaffolding to only twice the cost of bamboo scaffolding by developing the Metal-Bamboo Matrix Scaffolding System (MBMSS), which is a mixture of steel and bamboo structure. Swire reused the demolished timber board as temporary hoarding in the next project.

5.1.2 Common barriers to recycling of R&R waste

The common barriers to recycling of R&R waste can be classified into six major categories: (a) lack of sorting and storage spaces, (b) high cost, (c) insufficient government supporting policy, (d) complicated recycling processes, (e) immature recycling market, and (f) insufficient public education.

The process of sorting R&R waste is important to recycling. However, the site for R&R work is usually limited and crowded making it difficult to carry out onsite sorting. Moreover, it is difficult to find sorting and storage spaces near landfills. Currently, there is insufficient facilities provided for recycling industry. The sorting process of R&R waste is labor intensive, time-consuming and space demanding that may cause delay in construction period and disturbance to existing tenants/occupants.

Sorting concrete waste to appropriate size and the subsequently cleaning for reuse incur high cost in recycling. Waste management cost is inversely proportional to the project size. Swire estimated an additional of 20% and 3% of the construction cost were incurred in small and large project, respectively. Recycling contractors are expecting a payback period of 5 to 10 years.

P&T-AE commented that the Government's "business as usual" attitude in establishing waste management policies without providing sufficient funding and resources in supporting the development of recycling industry was the major obstacle to developing a mature recycling market. Land for developing recycling industry is scarce. OFL estimated that about 100,000 square feet of land was required for developing recycling industry. The financial incentive for developing recycling industry is low as a minimum of $100 million is required for setting up a recycling company. Besides, the lack of government long-term planning in infrastructure development always ends up in material wastage. For instance, the need to construct Terminal 2 of the Hong Kong International Airport without realizing the need in first instance had generated large amount of C&D waste, which can be avoided with prior planning.

The current recycling market is under development. Downstream recycling facilities for plastic, glass and paper are limited due to low revenue return. YSK2 added that even the price of recyclable metal waste had decreased from HKD 3000 to 1000 per ton but the transportation cost had increased since the banning of exporting metal waste to Mainland by the PRC government. The cost of recycling has increased as metal waste has to be exported to the third world countries. The high labour and land rental costs suffocate the development of recycling market. YSK2 reviewed that currently there was only one recycling contractor manufacturing Eco-brick from C&D waste. P&T-AE reflected that recycling contractors were interested in collecting waste from large-scale renovation projects only, which could generate profitable amount of R&R waste. LINK pointed out that branded tenants preferred to discard all the furniture of outgoing tenants during renovation in keeping their brand styles. Clients' lack of incentive, workers lacking the knowledge of recycling and low public awareness in recycling R&R waste also deter the development of a mature recycling market.

5.1.3 Strategies for C&D waste reduction

The strategies of reducing C&D waste as recommended by interviewees can be classified into six major aspects:

i. Pre-demolition audit and material control

P&T-CC and P&T-AE recommended main contactors to carry out pre-demolition audit in order to estimate the amount of materials to be used and waste generated from renovation project aiming to reduce material wastage, and R&R waste generation. Sub-contractor would be penalized if the amount of generated waste were higher than the estimated quantity. The cost saving that was achieved by waste management could be shared among the main contractor and sub-contractors. Implementing Pre-demolition audit can also arouse clients' awareness in waste management and facilitate developing "green business" for consultant companies. HDCC suggested inspecting the plumbing and drainage pipes prior to demolition and considering the alternative of repairing whenever condition allows. Implementation phase purchasing can help to minimize material wastage. BIM model can be used in early design stage of a renovation project through visualizing the construction processes in order to minimize abortive work and material waste.

ii. Reuse and recycling

Swire was utilizing different lift shafts to carry out onsite sorting of C&D/R&R waste. Inert and non-inert waste from large projects were transported by different lifts to the respective sorting areas. In smaller sites, construction waste were sorted and stored at different floors according to their types. Building designers are recommended to use durable and reusable materials as far as possible. HDCC reused bridge deck and metal scaffolding in the same or other projects. Currently only metal waste has economic value. LINK contractors used to collect metal waste and sell to recycling contractors. OFL recommended government to promote recycling of glass and rubber waste, which were easier to be sorted and cleaned. Eco-brick can be manufactured from rubber and glass waste. Rubber waste can also be used to produce playground paddings. Swire proposed to break up plasterboards and concrete wastes into smaller sizes, which could be used as filler for partition walls and concrete aggregate, respectively. The rebar extracted from concrete waste should be collected for recycling.

iii. Develop recycling market

A mature recycling market is an important facilitating factor in reducing construction waste. Presently the government is providing concrete waste free of charge to contractors of public projects. Government can facilitate the development of recycling industry by providing concrete waste to private contractors for recycling at basic cost as well as tendering out more private partnering projects. OFL suggested the government to support the waste collection services by subsidizing the logistic companies that transport C&D waste.

iv. Reclamation

CEDD stated that the Lantau Island reclamation project would cover an area of 130m^2, which required 200 tons of inert waste for filling. The current generation rate of C&D waste could not cover even half of the reclamation area. HDCC proposed government to allow using inert waste as a supplement to the expensive sea sand (HKD375/m^3), which could create financial incentive in concrete recycling. However, government only approve using sea sand in reclamation for urban development. YSK2 suggested that C&D waste could be treated and utilized as filling materials for land that do not require a long settlement period, such as recreational park.

v. Incineration

YSK2 agreed that incineration could be a feasible strategy to reducing C&D waste if the toxic gases emitted in the process of burning were treated prior to discharge. CEDD and EPD anticipated that C&D waste could be reduced sharply upon operation of the incinerator.

vi. Government support

Government should take lead in recycling C&D/R&R waste. Implementation of waste management and environmental management plan are currently required in public projects. Government should encourage implementing waste and environmental plans in private sector as well. P&T-CC suggested government to subsidize contractors who used recyclable materials in private projects by allowing developers or contractor, which had satisfied specified “green score” like BEAM Plus accreditation, to claim tax rebate. CEDD suggested that BEAM Plus to accredit 10% concession to construction projects which had satisfied specified standards in waste reduction. Swire proposed to include BEAM Plus as a mandatory requirement in waste management. P&T-AE has recommended two scenarios: either subsidizing the waste collection process according to project sum but allowing more margin profit for project sum below one million or subsidizing waste collection cost based on the amount of waste collected for recycling, say $100 per truck. HDCC and OFL suggested Government to review the present land use policy and allow more land for the development of recycling industry. Recycling industry should not be restricted to industrial land only. Open storage land could be used for recycling purpose. LINK suggested government to allocate land near landfills to be used as storage spaces of recyclable materials. YSK2 proposed government to establish a central policy team to establish strategies of promoting recycling market and set up an independent office or institute to monitor the recycling and reuse of C&D/R&R waste in private projects. Building Department can consider setting up a team to check compliance of waste management in private projects.

vii. Education

Presently, the construction workers lack the knowledge and skills in recycling C&D/R&R waste. Training courses should be conducted for workers. Construction Industry Council may consider conducting training courses for construction personnel to improve the incentive for waste management. Moreover, the public should be educated the concept of carrying out environment conservation and waste management in renovating their premises.

5.2 Summary of Site Visits

Site observations were arranged to seven different building sites at different stages of R&R work from Feb 2019 to July 2019. Some sites were visited before and after R&R work (Site B & Site F).

Detail information on site conditions, scope of renovation work, types of R&R waste, overview of waste management practices, barriers in implementing R&R waste management were collected through interviews with the Environmental Officers or Project Managers and site observations. Table 5.2 summarize the site visits. Figure 5.1. to 5.8. are photo-records of site visits.

Figure 5.1 Site visit at Site A - Religious Buildings – Sikh Temple

Figure 5.2 Site visit at Site B - Public Housing Estate 1 – Ping Shek Estate

Figure 5.3 Site visit at Site C - Hospital – Hong Kong Buddhist Hospital

Figure 5.4 Site visit at Site D - Public Housing Estate 2 – On Tat Estate

Figure 5.5 Site visit at Site E– Single Residential Building – Tak Shing Mansion

Figure 5.6 Site visit at Site F - Government Quarter

Figure 5.7 Site visit at Site F – Two Separate Dumping Skips for Inert and Non-Inert Waste Storage

Figure 5.8 Site visit at Site G - Educational Institution - PolyU

Table 5.2 Summary of Site Visits

Site	Date of Visit	Type of Building	Project Highlights	Waste Management Strategies	Comments
A	19 Feb 2019	Religious building	Rebuild temple instead of renovation after considering building condition and financial commitment	• No specific plan • Historic building components to be reinstalled • Electric appliances sold to Sikh members • Spare stock of floor tiles for future maintenance	Obstacles to minimizing waste • Insufficient recycling facilities • Lack of waste management knowledge • Recycling waste incurs extra cost
B **D**	21 Feb 2019 4 April 2019	Public Housing Estate 1 Public Housing Estate 2	Vacant Flat Refurbishment (VRF) Scheme under HD • Reinstate landlord's fixtures and fittings • Remove unwanted items installed by outgoing tenants • Remove hanging cabinets for safety	EMDI WO1/2018 on guidelines for site monitoring and control of VFR • Pre-inspection to prepare the "Refurbishment of Domestic Vacant Units Pre-work Inspection Checklist" • Minor repairing unless justified for complete replacement items	Factors of successful waste management: • Clear instructions & guidelines • Independent supervision by HD site staff
C	1 Mar 2019	Hospital	• Construction floor area is around 23,000m^2 • Contract sum $ 438m • In operation during renovation • Refurbishment work is carried out in phases	• Building elements to be retained as far as possible • Phase dumping • Daily Record Summary of C&D waste • Trip Ticketing System • A list of designated recycling contractors • Temporary reuse of demolition waste	Successful factors: • Support from top management is crucial • Client support is important • Educate construction staff and workers

E	30 Apr 2019	Single Residential Building	• Small scale R&R projects • Building refurbishment under Mandatory Building Scheme	No WMP	• Clients & contractors have no incentive for waste reduction • Refurbishment causing nuisance to occupants • No areas for on-site sorting & waste storage
F	23 May 2019	Government Quarter	• CFA of six buildings is 580,000 ft^2 • Re-flooring & repainting • Complete renovation of kitchens & bathrooms • Replacement of all doors • Window repair • Removal of asbestos elements	• Follow waste management plan of EPD and ASD • Selective demolition • Asbestos removal carried out by registered specialist contractor • R&R waste are sorted by types • 2 separate baskets for sorting inert & non-inert waste • Trip Ticketing System	• Selective demolition is effective in reducing R&R waste • Dumping area located on roadside due to site restriction
G	11 Jul 2019	Educational Institution	• New extension block to existing core T • Complete refurbishment for toilets	• No WMP • Selective demolition	Barriers to waste management: • No standardized waste reduction practices • C&D waste cannot stay overnight inside the campus • No on-site sorting due to limited size of site • On-site sorting not specified in Specification

5.3 Factors and Practices for Successful Waste Reduction of R&R Projects from Site Observation

The following are factors for successful waste management in R&R projects: encouraged to reduce waste generation in R&R projects: -

- Clients' commitment in waste reduction
- Top management commitment in R&R waste management
- Clear instruction and guidelines on waste management
- Educate worker on waste reduction
- Carry out regular site inspection on waste management

Good practices for successful R&R waste reduction are listed below:

- Apply selective demolition when possible
- On-site temporary reuse of demolition waste e.g., bridge deck and fence
- Use two separate dumping skips for sorting of inert and non-insert waste
- Place clear instructions in front of dumping skips in order to remind workers
- Phase dumping to perform on-site sorting in restricted sites
- Repair and making good as far as possible
- Sell secondhand furniture and electric appliances

Chapter 6 Development of R&R Waste Management Strategies

6.1 Proposed Strategies and Measures

The research team has identified the four potential R&R waste management strategies and measures that are suitable to be applied in Hong Kong.

6.1.1 Pre-refurbishment Auditing

6.1.1.1. Pre-demolition Audit

Pre-demolition audit (PDA) is the first step towards recycling of C&D waste aiming to understand the type and amount of elements and materials that will be deconstructed and/or demolished, and to issue recommendations on their further handling (EC, 2018). PDA can be applied to:

- Determine a clear idea of the "to-be-demolished" building infrastructure, including estimates of quantity and quality of waste materials that will be set free and recommendations for the waste management (Durao et al., 2014; Hurley, 2002),
- Develop tools for predicting and measuring waste from construction (Hardie et al., 2007),
- Provide a list of key demolition products that can be assessed using a reclamation valuation survey (Hardie et al., 2007),
- Identify and valuate the materials that can be reused and recycled, and propose segregation method (Hardie et al., 2007),
- Plan for selective demolition (Durao et al., 2014),
- Provide valuable information to client, architect, engineer, construction contractor and manufacturing industry in optimizing the existing buildings as part of the decommissioning, deconstruction and demolition process (EC, 2018; Hurley, 2002; McGrath, 2001).

The process of PDA includes five stages; (i) *Desktop Study*, (ii) *Field Survey*, (iii) *Inventory*, (iv) *Waste Management Recommendation*, and (v) *Reporting* (EC, 2018). PDA has three outputs, which are *Quantity Report, Potential Report,* and *Detail Auditing Report of Materials*.

i. Desktop Study

This stage aims to gather all the relevant information from the blueprints and sectional drawings or other work on the followings for identifying potential C&D waste and the construction techniques used in the building (Coelho and de Brito, 2011b).

ii. Field Survey

Field Survey carry out site visits including visual inspections, comparisons of findings with collected documents, planning of inspections and measurements, preliminary planning of deconstruction techniques and waste handling on site (EC, 2018).

iii. Inventory

In the Inventory stage, *Quantity Report* (including inventory and material assessment) recording overall quantity and quality of materials from building prior to demolition will be produced (EC, 2018).

iv. Waste Management Recommendation

A Potential Report will be produced at this stage identifying the potential of reuse & recycling, which includes (EC, 2018):

- Advice and guidelines for the safe removal of hazardous waste materials
- Re-use or recycling possibilities for certain (high value) materials
- Legally binding conditions for storage
- Transport and treatment of certain materials
- Recommendations deriving from the limitations of the field survey, etc.
- Specify the areas of the building potentially affected by contamination and the best way to deal with them before beginning the other activities of the project
- Consider selective dismantling to maximize the waste reduction

v. Reporting

A Detail Auditing Report of Materials (final report) will be produced, which is based on the desk-study report, minutes of the site visit; report of materials assessment and site management recommendation (EC, 2018).

6.1.1.2. Pre-refurbishment Auditing and Reuse/Recycling

Pre-refurbishment Auditing (PRA) was developed based on PDA. The aim of PRA auditing is to facilitate and maximize resource recovery of demolition materials for beneficial reuse/recycling, without compromising all safety measures and practices (BCA, 2019). The procedures of PRA is simplified with only 4 stages, which are (i) Information, (ii) Reports, (iii) Evaluation, and (iv) Reuse and Recycling (Figure 6.1).

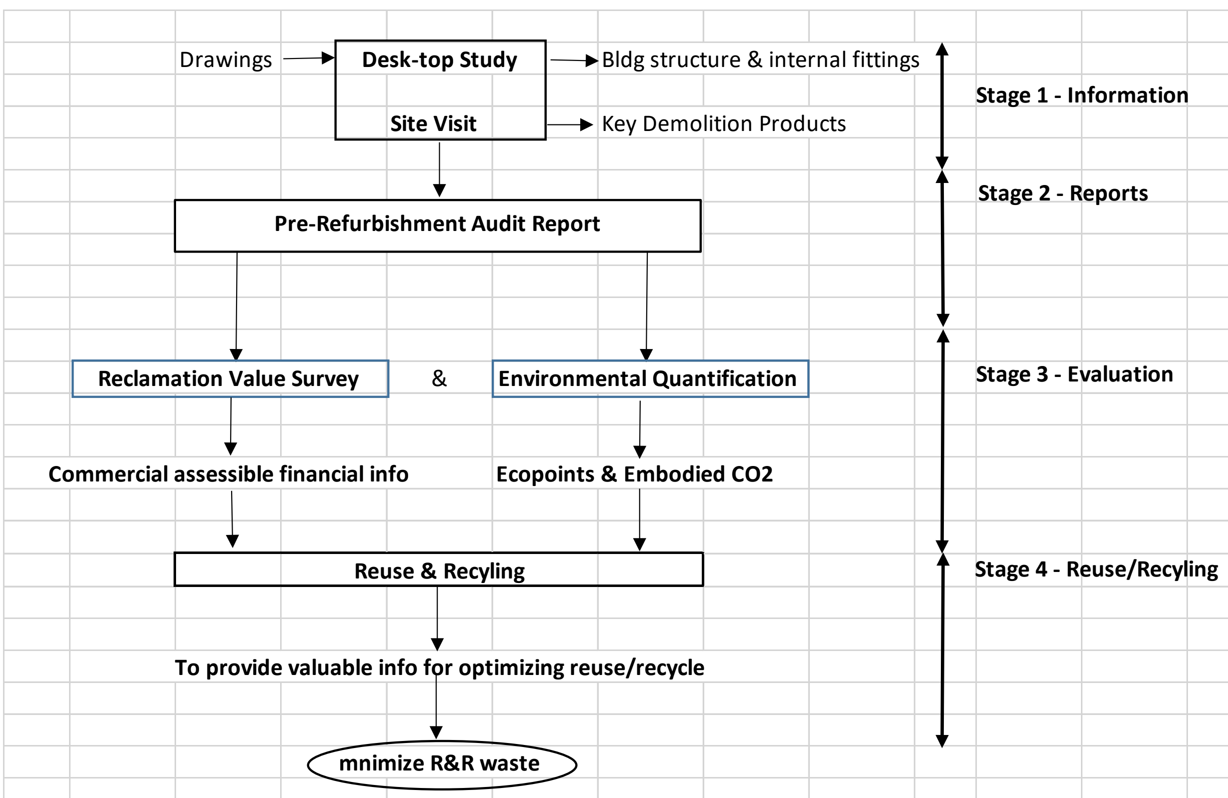

Figure 6.1 Flowchart of Pre-refurbishment Audit

i. Information Stage

The basic information of the building to be refurbished will be studied in details from building drawings and site visits to identify the features of the building such as age, condition, infrastructure, building components including furniture.

ii. Reporting

From Stage 1, a Pre-refurbishment Audit Report (Table 6.1) recording location and quantity of the anticipated R&R waste to be generated. The potential of the R&R waste for reuse and recycling will be assessed with target quantity. The actual quantity of reused and recycled R&R waste will be recorded.

Table 6.1 An example of Pre-refurbishment Audit Report

Building Fabric	**Location**	**Dimension/ Mass**	**Waste Potential**	**Target (%)**	**Achieved (%)**	**Remarks**
Concrete	External walls					
Bricks	Internal partitioning					
Copper	Bathroom & kitchen					
Glass	windows					
Furniture	Living & dining					
	Bedroom 1					
	Bedroom 2					
(others)						

iii. Evaluation

The environmental impacts of the discharged R&R waste and the potential of financial return from reuse or recycling these wastes will be calculated.

iv. Reuse and Recycling

A balance between the cost of environmental protection (including R&R waste sorting, transportation, etc.) and the financial return of reuse and recycling the R&R waste will be concluded from Stage 3 for final decision on reuse and recycling.

6.1.2 Development of Recycling Market

Recycling can contribute to "sustainable materials management" by reducing pressures on natural resource and save energy in producing the new materials (OECD, 2007). Recycling market development is defined as actions to enhance the economic vitality of the reuse/recycling industries, which includes (i) stimulating demand for recyclable materials and recycled content products; (ii) taking action to create new markets or expand existing markets; and (iii) fostering businesses that manufacture and market recycled-content products; and (iv) investing in R&D to increase recycling opportunities and efficiencies (Baldwin, 2013). The development is highly market-orientated subjecting to price volatility (OECD, 2004). The benefits of developing recycling market include job creation and reducing waste (Baldwin, 2013).

Organization for Economic Cooperation and Development (OECD) has identified five significant barriers to developing recycling market, which are search and transaction costs; information failure; consumer perceptions and risk aversion, technical externalities; and market power (OECD, 2004, 2005, 2006 and 2007). "Search cost" is particularly high due to diverse types of waste materials and the "transaction" costs are likely to be even more difficult in cases where the waste is mixed. However, recycling R&&R waste has the advantage of the categories of waste are limited mainly to timber, metal, concrete and paper. Consumers may be reluctant to buy items manufactured from recycled materials because of a lack of accurate information about their reliability and performance. Government can reduce search cost by establishing a trading platform for recycling, which is similar to e-commerce platform or assign the work to organizations like Construction Industry Council (CIC). Reference can be made to The Austrian Compost Ordinance, which is the central and comprehensive legal instrument laying down the production, marketing and labelling of compost as a product (Ableidinger, 2006), to standardize the provided information of recyclable R&R waste which cover timber, metal and concrete waste. However, public authorities can play three useful roles in these areas:

- Serve as a trusted source of demand by using recycled products
- Provide information on the quality of the products manufactured from recyclable materials
- Develop standards and performance criteria of recycled products

The increasing complexity of product design, and the materials used has increased the cost of recovering recyclable material. Public authorities can support research and development for technologies used in sorting and reprocessing facilities (OECD, 2007). Some of these costs and consumer perceptions about recycled products will become less important as the market matures. However, policy intervention is still necessary to regulate market development. A thorough understanding of the markets and the means by which different policies interact with each other and impact upon the market will be keys to developing the right mix of policy interventions (OECD, 2007).

The semi-structured interviews reviewed that the major barriers to developing local recycling market were due to (i) insufficient on-site sorting spaces; (ii) lack of government support; (iii) complicated recycling process; and (iv) lack of public incentive in recycling.

6.1.3 Sea Reclamation

'Lantau Tomorrow' Vision is a development project launched by Chief Executive Carrie Lam in her 2018 and 2019 policy address (Hong Kong Government, 2018 and 2019). It focuses on the creation of artificial islands with a total area of about 1,700 hectares through massive sea reclamation near Kau Yi Chau and Hei Ling Chau of the eastern waters of Lantau Island. The project aims to provide about 260 000 to 400 000 housing units in the future. Apart from social debates, the most concerned technical problems are the reclamation technique and the types of filling material (Netula, 2017). The 'Lan Tau Tomorrow' project requires around 58.65 million tons of fill materials. The major fill material for Hong Kong is sea sand, which is imported from mainland and other Asian regions. The sand price is high due to its shortage in supply (Tom, 2019). The reclamation projects of Hong Kong are facing critical financial challenges. Sea sand used in Hong Kong is mainly purchased from Guangxi (FactWire, 2018). Due to the rapid development of the Greater Bay Area, many sea reclamation projects are progressing in Guangdong province, which are purchasing sea sand from the same area. As the demand is greater than the supply, the price of sea sand is increasing rapidly particularly after release of 2018 Policy Address (C&SD, 2019). The price increased from HKD 169/ton in June 2018 to HKD 256/ton in July 2018 (Figure 6.2). The highest price of HKD 278/ton reached in May 2019. If the 'Lantau Tomorrow' project uses only sea sand as the fill material, the government will need to spend about HKD 162 billion for purchasing sea sand. Tables 6.2 and 6.3 illustrate the estimation quantity of fill materials and cost of sea sand, respectively (C&SD, 2019). There is an urgency to explore alternative materials for reclamation.

Table 6.2 Estimation of Required Quantity of Fill Material for ‘Lantau Tomorrow”

Reclamation Area	=1700 hectares (17 km^2)
Reclamation Depth	= Average Water Depth + Artificial Island Height + Settlement Compensation = 15m + 6m + 2m = 23 m
Required Volume of Fill Material	= 17×106 (m^2) × 23(m) = 3.91×108 (m^3) = 391 million m^3
Assume Density of Fill Material	≈ 1500 kg/m^3
Required Weight of Fill Material	= 3.91×108(m^3) × 1500 (kg/m^3) = 58.65 million tones

Table 6.3 Estimation Purchasing Cost of Sea Sand

Average Density of Sea Sand	= 1.5 g/cm^3 =1500 kg/m^3
Cost of completely using sea sand as fill material in sea reclamation	= [3.91×108(m^3) × 1500 (kg/m^3)]/1000 × 276 (HK$/ton) = HK$1.6187×1011 = 161.87 billion HK dollars

Price of sea sand in June 2019 = HKD 176/ton (C&SD, 2019)

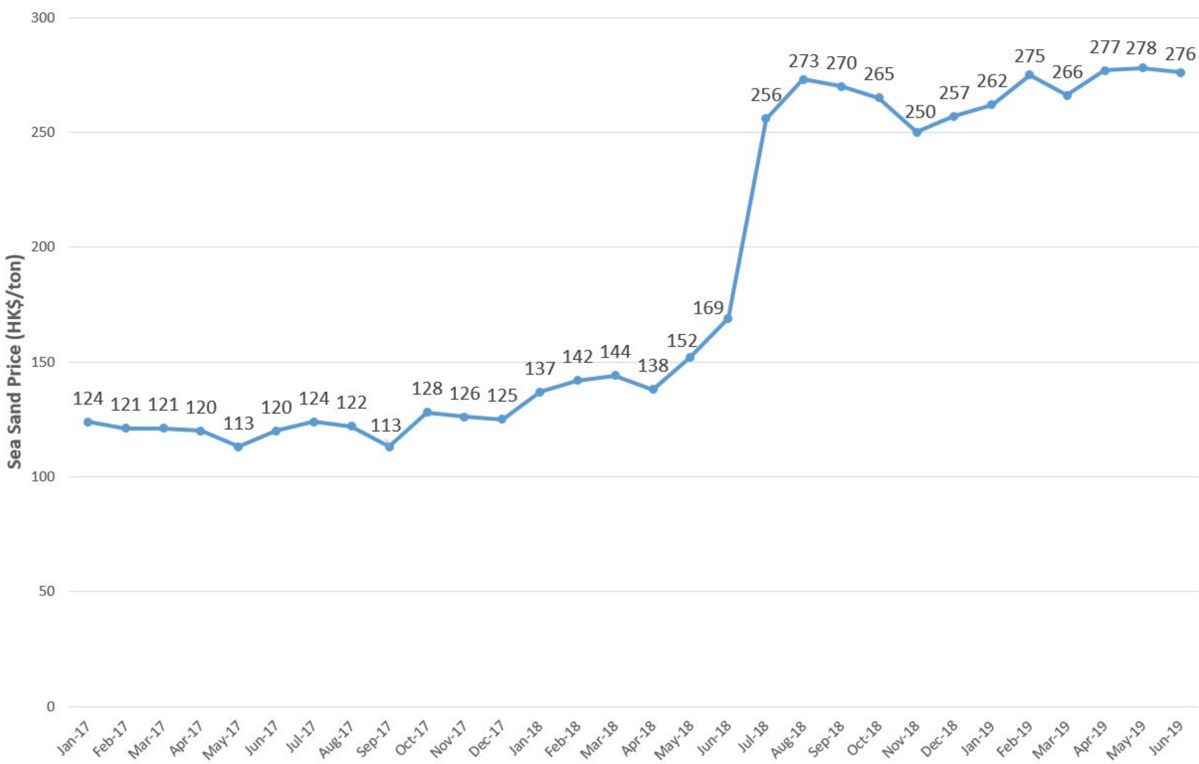

Figure 6.2 Sea Sand Price Trend in Hong Kong from 2017 to 2019

(Source: https://www.censtatd.gov.hk/hkstat/sub/sp330_tc.jsp?productCode=B1060005)

Around 1.06 million of construction waste (Table 6.4 and 6.5) was sent to landfill directly without sorting and proper treatment in 2017 (EPD, 2017). On-site sorting of R&R waste, which is a mixture of inert waste and large portion of other non-inert waste materials, is difficult for many renovation/refurbishment projects particularly in single residential buildings (Ren, 2013). Disposing R&R waste directly to landfills are more economic than sorting for reuse/recycling. Promoting and facilitating sorting out the inert part of R&R waste to be used as filling materials can save reclamation cost (He, 2019). Inert waste from R&R projects can be utilized in reclamation project for constructing urban open areas and recreational facilities (Han et al., 2013). In the semi-structured interview with Dr. Feng, an expert in sea reclamation reflected that R&R waste consists of about 90% inert waste, which can be used for reclamation after proper physical and chemical treatment. Proper sorting and mechanical down-sizing the inert part of R&R waste to 10-20 mm can be used as filling materials of reclaimed land reserved for recreational facilities, park or train stations in the 'Lantau Tomorrow' project.

Table 6.4 Overall construction waste received by treatment facilities in 2017

Waste Treatment facilities	Tons per day	Tons per year
Public Fill Reception Facilities	35, 541	12, 972, 465 (12.97 million)
Landfills	2, 895	1, 056, 675 (1.06 million)
Sorting Facilities	2, 124	775, 260 (0.78 million)

(EPD, 2017)

Table 6.5 Government Waste Disposal Facilities for Construction Waste and Charge Level

Government waste disposal facilities	**Type of construction waste accepted**	**Charge per ton[#]**
Public fill reception facilities	Consisting entirely of inert construction waste[+]	$71
Sorting facilities	Containing > 50% by weight of inert construction waste[+]	$175
Landfills[@]	Containing ≤ 50% by weight of inert construction waste[+]	$200
Outlying Islands Transfer Facilities[@]	Containing any percentage of inert construction waste[+]	$200
# Except for the Outlying Islands Transfer Facilities, the minimum charge load is 1 ton + Inert construction waste means rock, rubble, boulder, earth, soil, sand, concrete, asphalt, brick, tile, masonry or used bentonite. @ If a load of waste contains construction waste and other waste, that load will be regarded as consisting entirely of construction waste for calculating the applicable charge.		

(EPD, 2020)

6.1.4 Incineration

Incineration is proven to be a reliable technology that can reduce the volume and hazardous properties of solid waste by combustion, and generate electricity at the same time (LegCo, 2005b). In this scenario, incinerable wastes are disposed of at an incineration plant (Ortiz, 2010). Incineration reduces largely the mass and volume of R&R waste largely by burning. The benefits of incineration include electrical energy recovery (reduces the need for other energy sources), disposal of ashes (save landfill spaces) and recycling of residues (manufacture into other new construction materials such as in road construction) (Olsson et al., 2006; Ortiz, 2010). Incinerable waste includes special wastes contaminated with hazardous substance and non-special wastes containing wood, plastic, paper and cardboard. Non-incinerable wastes such as crashed concrete, bricks, ceramic tiles and metals can be recycled or disposed of in landfill or public fill bank (Ortiz, 2009). Incineration ash is presently used as a cement additive or as concrete aggregate in road construction. Incineration ash is mixed with cement, limestone and other additives to form eco-cement in Japan (Shimoda and Yokoyama, 1999). It can be applied as aggregate in foundation layer and capping material in road construction (Lynn, 2017). Metal recovery from ashes support the economic value of incineration (Berkhout et al., 2011). Besides, incineration ash can be used to form stabilizing layer for protecting the geo-membrane and underground structure of the landfill (Kong et al., 2016; Li et al., 2014). Heat produced during combustion can be converted to electricity energy through steam turbine (Olsson et al., 2006). China, Singapore, Italy and France have demonstrated the successful application of incineration in waste management (Bruder-Hubscher et al., 2002; Ho et al. 2017; Qiang et al., 2018; Toraldo and Saponaro, 2015).

In 2002, the government invited local and overseas companies to submit proposals on development of Integrated Waste Management Facilities (IWMF) in Hong Kong (EPD, 2004). In the following year the government laid down a comprehensive waste management strategy for the next ten years (LegCo, 2005a), including the development of IWMF for bulk reduction of waste. The capacity of the IWMF is about 3,000 tons per day, which will consist of an advanced incineration plant, a mechanical sorting and recycling plant, and ancillary facilities. The Advisory Council on the Environment adopted the moving grate incineration technology as the core technology in Phase 1 of IWMF in 2009 (ACE, 2009). After conducting EI and EIA study, the artificial island with an area of 11.8 hectares at the southwestern coast of Shek Kwu Chau was passed to be the site for IWMF (CMD, 2008; EPD, 2011; LegCo, 2011). The design and built contract of the IWMF followed by a 15-years operation contract was awarded to Keppel Seghers-Zhen Hua Joint Venture in 2018. IWMF is planned to be operated by 2024 aiming to reduce the bulk size of mixed municipal solid waste (MSW) substantially and recover useful resources (EPD, 2018). It is anticipated that parts of R&R waste can be incinerated for producing building materials. Government can consider offering financial incentive to contractors who carry out on-site sorting to retrieve incinerable R&R and send to IWMF. Figure 6.3 illustrates the flow of waste volume reduction and waste recycling framework.

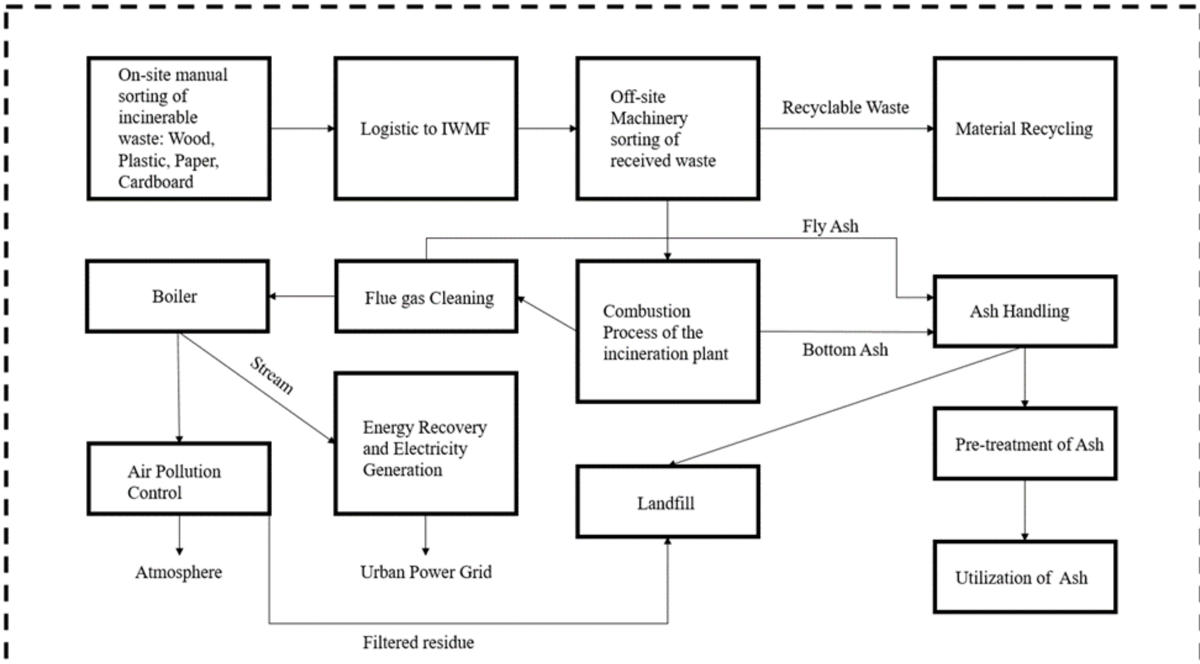

Figure 6.3 Proposed framework for construction waste incineration

6.2 Comments of strategies from the focus group meeting

A focus group meeting (FGM) was conducted on 11 of October 2019 at Building and Real Estate Department of the Hong Kong Polytechnic University. The meeting aimed to collect comments from stakeholders on the proposed strategies and measures to reduce R&R waste. Participants included an architect, a surveyor, a main contractor, a SME contractor, recycler, two scholars and representatives from Architectural Services Department, Environmental Protection Department, Civil Engineering and Development Department. The research team briefed the participants on the research findings and presented the four proposed strategies on minimizing R&R waste for their comments. The four strategies are (i) pre-refurbishment audit, (ii) development of recycling market, (iii) Sea reclamation, and (iv) incineration. Research group also mentioned that government support in developing and implementing R&R waste management strategies is a crucial factor for success. PowerPoint of the meeting is attached in Appendix B. Respective comments are summarized in below.

6.2.1. Pre-refurbishment Audit

Considerable opposition to the implementation of PRA is expected due to the incurred cost. Market readiness and stakeholders' acceptance shall be investigated prior to implementation. Public consultation on the process of PRA is essential. Require the coordination of CIC can be responsible for coordinating with construction industry in consultation and implementation. The auditing processes shall be considered early in the planning stage. A detail inventory of recyclable R&R waste shall be prepared enabling contractors to estimate the amount of recyclable waste and plan for the sorting and recycling process. The cost saving by implementing waste management efficiently will be shared among the construction team. Contractor will be penalized for failing to achieve the target reduction in R&R waste. The baseline for reward and penalty must be clearly defined to avoiding misuse. There may be some differences in the baseline for public and private projects. It is recommended that the baseline should be vetted and monitored by a third party. PRA can create "green business" consultancy. The Building Department may take up an active role in policy making and promoting PRA.

6.2.2. Development of Recycling Market

The construction industry has reservation in using recycled products due to insufficient provisions on information and references of the recycled materials. There are no clear guidelines on recycling. Contractors worry that they may be prosecuted for using substandard materials. No proper channel has been established for recycling companies to approach different government departments for obtaining approval of their products. The threshold for developing recycling business is too high requiring three to four years in establishing recycling facilities. Recycling contractors are facing the following difficulties in addition to the expensive running cost owing to high labour demand and rent:

- The stringent laws and regulations governing recycling,
- Additional cost of conducting Environmental Impact Assessment such as impact on air quality,
- Lengthy process to obtain approval on usage of recycled products from different government departments,
- Expensive logistic cost,

- Workers lacking the knowledge of recycling,
- Lack of public incentive in conducting recycling.

There is an urgency for government to develop local recycling industry as Mainland China has banned the importing of recyclable C&D waste. Government can consider adopting the following strategies in promoting local recycling market:

- Develop good practices in R&R management,
- Encourage the establishment of R&R Contractors Association (R&RCA) to train up workers in recycling and educate them the social responsibilities of reducing R&R waste,
- Promote public awareness in lengthening the life of building components by maintenance and repair instead of replacement,
- Educate the public the importance of waste sorting in building refurbishment,
- Publish guidelines on the topics of using environmental-friendly building materials, sustainable R&R technologies, and recycling of demolished furniture,
- Grant research finding to universities for developing innovative recycling technologies.

6.2.3.Reclamation

There is a much higher demand than supply of sea sand for the Lantau Tomorrow project. The inert part of R&R waste can be used as filling materials after sorting and treatment. Current policies encourage reusing C&D waste as filling materials in reclamation. Sorting facilities are provided at fill bank to select inert waste of appropriate size to be used in reclamation. The implementation of utilizing C&D waste can be extended to R&R waste after proper sorting and treatment. The government should increase the number of public sorting facilities or subsidize the private-operated sorting facilities as well as providing financial and technical support to promote sorting non-inert materials from C&D and R&R waste for reclamation.

6.2.4.Incineration

Government is building an incinerator which is expected to be completed by 2026 to 2028. The incinerator can cremate 3000 tons of municipal solid waste per day. However, there is no incineration development plan for Hong Kong. However, one incineration plant does not have the capacity to handle solid municipal and construction waste. Government should seek appropriate locations for construction of more incineration plants. Locating incinerators in outlying islands to avoid public opposition is not recommended as the cost of waste transportation will be increased thus margining profit gain. The public mindset of "not in my backyard" is the biggest challenge in developing incinerators as a means of waste management. Monitoring air quality in the neighborhood environment is an important consideration in incinerator operation. Hong Kong has stringent mandatory requirements in burning of solid waste. Adding R&R waste to the approved list of materials for incineration will complicate implementing incineration as a strategy of waste management.

6.2.5. Government Support

Government support is an important facilitating factor of R&R waste management. Government is taking the lead in minimizing C&D waste. The Building Department (BD, 2000) has issued the Practice Note for Authorized Persons and Structural Engineers 243 (PNAP 243) regarding minimization of C&D waste. It listed the opportunities to prevent waste from planning and design stage to construction stage. Waste Management Plan is introduced as a useful tool in ensuring that measures are taken during the construction stage to reduce C&D materials. The Public Fill Committee of Civil Engineering Department is prepared to offer advice to AP & RSE on the management and beneficial reuse of C&D material. The Works Bureau has established a Trip-ticket System in public works contracts for the proper disposal of C&D waste at public filling facilities or landfills and prevent illegal dumping. PNAP 243 is only a recommendation but not mandatory for private projects. There are no related policies for monitoring the implementation and compliances of the C&D waste management plan in private sector. It is suggested that BD took up the role of checking the implementation of waste management plan in periodic site visits or appoint independent inspectors/auditors to carry out periodic checking for private projects.

Government can consider creating incentive for contractors to implement waste management. However, direct tax rebate to contractors who have satisfied waste reduction requirements may jeopardize the principle of financial subsidy and attract illegal behavior in creating false documents. Moreover, the current Construction Waste Disposal Charging Scheme (WDCS), which allow contractors to pay less construction waste disposal charge depending on the amount of recycled

C&D waste. Introducing other financial subsidizing scheme create double benefit for contractors. It is recommended to form a central policy making team to study how to define a baseline for rewarding contractors for fulfilling R&R waste reduction and simplify the process of approving the application for rewards. Introducing an annual "Sustainable Refurbishment and Renovation Award" (SRRA), which is similar to Green Building Award, can encourage the good practice of waste recycling.

6.3. Recommendations to Government

Based on research findings from literature review, semi-structured interviews, site observation, reviews on documentation of C&D/R&R waste management and comments from participants of focus group meetings, the research team conclusively propose six R&R waste management strategies and measures to the government in the aspects of (i) Pre-refurbishment Audit, (ii) Development of Recycling Market, (iii) Sea Reclamation, (iv) Incineration, (v) Incentive and (vi) Education and Research, which are tabulated in Table 6.2.

Table 6.6 Recommended R&R waste management strategies and measures

	Strategies	**Measures**
i	Pre-refurbishment Audit (PRA)	• Consultation with building industry • Issue guidelines on PRA • Implement PRA in public projects • Promote reuse and recycling in public and private projects • BD to take up an active role in policy making and promoting PRA
ii	Development of Recycling Market	• Relax laws and regulations for approving recycling without jeopardizing public health and safety • Set up trading platform through CIC or other related non-profit organizations • Standardize labels for recycled building materials • Streamline the approval process • Facilitate forming R&RCA to train workers • Set up research funding for development of innovative technologies in recycling construction waste • Educate public on the importance of building maintenance & recycling
iii	Sea Reclamation	• Use inert waste from R&R projects as filling materials for urban open spaces in Lantau Tomorrow project

		• Increase the numbers of public sorting facilities or subsidize private-operated sorting facilities • Provide sorting facilities at landfills • Provide financial and technical support for sorting R&R waste for reclamation
iv	Incineration	• Offering financial incentive for carrying out on-site sorting incinerable R&R and send to IWMF • Lay down incineration development plan • Add R&R waste to the approved list of materials for incineration • Educate public the advantages of incineration
v	Incentive	• Introduce “Sustainable Refurbishment and Renovation Award” (SRRA)
vi	Education and Research	• Educate the public the importance of R&R waste minimization in environmental protection • Educate the public how to lengthen their buildings life • Educate R&R workers the social responsibility of reducing R&R waste • Provide research funding for development of innovative technologies in reducing R&R waste and exploring strategies and measures for R&R waste management

Chapter 7 Conclusions

7.1 Summary and Conclusions

Hong Kong is one of the leading financial centre constantly under expansion. There are over 5,000 buildings over 30 years of age, which may subject to carrying out extensive refurbishment under the Mandatory Building Inspection Scheme. Moreover, many building renovation projects are carrying out in residential and commercial buildings when new owners/tenants move in. Both construction and R&R work are consuming large amount of resources and generating huge amount of construction waste at the same time. The capacity of the landfills in Hong Kong is expected to reach saturation in 2020s. As R&R waste constitutes 10 to 20% of the C&D waste, there is an urgent need to study the problems generated by R&R waste and propose effective strategies and measures for R&R waste management.

The main types of R&R waste are concrete, timber, metal and glass. The effectiveness of R&R waste management can be measured by the amount of waste reduced. No single quantification method can fulfill all the scenarios. Site Observation is the most simple and direct method to obtain information of waste generation. Based on the information provided by Site Observation, the Generation Rate Calculation method is applied to find out the common unit of R&R waste generated from a particular site or construction activity in weight (kg/m^2), volume (m^3/m^2) or cost (kg/$1000). The amount of different types of R&R waste can be calculated from the area of the project or expenses of the type of material involved.

Reuse and recycling useful materials generated from demolition can effectively reduce the amount of R&R waste to be disposed at landfills. The main barriers in implementing R&R waste management relate to technical, economic, political and social aspects. The congested site condition makes it difficult to conduct on-site sorting particularly in occupied buildings. The process of waste sorting is labour and time consuming. The local recycling market is still immature. Downstream recycling facilities for plastic, glass and paper are limited due to low revenue return. The high cost of sorting and low financial return of recyclable materials impede R&R contractors to carry out on-site sorting and waste management. The high labour and land rental costs suffocate the development of recycling market. The government has established waste management policies without providing sufficient support and funding, which is the major obstacle to implementing

R&R waste management. Land for carrying out off-site sorting and developing recycling industry is scarce. The present maximum amount of government subsidy to recycling contractor is insufficient to set up a recycling company. The recycling contractors need to go through a lengthy process to obtain approvals from different government department on selling the recycling products. Moreover, the construction workers lack the knowledge and skills in recycling C&D/R&R waste and the public do not have incentive to carrying out environmental conservation and waste management in renovating their premises. Recommended strategies and measures in R&R waste management must be able to tackle these problems.

Based on research findings the research team conclusively propose six R&R waste management strategies and measures to the government in the aspects of (i) Pre-refurbishment Audit, (ii) Development of Recycling Market, (iii) Sea Reclamation, (iv) Incineration, (v) Incentive and (vi) Education and Research. Government should take the lead in conducting Pre-refurbishment Audit in public projects, and issue guidelines on Pre-refurbishment Audit as a reference to private projects, which is formulated after consultation with the building industry. The Building Department can consider taking up an active role in policy making and promoting Pre-refurbishment Audit. Government should study how to relax the laws and regulations for approving recycling materials without jeopardizing public health and safety and streamline the approval process to facilitate the development of recycling business. Other facilitating measures include setting up trading platform through CIC linking up R&R contractors with recycling contractors and/or potential buyers; establish a labeling system to standardize the qualities of recycled building materials; and designate funding for development of innovative technologies in recycling construction waste. Government can encourage R&R contractors to form association for training up skillful recycling worker. The public should be educated the importance of building maintenance, and the advantages of recycling and incinerating R&R waste in environmental protection. The inert materials sorted from R&R waste can be used as reclamation materials for the Lantau Tomorrow Project to reduce the cost of purchasing sea sand. Government can create more off-site public sorting facilities preferably near landfills or consider providing financial and technical support to private-operated sorting facilities. It is recommended to develop long-term incineration plan and extending the list of incinerable materials to cover R&R waste. Government can offer financial incentive to R&R contractors for sorting out incinerable materials and send to

IWMF. Introducing an annual “Sustainable Refurbishment and Renovation Award” can create an incentive for R&R contractors to implement waste management.

7.2 Review of the Objectives

The research has achieved the three objectives as listed in Section 1.4 with the following main findings:

Objectives	**Main Findings**
Objective 1 To examine the type and amount of waste generated, and how waste is created during refurbishment/renovation work of existing buildings in Hong Kong	The main types of R&R waste are concrete, timber, metal and glass. Most of these can be reuse or recycled. Construction industry disposed an average of about **4,000 tonnes** of construction and demolition waste at landfills per day in 2017. **10 to 20%** of the waste comes from refurbishment and renovation of existing buildings. Generation Rate Calculation method can be used to estimate R&R waste in weight (kg/m^2), volume (m^3/m^2) or cost (kg/$1000).
Objective 2 To identify the best practices promoting, and the perceived barriers hindering the management of waste reduction on refurbishment/renovation projects specifically in Hong Kong	The best practices include proper design, BIM, use sustainable building materials, selective demolition, on-site and off-site sorting, GPS and GIS, online waste exchange, pre-fabrication, machinery sprayed plastering, non-timber hoarding, metal formwork, incentive reward program, and education and training. The main barriers are related to financial consideration: insufficient space to carry

	out on-site sorting; waste sorting is labour and time consuming; low profit in recycling due to immature local market; and inadequate government support.
<u>Objective 3</u> To develop effective strategies and measures likely to minimize and manage the C&D waste generated by refurbishment/renovation projects	Six R&R waste management strategies and measures are proposed: 1. Pre-refurbishment Audit 2. Development of Recycling Market 3. Sea Reclamation 4. Incineration 5. Creating Incentive 6. Education and Research

7.3 Policy Implications and Recommendations

These key findings, as reported in the previous section, lead to a number of policy implications and recommendations as follows:

a) Pre-refurbishment Audit

The aim of pre-refurbishment audit is to retrieve reusable/recyclable building materials from the building during dismantling work. The contractor will check and record down what type and anticipated quantity of building materials that can be recovered for reuse/recycling before commencement of renovation work. The contractor will then dismantle the existing finishes and fittings step by step in order to sort out the items that are planned to be reused/recycled. The recyclable items will be sold to recycling contractors. The saving in cost will be shared between the contractor and the workers. If the amount of sorted recyclable materials is less than the planned, the contractor will be penalized. Pre-refurbishment audit can create incentive for contractors to sort out the recyclable waste, thus reducing consumption of natural resources and amount of waste to be disposed at landfills.

Government can develop guidelines for carrying out pre-refurbishment audit and take the lead to include pre-refurbishment audit in public projects to set up an example for private projects to follow.

b) Development of Recycling Market

Concrete, timber, metal and glass wastes generated from refurbishment and renovation work can be recycled for use. However, the local recycle market is immature lacking the technologies and market to facilitate the development of recycling market. Currently only metal can be sold for recycling. Others will be disposed of as their sale values are low and difficult to be cleaned for recycling. Government should study how to facilitate the development of local recycling business such as allotting research funding to universities or other organizations for developing innovative technologies to cleanse or prepare concrete, timber and glass (in addition to metal) suitable for recycling. Government can consider establishing a labelling system standardizing the quality of products manufactured from recycling materials, which can provide confidence on the qualities of recycled products to potential buyers.

c) Sea Reclamation

The non-decomposable components of refurbishment/renovation waste such as crushed concrete can be used as filling materials in reclamation. The Lantau Tomorrow Project will create a third core business district covering 1,700 hectares of artificial islands through massive land reclamation near Kau Yi Chau and Hei Ling Chau of the eastern waters of Lantau Island. The filling material, sea sand will be bought from Mainland. The cost of sea sand is very expensive, which is estimated to be more than 160 billion dollars. Inert waste from refurbishment/renovation projects can be utilized in reclamation project for constructing urban open areas and recreational facilities, thus reducing construction cost. However, construction sites are usually too congested to carry out labour and time consuming waste sorting. Contractors are reluctant to carry out on-site sorting due to high operating cost and may causing delay to the project. Government can create more off-site public sorting facilities preferably near landfills or consider providing financial and technical support to private-operated sorting facilities.

d) Incineration

Incineration is a reliable technology that can reduce the volume of solid waste by combustion and generate electricity at the same time. The volume of refurbishment/renovation waste can be reduced by incineration, which occupies less landfill spaces. Alternatively, the ash can be used as a cement additive or as concrete aggregate in road construction. Metal can be recovered from ashes for recycling. Government should consider to develop long-term incineration plan and extend the list of incinerable materials to cover refurbishment/renovation waste as well as offering financial incentive to contractors who sort out the combustible waste to incinerators.

e) Incentive

Good reputation is a valuable asset of a company and can act as an effective advertisement to the public. Government can improve waste management in refurbishment and renovation projects by introducing an annual "Sustainable Refurbishment and Renovation Award" to contractors who have successfully achieved in reducing refurbishment/renovation waste to a specified level.

f) Education and Research

Government can assist contractor associations to train up skillful recycler workers. The public should be educated the importance of building maintenance, and the advantages of recycling and incinerating refurbishment/renovation waste in protecting our environment making it a safe and healthy place to live in for us and our generations after. Government should set aside funding for carrying out research to explore or improve the technologies of recycling construction waste. The funding is recommended to be open for academia and public application.

7.4 Dissemination of Research Findings

The research findings will be summarized in two papers with topics covering “perceived difficulties in implementing R&R waste management” and “recommended measures on R&R waste management ”, which will be submitted to international refereed journals for publication.

A CPD seminar has been liaised with CIOB to present the research findings to building professionals tentatively in 8 July 2020 when the Novel Coronavirus epidemic has already declined.

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Appendices

Appendix A ***-*** *Interview Guides*

Sample of Interview Guide

1. Are there any difference(s) in the C&D waste generated from construction of new buildings and refurbishment of existing buildings?

請問新樓宇的建築工程及現存樓宇的翻新工程所產生的“拆建廢料”有何不同?

2. Are there any difference(s) in the renovation waste generated from residential and non-residential buildings? Please briefly describe the scope of renovation works and specify the types of non-residential buildings.

請問住宅及非住宅樓宇的“裝修廢料”有何不同? 請簡述翻新工程的範圍，及非住宅樓宇的類型。

3. Please list the common types of C&D waste generated from the refurbishment work from (a) residential and (b) non-residential buildings.

請分別列出由(a)住宅及(b)非住宅樓宇翻新改造工程所產生的常見“裝修廢料”類別。

4. Can you estimate the percentage of renovation waste responsible for the material generated from construction and demolition sector in Hong Kong?

就您所估算，“裝修廢料”佔了全港總“拆建廢料“的百分之多少？

5. Which types of renovation waste ranked the top 3 in the generated amount?

請問哪些類型的“裝修廢料”佔總“拆建廢料“產生量的前三位？

6. What types of renovation waste can be reused or recycled?

請問哪些類型的“裝修廢料”可以重複使用或回收再造？

7. How do you estimate and quantify the renovation waste produced on site?

請問您如何估算及量化由建築地盤所產生的“裝修廢料“？

8. Do you think C&D waste management in building refurbishment is important to preserve our environment?

請問您認為樓宇翻新改造項目中的“拆建廢料”管理對於保護我們的環境至關重要嗎？

9. Do you try to reduce C&D waste in your renovation projects? OR do you reuse or recycle C&D waste? (Please elaborate)

請問您是否曾經嘗試減少工程項目的“拆建廢料”？ 或者您是否曾有循環再用或循環再造”拆建廢料”? (請詳細說明)

10. (If answer to Q.9 is "NO") > What is the main reason you do not practice reuse/recycle of C&D waste in renovation projects?

(如無上一問題所述經驗) 請問在翻新改造項目中, 您不進行 “拆建廢料” 循環再用/再造的主要原因是什麼？

11. What are the barriers and difficulties to renovation waste management and reduction practices in Hong Kong?

請問目前香港的“裝修廢料”管理和減廢措施正面對哪些障礙和困難？

12. Which strategies below are effective in C&D waste reduction for building renovation?

請問以下哪些策略可有效減少翻新改造工程中的“拆建廢料”？

a) Material control [ ]. Any difficulties?

建築材料控制[ ]. 潛在困難?

b) Waste sorting [ ]. Any difficulties?

廢料分類[ ]. 潛在困難?

c) Reuse and recycle [ ]. Any difficulties?

循環再用及再造[ ]. 潛在困難?

d) Active & mature market of the recovered materials [ ]. Current situation?

成熟及活躍的廢料回收市場[ ]. 目前香港的情況?

13. Can you recommend other contractor/project manager in building refurbishment to us?

Please provide company name, contact person and contact method.

請問您能否介紹其他從事樓宇翻新改造工程的承建商/分判商/項目經理予我們進行採訪？

煩請提供公司名稱，聯絡人姓名及聯絡方式，

THANK YOU！

感謝您的寶貴意見！

Appendix B - *PowerPoint Slides for Focus Group Meeting*

Strategies and Measures for Construction and Demolition Waste Management of Refurbishing/Renovating Existing Buildings in Hong Kong

for

Policy Innovation and Co-ordination Office

Focus Group Meeting (11 October 2019)

Dr. Ann T.W. Yu, Principal Investigator
Dr. Irene Wong, Research Fellow
Mr. Kelvin S.H. Mok, Research Assistant

1

Purpose

To obtain comments, views and ideas of the participants on the Strategies and Measures for Reduction and Management of Refurbishment and Renovation Waste

Agenda

12:00 – 12:15	Reception
12:15 – 12:20	Welcome and introduction
12:20 – 12:40	Presentation by researchers
12:40 – 1:50	Feedback and discussions
1:50 – 2:00	Wrap up and conclusion

2

2

Background

- Hong Kong has over 42,000 existing buildings, majority are over 30 years old
- Over 5,000 residential and composite buildings aged 50 years and above
- These buildings need to be renovated and demolished since inadequate and improper maintenance leads to urban decay
- The refurbishment and renovation (R&R) of these buildings will contribute a large portion of R&R waste to landfills.

3

3

Introduction

Definition of Refurbishment and Renovation Waste (R&R)

- A hybrid of C&D waste from improvements and repairs to existing structures (Public Works and Government Services Canada, 2013)
- Mainly composed of concrete, asphalt, wood, metals, gypsum wallboard, and roofing (Nitivattananon and Borongan, 2007)

Effects

- Environmental pollution + endanger public health & safety + jeopardize profitability of enterprises + saturate landfills + waste public money in waste treatment (Poon et al, 2003; Esin and Cosgun 2007; Yuan and Shen, 2011; Adjei et al., 2013)

➡ **R&R Waste Management is crucial**

4

4

Research Objectives

1. To examine the types and amount of waste generated, and how waste is created during R&R works of existing buildings in Hong Kong.

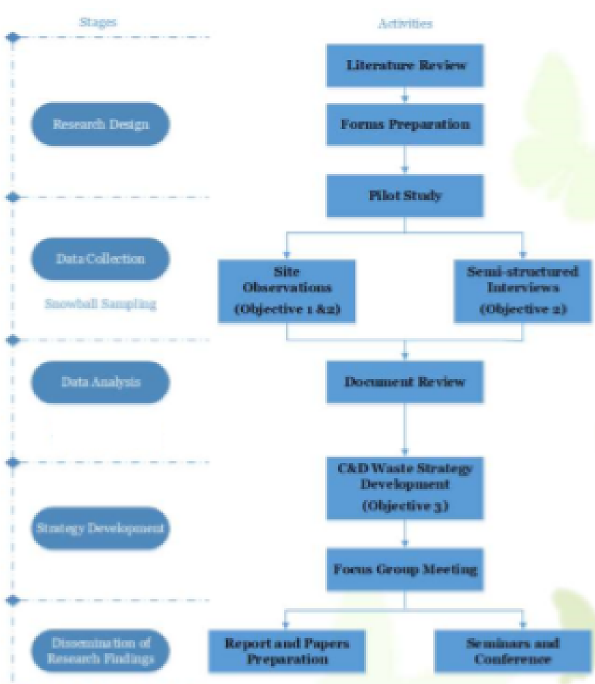
2. To identify the best practices promoting, and the perceived barriers hindering the management of waste reduction on R&R projects specifically in Hong Kong.

3. To develop effective strategies and measures likely to minimize and manage the C&D waste generated by R&R projects.

5

5

Research Methods



6

6

Renovation waste types from academic papers

R&R Waste

Inert Waste
- Brick & tiles
- Bituminous mixtures
- **Concrete & mortar***
- Lime sand

Non-inert Waste
- **Wood/timber***
- Gypsum & plaster
- Composite board
- Plastic & rubber
- Paper & cardboard
- Iron & steel
- Aluminum alloy
- Glass
- Insulation materials
- Asbestos

* Most common R&R waste

7 (Bergsdal et al., 2007; Thorpe, 2010; Hardie et al., 2011; Appleby, 2011; Tischer, 2013; Mália et al., 2013; Ren, 2013; Baba et al., 2013; Hosseini, 2015; Lu et al., 2015; Villoria Sáez et al., 2016; Ghose et al., 2017; Yu et al., 2018; Tallini & Cedola, 2018)

7

Overseas C&D Waste Management Strategies and Measures

Country (Recycling Rate)	Strategies	Legal	Environmental/ Social	Assessment
Spain (17%)	NWD	NWD	NWD	BREEAM ES
US (25%)	• Adaptability • Deconstruction • Reuse	• Landfill tax • Solid waste disposal	• Source reduction	BREEAM USA; LEED
Canada (25%)	• Resource Recovery Fund	• Landfill tax • Onsite sorting • Waste Audit	• Invite proposal for C&D/R&R management	CaGCB; LEED Canada
Sweden (50%)	• Refund reuse/recyclable waste	• Landfill tax + prior treatment	• Inspection Plan prior to commencement	BREAAM SE; LEED 2009
UK (62%)	• Reduce land tax for complying Site Waste Management Plan	• Landfill Tax, Enforce waste separation	• Waste Management Plan, • Packaging (Extended Producer Responsibility)	BREEAM UK
Japan (65%)	• Basic Environmental Acts as policy, • Sound material-cycle society, • Incineration	• Construction Materials Recycling Law for by-products • Demolition contractor registration	• Basic Environmental Act • Work Plan for sorting	CASBEE - RN
Singapore (99%)	• **Holistic approach: environment vs. comfort – partnering with stakeholders & community,** • Pre-demolition Audit • Sequential Demolition, • Onsite Sorting; • Million Green Mark Incentive Schemes	• Demolition Protocol; • Licensing for disposal;	• Building Control (Environmental Sustainability) Regulations;	BCA Green Mark Scheme

The **effectiveness** of C&D waste management can be reflected in the **recycling rate**

8 (BCA, 2019; Chew, 2010; NEA, 2019; Tam, 2008)

8

Influencing Factors of Sustainable C&D Waste Management

a) ***Market-based economic aspect***: tax, government subsidizes & economic incentives

b) ***Environmental/social aspects***: environmental standards & culture; public health & safety; social participation

c) ***Legal aspect***: laws & regulations, implementing R&R waste management policy and quality standard

(Calvo et al., 2014; Manowong, 2012)

9

9

Best Practices for C&D Waste Management

a) Adaptability
b) Pre-demolition Audit
c) Waste Management Plan
d) Selective Demolition
e) Onsite Sorting
f) Reuse/recycling
g) Incineration

10

10

R&R Waste Management in HK

- 32% recycling rate in 2017

Market-based Economy	Construction Waste Disposal Charging Scheme 2005	• Minimize R&R waste to landfills • Attribute more cost for waste management
Environmental	Green Manager Scheme	• Encourage waste and energy saving in daily life
	Waste Management Plan 2003	• Benefits on-site material reuse and waste reduction
	'Use of Recycled Aggregates in Concrete' technical guideline 2003	• Encourage the collection and recycle of aggregate
	"Construct for Excellence" report by CIRC jointed with BD, LD and PD	• Encourage green building design and maximize the use of recycled materials and reduce waste
Legal	Waste Disposal Ordinance 2003	• Framework for managing R&R waste from the point of generating to the point of final disposal
	Waste Disposal (Designated Waste Disposal Facility) Regulation	• Framework for the maintenance within sites used for waste disposal activities
	Trip Ticket System 2004	• Mechanism for preventing illegal dumping
Social	'Best Practice Guide for Environmental Protection on Construction Sites 2009' by HKCA	• Help frontline management teams in managing certain critical and environment-prone site issues
Assessment	HK BEAM Plus 2.0 – Existing Building	• Green standard for renovation work

11

(Lu and Tam, 2013)

11

Benefits of R&R Waste Management

- ***Social benefits***: Maintaining health and comfort to the building occupants > optimize energy use + reduce waste + increase productivity
- ***Economic returns***: Refurbishment takes ¾ of time & 50-80% of cost for demolition & new construction (Gorse and Highfield, 2009)
- ***Environmental benefit***: retains most of the existing structure and fabric > yield the greatest energy savings (Gorse and Highfield, 2009)

12

12

Barriers to R&R Waste Management

- ***Characteristics of construction industry***: restricted site area + limited construction period + high labour cost + fragmented nature of the refurbishment
- ***Buildings in occupation***: different owners and tenants are difficult to have common consensus in sustainable refurbishment decisions (Living Cities, 2010)
- ***Construction practitioners' attitudes towards reuse and recycle***: duplicate effort in sorting + less appealing than new objects + expensive cost of recycling
- ***Lack of economic incentive***: less amount of recyclable/reusable waste generated + high sorting cost (Seydel et al., 2002; Hosseini, 2015)
- ***Changing conditions and unpredictable factors***: limited available information at early decision making process

13

13

Site Observations

Sites	Types	Phase of Renovation	Description	Date of Visit
A	Religious Building	Mid-stage	Built in 1901, Heritage building Grade II, 2-storey building redevelop to a 4-storey structure with new temple, a kindergarten, a library, two conference rooms, a museum, a canteen and a basement car park	19 Feb 2019
B	Public Residential Housing	Initial to Mid-stage	Built in 1973, site visits to two flats with 330 ft^2 and 420 ft^2 respectively	21 Feb 2019
C	Hospital	Mid to end stage	Built in 1966, 4 blocks of 7-storeyed buildings, total renovation area is around 23,000m^2 with contract sum of HK$ 573 million	1 Mar 2019
D	Public Residential Housing	Initial stage	Built in 2016, site visits to two flats with 150 ft^2 and 230 ft^2 respectively	4 Apr 2019
E	Single Residential Building	End stage	Built in 1993, a 13-storeyed building with a mall on ground floor to 2/f	30 Apr 2019
F	Government Quarter	Mid-stage	Built in 1980, 6 blocks of 21-storeyed buildings, 240 units in total and 2 flats on each floor, site visit to a flat with 2287 ft^2	23 May 2019
G	Educational Institution	Mid-stage	Site visits to two renovation projects in PolyU Campus	11 Jul 2019

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Building Type	Major R&R waste type	Waste Management Practice	Reuse/Recycle
Religious (partial redevelopment)	• Crushed concrete • Metal (windows) • Sanitary wares • Furniture & upholstery • Electric appliances	Nil	• Historic chandeliers & doors reinstalled • Electric appliances sold as 2nd hand to members
Hospital	• Crushed concrete • Floor & wall tiles • Metals windows • Electric wiring • Furniture • Sanitary ware & metal pipes • Dry wall partitions • False ceiling • Asbestos	• *Phase dumping* • *Trip Ticketing System* • *Paperless policy*	• Recycle metal • Temporary reuse dry wall & fluorescent lamps in site office & hoarding • Recycling bin
Educational Institution	• Crushed concrete • Floor & wall tiles • Metal & PVC pipes • Timber • Cardboard • Plastic packaging	*2-trucks arrangement:* 3-ton truck from podium > 15-ton at G/F > waste disposal	• Reuse metal rubbish bins & tissue barrels
Residential (HD)	• Crushed concrete • Floor & wall tiles • Metals – windows, doors, collapsible gates, burglar bars, pipes, faucets & A/C • Electric wiring • Wooden doors & cabinets • Paper & plastic	*Guidelines for Vacant Flat Refurbishment* – reinstate or complete replacement	• Recycle metal & electric wiring
Residential (govt. quarter)	• Crushed concrete • Floor & wall tiles • Metals	• *Selective demolition* • *Onsite sorting* • *Trip Ticketing System*	• Make good cabinets & air-conditioners • Dumping skips labeled with notice of proper waste dumping

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Site Photos

2-trucks dumping

Phase dumping

Metal recycling

reinstate

Site limitation

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Encouraged Practices on R&R Projects from Site Observations

- On-site temporary reuse of demolition waste
- Top management commitment in waste reduction
- Phase dumping mechanism performs on-site sorting indirectly
- Restored or making good some fittings and fixtures from previous user
- Sold furniture and electrical appliances as second hand after repairing
- Place clear announcements in front of dumping skips in order to remind workers

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Semi-Structured Interviews

- **Interviewees:**
- LINK REIT (*Real Estate Investor*), Swire Properties Ltd. (*Real Estate Investor*), P&T Architects and Engineers Ltd. (*Designer/Consultant*), YSK2 Engineering Co. Ltd. (*Demolition Contractor*), Chun Wo Construction Ltd. (*Contractor*), Hong Dau Construction Co. Ltd. (*Contractor*), P&T Construction Co. Ltd. (*Contractor*), On Fat Lung Innovative Resource Ltd. (*Recycling Company*), Civil Engineering and Development Department & Environmental and Protection Department (*Govt.*).

- **Scope of interview questions:**

a) Differences and similarities in renovation of residential and commercial projects
b) Waste management plan
c) Reuse and recycling of C&D/R&R wastes
d) Difficulties and barriers in implementing waste management
e) Effectiveness of different strategies and technologies of C&D/R&R waste management
f) Recommendations to motivate waste recycling/reuse

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Proposed Strategies & Measures by Interviewees (I) – 25 mins

1. Pre-demolition audit/material control

- Control the amount of materials used and wastage
- If generated R&R waste larger than estimation > sub-contractor will be penalized
- Saving in cost by waste management to be shared among main contractor and subcontractors
- Arouse clients' awareness in waste management
- Promote "green business" in consultancy

2. Reuse/recycling

- use durable and reusable materials
- Reuse bridge deck & metal scaffolding

3. Develop recycling market

- Contractor of public projects obtain free concrete waste for recycling
- Govt. to provide private contractors with concrete waste for recycling at basic cost
- Govt. tender out more private-partnering project

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Proposed Strategies & Measures by Interviewees (II) – 25 mins

4. Reclamation

- Lantau Island reclamation project covering 17 km^2 requiring 391 million square meter of fill material for filling
- Government allow using inert waste to supplement the expensive sea sand **(HKD278/ton=HKD417/m^3 on June 2019)**
- Treated C&D waste utilized as filling materials according to the use of reclaimed land and period allowed for settlement (for immediate or long-term use)

5. Incineration

- Emitted toxic gases should be treated prior to discharge

6. Government Support

- Implement waste management and environmental management plan in public projects
- Subsidize contractors in using recyclable materials in public projects
- Allow clients/contractor to claim tax rebate in private projects
- Allowing more margin profit for project sums below< 1m or subsidizing waste collection cost based on the amount of waste collected for recycling
- Review land use policy
- Establish a central policy-making team to work on recycling
- BD to check compliance of waste management in private projects

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Barriers to Waste Management on R&R Projects from Interviews – 20 mins

4 major categories

1. **Government policy**
   - Established waste management policies without supporting the development of recycling industry
   - Lacking long-term planning in infrastructure development > materials wastage
2. **Recycling process**
   - Sorting & cleaning concrete waste to appropriate sizes incur high cost in recycling
   - Labour intensive & limited space for onsite sorting
   - high labour and land rental costs
3. **Immature recycling market**
   - Low revenue return (recyclable metal decreases from $3000 to 1000/ton)
   - Low financial incentive for small project
4. **Public education**
   - Workers lacking the knowledge of recycling
   - Low public awareness

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Guidelines for Vacant Refurbishment of Housing Authority (HA)

(summarized from EMDI W01/2018 of Housing Department)

1. Purpose

Provides guidelines for site monitoring and control of vacant flats refurbishment (VFR) works including checking of work packages, site inspections.

2. Background

The tenant is obliged to reinstate landlord's fixtures and fittings and remove those items added by him/her and all unwanted articles at his/her own expense before moving out of a rental flat. They can also entrust the reinstatement works to HA and reimburse the cost.

However, if the fittings and fixtures installed by the outgoing tenants are found to be in good conditions and reusable, the inspection team (comprising of Estate Management and project staff) should take a more pragmatic and customer-orientated approach in determining if these fittings and fixtures can be retained in order to reduce R&R waste and add value to the flat provided that public health and safety are not impaired. Pre-work inspection should be carried out to identify the condition of the existing flat and prepare the "Refurbishment of Domestic Vacant Units Pre-work Inspection Checklist" in Annex 1.

3. Waste Management Measures - Justifications for Complete Replacement Items

In order to avoid unnecessary replacement works are carried out during VFR, project staff are required to keep evidence and justifications, such as photos and written records, to justify the need for complete replacement of the selected items.

4. Criteria for Complete Replacement/Remove/Retain

4.1. Re-screeding/Retiling to wall and floor

a) In old housing blocks with no waterproofing provide, re-screeding work is necessary
b) Waterproofing and re-screeding works is warranted to be carried out in affected areas if seepage is found, such as kitchen, toilet or verandah.
c) Minor repairs, repointing and cleansing to be carried out to floor/wall tiles when only stain, dirt, or isolated broken tiles are found. **No** retiling is required.
d) The floor/wall tiles to be retained if the existing floor/wall finishes left by outgoing tenants remains in acceptable condition.

4.2. Replacement of collapsible gate

Existing collapsible gate, which complies with the current code of practice being openable from inside without using a key and in good condition should be retained and repaired. Minor repairs are suggested, such as repaint, re-secure, ease and adjust the gate. Collapsible that cannot be opened from inside without using a key should be replaced by the new standardized collapsible gate.

4.3. Replacement of internal louvers

To avoid issuing duplication work items for replacement of internal louvers, checklist item 16 of 'Completely replace louver frames and blades inside living area (SOR item 27127A) should be selected for some block types without partition wall between living room and balcony, if necessary.

4.4. Replacement of consumer unit

a) Existing consumer units normally have been renewed under the Electrical Re-wiring and Reinforcement (ERR) woks. The renewed units should not be replaced simply due to their configurations being different from the new Specification as stated in Contract.
b) Conditional repair/replacement is adequate when defects are found during the inspection. In some cases, modification to existing consumer units may be necessary.

4.5. Retain/Remove wall mounted cabinet

a) All existing wall mounted cabinet left behind should be removed unless project staff ascertain the safety of the wall mounted cabinet and the cabinet is in good condition after inspection; door hinges will be replaced when required.
b) Hanging cabinets should be removed if mounted on dry wall partitions.
c) Wall mounted cabinet should be removed when it is not likely to be fit for the incoming tenant.

REFURBISHMENT OF DOMESTIC VACANT UNITS PRE-WORK INSPECTION CHECKLIST

WO Num. (T.T.)				Inspection Notes:
Code Address		Draft WO Created On		
Surveyed By (T.T.)		Surveyed On		
Last Updated By		Last Updated		

Recommended standard | Confirmed

Touch Up Items

	Recommended standard	Confirmed	
1	N		Essential touch up package to Living Area
1h	N		Supplementary touch up package to Living Area
1j	N		Supplementary touch up package to Service Area
1k	N		Essential touch up package to Service Area
1m	N		Essential touch up package to Living Area (only replace the lock cylinder of the entrance door lock)

Option I Items

	Recommended standard	Confirmed	
2e	N		Rescreeding & retiling including WP system to floor & skirting of any one toilet in a flat
2j	N		Rescreeding & retiling including WP system to floor & skirting of whole service area excluding toilet
2k	N		Rescreeding & retiling including WP system to floor & skirting of balcony or utility
2m	N		Rescreeding & retiling including WP system to floor & skirting of kitchen
2t	N		Rescreeding & retiling including WP system to floor & skirting of both toilets in a twin-toilet flat
3c	N		Replaster & retiling including WP system to wall of any one toilet in a flat
3j	N		Replaster & retiling to wall of whole service area excluding toilet
3k	N		Replaster & retiling to wall of balcony or utility
3m	N		Replaster & retiling to wall of kitchen
3t	N		Replaster & retiling including WP system to wall of both toilets in a twin-toilet flat
4	N		Replumb with supply points for shower/bathtub, basin, sink & washing machine
4a	N		Partial replace fresh water supply pipes
4b	N		Replumb (including lever mixer) with supply points for shower/bathtub, basin, sink & washing machine
4c	N		Partial replace fresh water supply pipes (including lever mixer)
5a	N		Replace W.C. pan (1 No.)
5u	N		Replace W.C. pan (2 Nos.)
6c	N		Replace high or low level flushing cistern with or without backboard (1 No.)
6d	N		Replace high or low level flushing cisterns with or without backboards (2 Nos.)
6e	N		Replace low level vitreous flushing flushing cistern (1 No.)
6f	N		Replace low level vitreous flushing flushing cisterns (2 Nos.)

T.T. takes over keys of vacant flat from H.O.

Name : __________ (T.T.)
Post : __________
Date : __________

Contractor takes over keys of vacant flat from T.T.

Name : __________ (Contractor)
Post : __________
Date : __________

T.T. takes over the keys together with all relevant documents from Contractor after Contractor reporting completion of works (e.g. WR1, WR3, B.S. Testing Report)

Name : __________ (T.T.)
Post : __________
Date : __________

T.T. certifies that the specified works scope has been completed/rejects incomplete works.

....
(Incomplete)

Name : __________ (T.T.)
Post : __________
Date : __________

....
(Completed)

Name : __________ (T.T.)
Post : __________
Date : __________

T.T. handovers keys of refurbished flat to H.O.

Name : __________ (H.O.)
Post : __________
Date : __________

This checklist should be kept by Technical Team (T.T.) in Estate Office in the sequence of works order number.
This checklist is to be used in conjunction with SOR 201600081C Edition only.
REV. VFR Feb 2011

6g	N		Replace low level vitreous flushing flushing cistern including stainless steel brackets (1 No.)
6h	N		Replace low level vitreous flushing flushing cisterns including stainless steel brackets (2 Nos.)
7	N		Replace basin (1 No.)
7d	N		Replace basin with fibre cement reinforced calcium silicate vanity top, backing board and metal supporting frames (1 No.)
7e	N		Replace basin with fibre cement reinforced calcium silicate vanity top, backing board and metal supporting frames (2 Nos.)
7t	N		Replace basin (2 Nos.)
8	N		Replace kitchen sink
37	N		Supply and install fixed grab rail at bathroom; 32 - 40mm diameter; 600mm long (1 No.)
37a	N		Supply and install fixed grab rail at bathroom; 32 - 40mm diameter; 600mm long (2 Nos.)

Option II Items

1f	N		Remove unauthorized window in balcony and make good to original form
1g	N		Remove & cart away all furniture, fixtures & electrical & CABD installation left by former tenant and make good
9	N		Rescreeding to floor of living area
9a	N		Replace existing vinyl floor tiles of living area
10	N		Replace collapsible/sliding/swing gate & frame complete with ironmongery and painting
10b	N		Supply & install of collapsible gate and frame complete with ironmongery and painting
11e	N		Replace flat entrance door leaf complete with painting and ironmongery (exlcuding door frame & door closer)
11f	N		Replace flat entrance door frame complete with painting (excluding door leaf)
11g	N		Replace flat entrance door leaf & frame set of min half hr FRP complete with ironmongery & painting (excluding door closer)
11h	N		Replace door closer to flat entrance door leaf
11j	N		Replace flat entrance door leaf & frame set complete with ironmongery & painting (excluding door closer)
12c	N		Replace wooden toilet door leaf & frame set with/without lourve & fixed light complete with ironmongery & painting (1 No.)
12d	N		Replace wooden toilet door leaf & frame set with/without lourve & fixed light complete with ironmongery & painting (2 Nos.)
12e	N		Replace pressed steel toilet door leaf & frame set with/without fixed light complete with ironmongery & painting (1 No.)
12f	N		Replace pressed steel toilet door leaf & frame set with/without fixed light complete with ironmongery & painting (2 No.)
13h	N		Replace kitchen door leaf complete with ironmongery & painting (excluding door frame)
13j	N		Replace kitchen door frame complete with painting (excluding door leaf)
13k	N		Replace kitchen door leaf & frame set of min half hr FRP complete with ironmongery and painting
13m	N		Replace bedroom and/or pipe duct door leaf & frame complete with ironmongery & painting (1 No.)
13n	N		Replace bedroom and/or pipe duct door leaf & frame complete with ironmongery & painting (2 Nos.)
13p	N		Replace bedroom and/or pipe duct door leaf & frame complete with ironmongery & painting (3 Nos.)

13q [N] [ ] Replace kitchen door leaf & frame set complete with ironmongery and painting

14h [N] [ ] Replace concrete balustrades
14j [N] [ ] Replace glazed metal partition/grille/louvres & balcony door & frame complete with ironmongery & painting
14k [N] [ ] Repair glazed metal partition/grille/louvres & balcony door & frame
14m [N] [ ] Replace the whole of the composite partition including reconstruction of dwarf brick wall
14n [N] [ ] Replace balcony door and grille/louvre partition including frames, glazing and ironmongery, and repair dwarf brick wall
14p [N] [ ] Replace balcony door including frame, glazing and ironmongery, and repair grille/louvre partition and dwarf brick wall
14q [N] [ ] Replace grille/louvre partition including frames, glazing and ironmongery, and repair balcony door and dwarf brick wall
14r [N] [ ] Repair composite partition
14s [N] [ ] Replace glazed metal balcony door complete with ironmongery and painting and repair glazed metal partition/grille/louvre between living area and balcony

15d [N] [ ] Repair louvre and burglar grilles between public corridor & living area
15e [N] [ ] Replace louvre and burglar grille between public corridor and living area; louvre area n. e. 0.5m2
15f [N] [ ] Replace louvre and burglar grille between public corridor and living area; louvre area 0.5 - 1.0m2
15g [N] [ ] Replace louvre and burglar grille between public corridor and living area; louvre area 1.0 - 1.5m2
15h [N] [ ] Replace louvre and burglar grille between public corridor and living area; louvre area above 1.5m2
16b [N] [ ] Replace internal louvre (other than formed part of the partition between Living Area and balcony); louvre area n.e. 1.0m2
16c [N] [ ] Replace internal louvre (other than formed part of the partition between Living Area and balcony); louvre area 1.0 - 2.0m2
16d [N] [ ] Replace internal louvre (other than formed part of the partition between Living Area and balcony); louvre area exc. 2.0m2
17a [N] [ ] Replace louvre at external facade; louvre area n.e. 1.0 m2
17b [N] [ ] Replace louvre at external facade; louvre area 1.0 - 2.0 m2
17c [N] [ ] Replace louvre at external facade; louvre area 2.0 - 3.0 m2
17d [N] [ ] Replace louvre at external facade; louvre area exc. 3.0 m2
18g [N] [ ] Reinstate window casement (1 No.)
18h [N] [ ] Reinstate window casement (2 Nos.)
18j [N] [ ] Reinstate window casement (3 Nos.)
18k [N] [ ] Reinstate window casement (4 Nos.)
18m [N] [ ] Replace windows at external facade (window area n.e. 2.0 m2)
18n [N] [ ] Replace windows at external facade (window area 2.0 - 4.0 m2)
18p [N] [ ] Replace windows at external facade (window area 4.0 - 6.0 m2)
18q [N] [ ] Replace windows at external facade (window area 6.0 - 9.0 m2)
18r [N] [ ] Replace windows at external facade (window area exc. 9.0 m2)
19d [N] [ ] Repair burglar grille at external facade
19e [N] [ ] Provision of truss-out scaffolding as Special Temporary Works for whole flat

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REV. VFR Feb 2011

19f	N		Replace burglar grille at external facade; burglar grille area n.e. 2.0 m2
19g	N		Replace burglar grille at external facade; burglar grille area 2.0 - 4.0 m2
19h	N		Replace burglar grille at external facade; burglar grille area exc. 4.0 m2
20	N		Replace shower area
21	N		Replace bath tub
22c	N		Replace cooking bench, sink bench & shelf at kitchen
22d	N		Repair cooking bench, sink bench & shelf at kitchen
23c	N		Replace grease receptacle at kitchen
23d	N		Repair grease receptacle at kitchen
24	N		Install new water meter
25	N		Remove unauthorized or non-standard enclosure, partition walls or structure and reinstate to original condition
26	N		Carry out spalling repair works for the whole flat
26d	N		Reconstruct full height brick partition walls
32	N		Supply and install of fire collar
35e	N		Replace laundry rack at external wall

Building Services Items

27b	N		Renew electrical & CABD installation (including renewal of consumer unit) & issue WR1 form
27c	N		Renew electrical & CABD installation (excluding renewal of consumer unit) & issue WR1 form
28a	N		Repair electrical & CABD installation & issue WR1 form
28c	N		Repair electrical provisions with addition of A/C circuit & issue WR1 form
29	N		Test the existing electrical installation & issue WRI form
30	N		Carry out inspection to gas installation &/or disconnect/dismantle unsafe gas installation
31	N		Co-ordinate & pay for alteration/installation/reinstatement works executed by gas supply company
33	N		Co-ordination & pay for CABD system repair/replacement/reinstatement works inside the flat
34	N		Co-ordination & pay for CABD system repair/replacement/reinstatement works inside & outside the flat

This checklist should be kept by Technical Team (T.T.) in Estate Office in the sequence of works order number.
This checklist is to be used in conjunction with SOR 201600081C Edition only.
REV. VFR Feb 2011

Disposal Delivery Form (Trip Ticket)

Serial No. 0012345678

Date:

:

Designated PFF/Landfill :

/ :

Vehicle Licence Plate Number. :

Issued By:

:

Approximate Load :

:

☐ 1/4 ☐ 1/2 ☐ 3/4 ☐ Full

Remark:

:

(This part retained by issuing office)

( )

CEDD(CEO)84

Serial No. 0012345678

Date:

:

Designated PFF/Landfill :

/ :

Vehicle Licence Plate Number. :

:

Issued By:

:

Chop of Designated Public Filling Facility/ Landfill /

Construction and Demolition Materials
Disposal Delivery Form

Serial No. 0012345678

(Information contained in this form may be displayed on Internet)

Date: : ________________ Time of departure from site: : _______________ Vehicle Licence Plate Number: :

Designated Public Filling Facility/Landfill: / : Location of Site: :

☐ Central & Western	☐ Wanchai	☐ Eastern	☐ Southern	☐ Sai Kung
☐ Yau, Tsim, Mong	☐ Shamshuipo ?	☐ Kowloon City	☐ Wong Tai Sin	☐ Outlying Islands
☐ Kwun Tong	☐ Kwai Tsing	☐ Tsuen Wan	☐ Tuen Mun	☐ Shatin
☐ Yuen Long	☐ North	☐ Tai Po		

Approximate Load : ☐ 1/4 ☐ 1/2 ☐ 3/4 ☐ Full

:

Please stick contract no. barcode above

Chop of Designated Public Filling Facility/Landfill /

Chop of Engineer ' s/Architect ' s Representative /

A sample of "Daily Record Summary"

(1) Contract no. & title: ______________________

(2) Date of disposal: ______________

(3) Designated disposal ground(s): (a)

(b)

(c)

others ______________

(4) Approved alternative disposal grounds: ______________

DDF Serial no.	Vehicle registration no.	Departure time from site	Approx. vol (e.g. Full/Three Quarter/Half/One quarter)	C&D material type (e.g. inert or non-inert)	Actual disposal ground	Arrival time at disposal ground	Remarks

← Part 1[1] → ← Part 2[2] →

Part 1

Submitted by : ______________ [Name of Contractor's Designated Person]

Signature : ______________

Date : ______________

Received by : ______________ [Name and signature of the officer]

Post : ______________

Date & Time : ______________

Part 2

Submitted by : ______________ [Name of Contractor's Designated Person

Signature : ______________

Date : ______________

Received by : ______________ [Name and signature of the officer]

Post : ______________

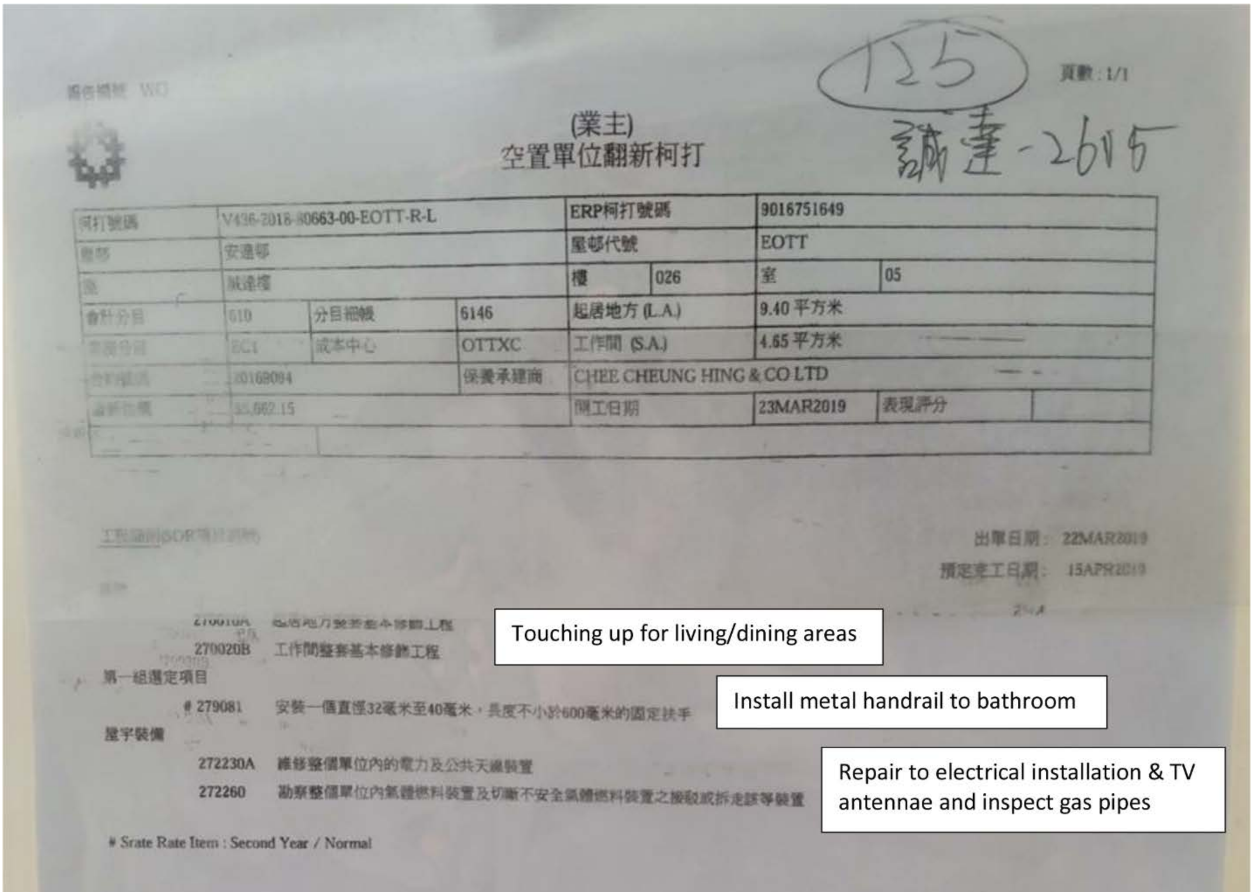
Date & Time : ______________

[1] Part 1 - The Contractor shall complete Part 1 and submit it to the Architect 's/Engineer's Representative by 1:00 pm of the following working day of the disposal trip.

[2] Part 2 - The Contractor shall complete Part 2 and submit it to the Architect 's/Engineer's Representative within 3 working days of the disposal trip.

Appendix E - *Example of Work Order of Vacant Flat Refurbishment in Newer Estate*

An example of Work Order of Vacant Flat Refurbishment in newer estate issued to contractor



[illegible] WO

頁數 : 1/1

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誠達-2615

(業主)
空置單位翻新柯打

柯打號碼	V436-2018-80663-00-EOTT-R-L			ERP柯打號碼		9016751649	
屋邨	安達邨			屋邨代號		EOTT	
座	誠達樓			樓	026	室	05
會計分目	610	分目細帳	6146	起居地方 (L.A.)		9.40 平方米	
[illegible]	EC1	成本中心	OTTXC	工作間 (S.A.)		4.65 平方米	
[illegible]	20169084		保養承建商	CHEE CHEUNG HING & CO LTD			
[illegible]	35,662.15			開工日期		23MAR2019	表現評分

出單日期 : 22MAR2019

預定完工日期 : 15APR2019

[illegible]

270020B 工作間整套基本修飾工程

第一組選定項目

\# 279081 安裝一個直徑32毫米至40毫米，長度不小於600毫米的固定扶手

屋宇裝備

272230A 維修整個單位內的電力及公共天線裝置

272260 勘察整個單位內氣體燃料裝置及切斷不安全氣體燃料裝置之接駁或拆走該等裝置

\# Srate Rate Item : Second Year / Normal

Appendix F - Floor Plan of Government Quarter