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Current Practices of Construction and Demolition Waste Management (CDWM):

Based on Observations at Swedish Construction Site

Master Thesis in the Master's Programme Design and Construction Project Management

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ABSTRACT

The purpose of this master thesis is to understand the current practice of Construction and Demolition Waste Management (CDWM) in the case area of a Swedish construction site. In addition, this paper aims to comprehend how Building Information Modelling (BIM) could support CDWM in the case area. This paper presents a case area of Swedish construction industry, and the results are based on observation, semi-structured interviews, and questionnaires.

The current practice of case area's CDWM includes on-site sorting, reuse, recycling, Just-in-time delivery (JIT), using prefabricated construction materials and color-coded waste containers. The practice of the CDWM mainly focused on sorting and recycling. The information regarding CDWM was shared among project stakeholders by using brochures, presentation, meeting, and information board. In addition, the contractor and subcontractors have a contract that stated who is responsible to take care of the waste on site.

The use of BIM has been given attention in the current literature to support CDWM. BIM has not been used for CDWM in the case study. However, the case study's company has an optimistic view about how BIM could support CDWM. Additionally, there is positive effort to implement BIM for CDWM for future projects at the company level. If BIM is used for case area's CDWM, it could support the CDWM in many ways, such as minimizing CDW through design validation, providing material information regarding waste, and quantifying the generation of waste before construction or demolition.

To bring change and improvement in the current practices of case area's CDWM, there should be an education, workshop, and training regarding the concept of CDWM, waste management strategies and benefits of BIM in managing CDW to construction project participants. This, in turn, can help the case study's firm and the general public to attain environmental, social and economic benefit from CDWM.

Keywords: BIM, CDWM, CDW, Information flow, waste management strategies

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Preface

This master's thesis is a final project of MSc program in Design and Construction Project Management, at the Department of Architecture and Civil Engineering, Division of Construction Management at Chalmers University of Technology. The thesis was carried out by Mahlet Tesfaye Haile and Yudhi Dwi Hartono from January to August 2017. This thesis involved many activities and individuals from academia to practitioners from the construction industry in Sweden.

First of all, we would like to thank our supervisor, Petra Bosch Sijtsema, for her guidance from the beginning to the end of our master thesis. She is consistent in reading, correcting and giving valuable suggestions to our thesis work. We could not have imagined having a better supervisor for our research paper.

Secondly, we would like to extend our great thanks to our mentor from NCC company, Fredrik Johansson, who help us to conduct the interview with the practitioners of the company. We would also like to acknowledge all interviewees who gave a valuable information during the interview time: the researcher from Chalmers, project members from case's area of Children's Hospital (Östra Barnsjukhuset), the environmentalist from the company and the market manager from NCC recycling company.

Thirdly, we would like to express our gratitude to *Indonesia Endowment Fund for Education* (LPDP) and *William Chalmers Scholarship* for giving us a full scholarship to study in Sweden.

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Gothenburg, August 2017
Mahlet Tesfaye Haile and Yudhi Dwi Hartono

1 Introduction

1.1 Problem Statement

Construction and Demolition Waste Management (CDWM) is a waste management practice in the construction industry and comprises the minimizing and management of Construction and Demolition Waste (CDW); reusing, recycling and disposal (Teo and Loosemore, 2001). CDWM is considered to be a vital issue for sustainable development, which deals with environmental, social and economic development (Lu and Yuan, 2011). Richardson and Springer (2013) mentioned that economic and social benefits are also acquired by planning construction waste precisely and managing the waste properly. Additionally, CDWM in a construction industry can achieve environmental and economic benefits (Bon-Gang and Zong, 2011).

However, CDW may prevent the construction industry from achieving such benefits. This is because; the output of CDW has increasingly resulted in serious problems in environmental, social and economic realms. The harm to the environment includes the depletion of limited landfill resources and an increase in energy consumption. (Marzouk and Azab, 2014). Furthermore, globally, construction activities contribute a lot to waste generation (Chinda, 2016; Teo and Loosemore, 2001; Yuan and Shen, 2011). Waste can be generated at any phase of the construction process from design to the operation and maintenance phase. It seems difficult to manage waste at the entire phase of construction due to the unique and temporal nature of construction projects as well as the fact that less priority is given to waste management in the construction industry. In addition, site managers and other construction project stakeholders (such as clients, designers, builders, and subcontractors) in the construction industry seem to pay less attention to CDWM (Udawatta et al., 2015). Furthermore, it seems also that there is lack of information about CDWM and poor communication among site workers, subcontractor and this might result in mismanagement of construction waste (Li, 2012).

To solve the aforementioned problem, this study tries to understand the present practices of CDWM and how information regarding CDWM is shared among the aforementioned stakeholders in the case area of a Swedish construction site. This study attempts to provide solutions by understanding how BIM could support CDWM in the case area. This, in turn, might help contractor firms and the general public to acquire economic, social and environmental benefit from CDWM.

1.2 Relevance of the Study

It is undoubtedly that the construction industry contributes to the biggest percentage of waste generation in most countries. However, waste management is not perceived as a project priority in the construction industry (Kareem et al., 2015; Teo and Loosemore, 2001). Therefore, this study can assist the case study's firm to improve their practice by using waste management strategies as well as by applying BIM. This, in turn, helps the firm to obtain environmental, social and economic benefits from CDWM.

Furthermore, in the future, the case study and other construction industries can use the study as a possible solution to improve practices of CDWM. This is because; the study will provide recommendation regarding different strategies of waste management and BIM.

1.3 Purpose

The purpose of the study is to understand the current practice of CDWM in a case study area. As well as to comprehend how new technology (such as BIM) could support CDWM is also the objective of the study.
The specific objectives of the study are stated as follows:

- To understand the current practices of case area's CDWM
- To understand the information flow concerning the CDWM
- To understands what aspects of current CDWM could be supported/improved with the help of BIM

1.4 Research Questions

- What are the current practices of case area's CDWM?
- How is the information regarding CDWM shared with site workers, subcontractors and contractor in the case study?
- What aspects of current CDWM could be supported/improved with the help of BIM?

1.5 Scope and Limitations of the study

The thematic scope of this research is limited to CDWM in the construction industry and BIM on the construction site. CDWM is also considered within the scope range of the research as the study focuses on waste management effort in the construction industry. For this specific study, the chosen construction site is Östra Barnsjukhuset, which is a new big construction project located at Mölndal, Västra Götaland County, Sweden.

Due to time constraints, only one case study area was selected from construction companies of Gothenburg. Existence of few literatures about how information regarding CDWM should be shared was also limitation of the study.

1.6 Structure of the Report

The research paper is composed of eight chapters and is organized in the following manner. The first chapter gives a brief introduction to the research problem, purposes, research question, significance/relevance and scope of the study. The second chapter reviews the literature regarding the concept of CDW, and its management effort, challenges, information flow and communication as well as the potential of BIM as its, provide future solutions for managing CDW. The third chapter elaborates on the type of research approach selected for this study. Additionally, this chapter explains, the various techniques and tools adapted and used to collect the necessary information and data for the study. This section also described reliability and validity of the selected method. The fourth chapter focuses on the current practice of CDWM in Swedish Construction site as well as the description of the case study. The fifth chapter presents the results and findings of different type of data collected. The sixth chapter includes discussion in which the empirical data is related to theory. The seventh chapter includes recommendations regarding CDWM and BIM. The eighth includes the concluding remarks of the report.

2 Theoretical Framework

The theoretical framework is formed by reviewing the literature regarding waste management in the construction industry and other related literatures associated with the thesis topic. The first section includes the concept of CDWM, challenges in Managing waste of Construction Project, and information flow and communication regarding CDWM. The second section discusses the concept of BIM, Benefits of BIM in managing construction wastes and the method how BIM can benefit the current practices of CDWM.

2.1 Construction and Demolition Waste Management (CDWM)

2.1.1 Concept of Construction and Demolition Waste Management (CDWM)

During the past decades, practitioners and researchers have paid more attention to Construction and Demolition waste (CDW) issues, and an excessive number of researches have published about CDW (Lu and Yuan, 2011). It is vital to define the notion of Construction and Demolition waste (CDW) in order to understand waste in construction industry more deeply (Kareem et al., 2015). Before defining CDW, the term waste is defined: Waste is unusable and unwanted material, and it is also called rubbish, trash, garbage (Kareem et al., 2015). Ortiz et al. (2010), as cited in Bakshan et al. (2015: 70), defined waste as *"a material by-product of human or industrial activity that has no residual value*." Waste is any material which is no longer used in a normal commercial cycle or chain of utility as the holder has a plan to throw away materials (Sertyesilisik et al., 2012).

CDW has no single and agreed definition, and different countries perceive CDW in different ways. The Hong Kong Polytechnic (1993) as cited in Kareem et al. (2015: 21) defined construction waste as follows:

> *"Construction waste as the bye-products generated and removed from construction, renovation and demolition sites of building and civil engineering structures."*

Bakshan et al. (2015) argued that construction waste is an element or subset of CDW and contains wastes that are produced during new construction. On the contrary, Chen and Lu (2016) argued that the term and CW and CDW are utilized interchangeably when the waste sources are not the centre of attention.

The existence of different perspectives on CDW has resulted in different waste management philosophies. For example, in Japan, CDW is not considered as waste rather it is a construction by-product. As a result, waste management efforts focused on recycle and reuse programs. In Hong Kong, CDW is classified into two, and these are inert materials (such as earth, concrete, debris, etc.) and non-inert waste (such as bamboo, timber, vegetation. etc.) (Lu and Yuan, 2011).

Chinda (2016); Yuan and Shen (2011); Zhao et al. (2010); Udawatta et al. (2015) as well as Roche and Hegraty (2006) as cited in Chen and Lu (2016), defined Construction and demolition waste (CDW) as waste that is generated from construction, renovation and demolition activities. Roche and Hegarty (2006) as cited in Lu and Yuan (2011) mentioned that CDW may include hazardous materials and surplus that is generated during the construction work.

The disposal of construction waste has a negative impact on the environment as it has resulted in air pollution (CO2 emission) water pollution, soil pollution, etc. (Wu et al., 2016; Ajayi et al., 2015 and Vivian et al., 2014). Construction Waste has also socio-economic impact (Wu et al., 2016). Udawatta et al. (2015) argued that construction waste has not only economic impact but also it has negative environmental impact. Bakshan et al. (2015) stated that construction and demolition waste has environmental impact and risks to human health.

2.1.2. Generation of Wastes in Construction Industry

The construction industry is one of the industries that contributes to the overall socio-economic development of any country. However, the construction industry is the main contributor to environmental degradation as the industry is exploiting natural non-renewable resources and pollutes the environment (Kareem et al., 2015). In addition, Lu and Yuan (2011); Mendis (2011); Marzouk and Azab (2014); Udawatta et al. (2015) discussed that the construction industry contributes to land depletion and deterioration, energy consumption, dust and gas emission, noise pollution, and solid waste generation. Chinda (2016); Teo and Loosemore (2001); Yuan and Shen (2011) discussed that enormous amounts of waste have been generated from construction activity.

The amount and type of wastes that are generated from construction work differ from country to country. For instance, in Germany, the amount of construction and demolition waste is about 30 and 14 million tons respectively. In Hong Kong, according to the Environmental Protection Department (EPD), the construction waste accounts for 25% of total municipal solid waste (Ajayi et al., 2015). Won et al. (2016) noted that waste generated in C&D processes comprised around 50% of the solid waste in South Korea in 2013. Moreover, Bon-Gang and Zong (2011) mentioned that the amount of waste produced from construction industry is about four times of the household waste.

Waste can be generated at any phase of the construction process. That means waste can be produced from inception, design, construction, and operation of the built facility/ civil engineering structure (Richardson and Springer, 2013; Teo and Loosemore, 2001).

Bakshan et al. (2015) discussed that building construction projects produce various type of waste materials at shoring, excavation, foundation, structural concrete, masonry and finishing stages. The waste materials in building construction project can be classified into three main categories: inert, non-inert and hazardous (Bakshan et al.,2015). An extensive amount of waste can be produced from construction project if the project does not consider constructability in the design process (Saheed et al., 2016).

Wu et al., 2014 as cited in Wu et al. (2016) mentioned that the construction industry has carried out immense resource consuming activities which contribute to the production of construction waste. Additionally, Bakshan et al. (2015) described that the growth in construction activities contribute to construction waste generation. Li (2012) argued that potential of a project team in management can be a factor for construction waste generation. Waste generation can be influenced by project size, duration, and worker numbers as well as activities during project delivery processes. For instance, if project size is bigger, the amount of waste is likely to be increased (Li, 2012). Saheed et al. (2016) argued that extensive amount of waste can be produced from construction project if the project does not consider about constructability in the design process. On the contrary, Ajayi et al. (2015) argued that the existence of ineffective strategies for managing construction waste has contributed to the generation of C & D waste intensively.

2.1.3 Management of CDW in Construction Industry

To solve Construction and Demolition waste problems, many strategies, methods, techniques, principles, and models regarding waste management have been devised by different scholars. Sertyesilisik et al. (2012) discussed waste management methods. These methods include a well-structured waste management plan; use colour coded waste containers in order to sort waste for recycling, agreement between contractors and subcontractors to determine who is responsible for waste on-site. The other method includes appointing a waste manager that works on delivery and materials storage to address the problem of damaged material due to improper handling, delivery, climate and insufficient storage (Sertyesilisik et al., 2012). Richardson and Springer (2013) argued that there are two methods to address construction waste. The first method deals with the minimisation of waste by applying source reduction techniques at design and procurement phases of a project. The second method is to manage inevitable waste materials that are already produced through three hierarchical methods (reuse, recycling, and disposal).

A waste management method hierarchy has been developed by different scholars, and the hierarchical model consists of strategies that range from 4 to 7. For instance, Yuan and Shen (2011) discussed that waste management method hierarchy contains four strategies. These strategies are reduction, reuse, recycling and disposal, and arranged in ascending order from low to highs based on its environmental impact (see figure 1). Additionally, the hierarchy that is proposed by Bell and McWhinney (2000) as cited in

Li, (2012) contain 7 strategies. i.e., avoid, reduce, reuse, reprocess, reclaim, treat and dispose of (see figure 2).

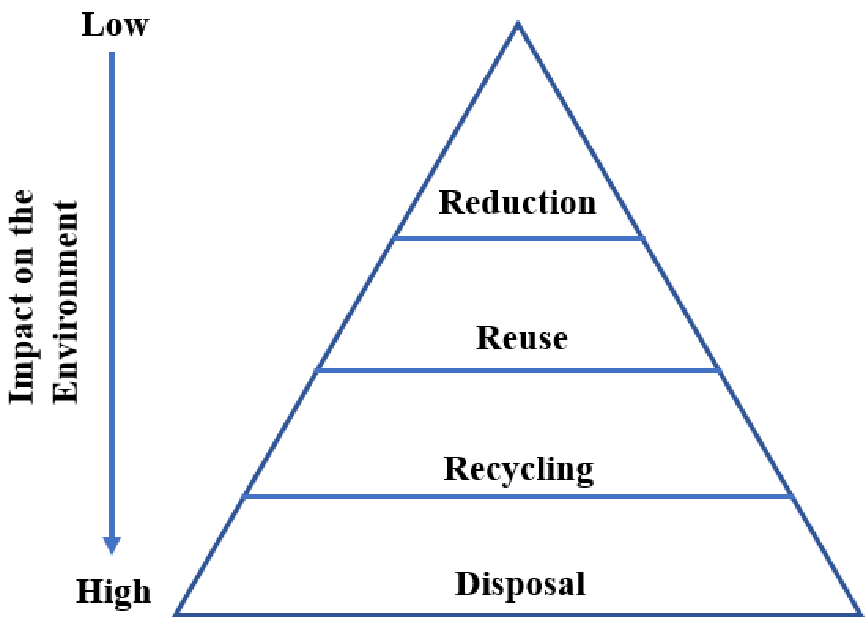

Fig 2.1 The C&D waste management method hierarchy (Yuan and Shen, 2011: 672)

Fig 2.2. Waste management hierarchy (Bell and McWhinney 2000) (Li, 2012: 2)

Moreover, Kareem et al. (2015) and Yuan (2011) discussed principles of waste management, i.e. the '3Rs' principle (reduce, reuse and recycling) that can guide waste management plans as well as practice and research of construction and demolition management. The principle has been arranged in ascending order based on their impact on the environment. A reduction is a more effective and efficient waste management method than reuse and recycling. This is because reduction can minimize CDW generation and transportation costs for waste disposal and recycling. Next, to reduction, reuse is a more effective method for managing waste than recycling (Kareem et al., 2015; Lu and Yuan, 2011).

In addition to the above waste management methods and hierarchical models, Ajayi et al. (2015) discussed different waste management strategies. These are sorting and recycling, material re-use, use of waste prediction tools, site waste management planning (SWMP), design for flexibility and deconstruction, waste efficient procurement, offsite construction as well as legislative and tax measures, and each of the strategies is described as follows:

Sorting and recycling is a strategy that can be adopted after waste has existed. Barros et al. (1998) as cited in Ajayi et al. (2015: 102) stated that:

> *"Recycling contains sorting of waste materials into recyclable and non-recyclables during construction activities or at the recycling site".*

Such a strategy has the potential to divert waste from landfill sites as well as prevent the use of raw materials for material production. Construction waste recycling operations have assisted communities to have free space in their landfill site. Recycling operations are relevant to reduce CO2 emission and save energy as well as create job opportunities. For successful recycling operations, the existence of committed construction professionals to sort the waste materials are vital.

Material re-use: like recycling, material reuse is vital to divert waste from landfill sites. Unlike recycling, such waste management strategy makes possible the reuse of materials without any change to its physical and chemical state. For example, construction demolition material has been used again for land reclamation, concrete aggregates, and road surfacing.

"Reuse" principle is more preferable than recycle. *The objective of the principle is to extend lifetime of existing structures or materials (*Wu et al., 2016: 899).

Use of waste prediction tools: are used as a means to measure and predict construction waste. Waste prediction tools are also vital for managing construction waste effectively. For instance, Net Waste is a tool used in the UK to estimate waste arising from the construction process. Different models have been used across the world to predict construction waste. Waste prediction tools should be implemented in the design phases of the construction process (Ajayi et al., 2015).

Site waste management planning (SWMP): in many countries, SWMP is a legislative prerequisite. For example, in the UK, every project, which is above £ 300,000, has SWMP as a requirement in their legislation framework (Ajayi et al., 2015).

Design for flexibility and deconstruction: This happens when a design of a building is optimized to the standard of the industry so that it is removed materials perfectly fit into another optimized project.

Waste efficient procurement: the procurement phase is a very important phase for waste management planning in a construction project. The reason for construction wastes are improper material storage, packaging material, and double handling are related/ associated with the procurement stage, For this reason, different strategies such as Just in time delivery (JIT), reduced packaging material and improved collaboration between the supply chains have to be applied to ensure waste efficient procurement. JIT is used to minimize waste (Ajayi et al., 2015).

Offsite construction: it is waste management strategy in which building materials are produced offsite and assembled onsite. Prefabrication and offsite production are means for minimizing waste generation in the construction industry (Ajayi et al., 2015). Vivian et al. (2014) discussed that adoption of prefabrication can minimize construction wastes that are resulted because of poor workmanship, excess order, design alteration, damage during installation and cutting. Prefabrication can reduce construction cost through mechanization, standardization, and industrialization.

Legislative and tax measures: the measures include a polluter pay principle such as "pay as You Throw" (PAYT), which is variable landfill tax. In the case of PAYT, *charges are paid per unit volume or weight of all waste disposed on landfill site.* The objectives of the principle are to discourage disposal of waste to the landfill site and encourage the 3R principles. Using the principle of PAYT, which is used in a number of EU countries (such as Greece, Sweden, Netherlands, Switzerland, and the UK) has enabled to minimize the amount of waste disposed on the landfill site. Before the adoption of PAYT, there was a fixed billing scheme in the US as landfill penalty. But the scheme has not shown any improvement in waste reduction on the landfill sites of US. In addition to the aforementioned tax measures, legislative measures also help to minimize C & D wastes. Legislative toolkits play a great role in increasing the awareness of the construction industry about waste management (Ajayi et al., 2015).

Some of the above-mentioned waste management strategies are also discussed by other scholars. For example, Saheed et al. (2016) also discussed a design for flexibility and deconstruction. According to Saheed et al. (2016), construction waste intensiveness can also be reduced through the production of deconstruction plan and designing a building that is flexible and adaptable. Additionally, Li (2012) and Sertyesilisik et al. (2012) discussed SWMP. Sertyesilisik et al. (2012) explained that SWMP assists in managing waste on-site, and the plan has made possible the management and recycling of waste on-site in a structured way. It can also reduce/ decrease waste cost/expense and increase the profitability of the construction sector. SWMP can help to reduce risk that has happened due to waste related accidents. Additionally, Li (2012) discussed the need for on-site waste plan to manage/control waste in a construction supply chain. Lu and Yuan

(2012) and Wang et al. (2010) also explained about sorting of construction waste.

sorting construction waste before disposal/dumped in landfill has perceived as good practice (Lu and Yuan, 2012). Moreover, to facilitate sorting, collaboration between site managers and waste contractors is crucial (Sezer, 2017**)**. There are two types of **s**orting: i.e., on-site sorting and off-site sorting. The advantage of on-site waste sorting includes maximising reuse and recycling rate, mitigate the waste transportation cost and disposal, prolong life of landfills. (Wang et al., 2010). In addition, according to Wang et al. (2010) "*manpower, recycled materials market, waste sortability, good management, site space and equipment for sorting of construction waste are critical success factors for on-site sorting of construction waste*". Off-site sorting can contribute to construction waste reduction (example: off-site construction waste sorting program at Hong Kong in 2006). sustainable policy support and implementation, encouraging off-site construction waste sorting through increased disposal cost lead to success of the off-site construction waste sorting program. This in turn can help the reduction of construction waste (Lu and Yuan, 2012).

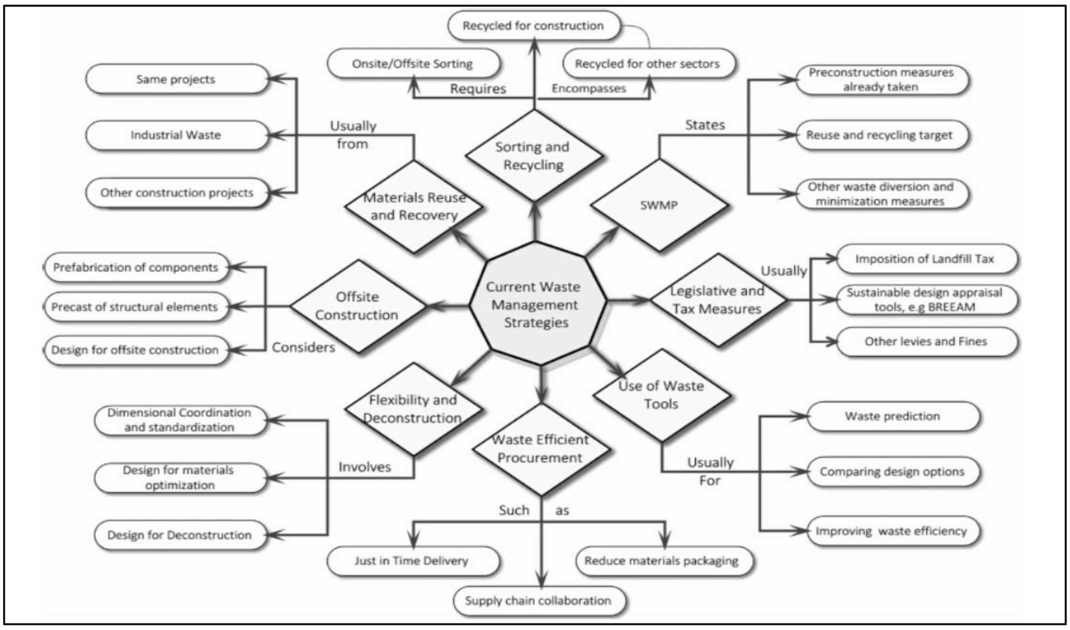

Figure 2.3 Summary of existing waste management strategies (Ajayi et al., 2015: 103)

Construction and demolition waste management strategies are relevant in order to achieve environmental and economic benefits (Richardson and Springer, 2013; Teo and Loosemore, 2001). According to Bon-Gang and Zong (2011), different benefits such as cost saving and profit maximization; minimize demand for landfill spaces, improve resource management, company's image improvement, as well as productivity and quality improvement, can be achieved through implementation of waste management strategies properly in the construction industry. Additionally, Richardson and Springer (2013) mentioned that economic and social benefits are also acquired by planning construction waste precisely and managing the waste properly.

However, there are factors and practices that contribute to the ineffectiveness of construction and demolition waste management strategies and this in turn results in immense amounts of construction waste as it is described by different scholars. According to Ajayi et al. (2015), The factors and practices are classified into five. These are *"end of pipe treatment of waste", eternality and incompatibility of waste management tools with design tools", "perceived or unexpected high cost of waste management" and "culture of waste behaviour within the industry*. Udawatta et al. (2015) discussed about factors that can influence effectiveness of CDWM and its strategies, and these practices include stakeholders' attitude towards WM practices and cost-drive nature of a construction industry as it is explained as follows:

Cost-drive nature of a construction industry: decisions to execute waste management practices in a construction industry depend on financial profit.

Attitude towards WM practices: most construction project participants' (such as clients, designers, builders, and subcontractors) attitudes do not support waste management practice since the aforementioned project participants are influenced by the profit driven nature and competitiveness of the construction industry (Udawatta et al., 2015). For instance, to execute waste management practices, there is no incentive for contractors, and subcontractors do not have that much concern for waste management as time has financial value for them (Udawatta et al., 2015). In addition, waste management practices are influenced by clients' interests as the client is the investor to the construction project and play a key role in processes of decision making (Udawatta et al.,2015). It is crucial to enforce the regulation in order to improve waste management practices until such practices adopted /accepted culturally in a construction industry throughout the supply chain. (Udawatta et al., 2015). The following diagram Udawatta et al. (2015) has illustrated attitudes and behaviours of construction stakeholders towards waste management in the following diagram.

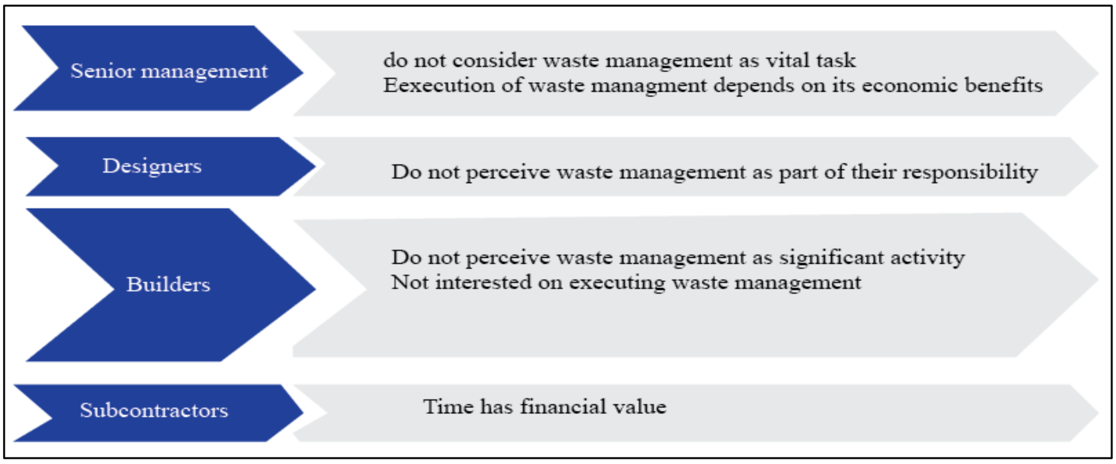

Figure 2.4: Attitudes of construction project participants towards waste management (Udawatta et al., 2015: 143)

Site managers play an important role in waste management practice at the construction implementation phase (Sezer, 2017). However, site managers do not perceive waste management as a vital task (Udawatta et al., 2015). Saheed et al. (2016) and Udawatta et al. (2015) argued that architects take part in practices of waste management and minimisation to less extent. This is because; architects have no knowledge regarding causes of design waste generation, and they thought that contractors are responsible for waste minimization. In view of this, the profit-driven nature of the construction industry and the less positive attitude of the aforementioned stakeholders may lead to an intensive amount of CDW.

To achieve reduction of an extensive amount of waste in the construction industry, and enhance the effectiveness of waste management strategies, the following six strategies are necessary "*tackling of waste at design stage, whole life waste consideration, compliance of waste management solution with BIM, cheaper cost of waste management practice, increased stringency of waste management legislation and fiscal policies, and research and enlightenment"* (Ajayi et al. pp 101, 2015). Saheed et al. (2016) also explained that Waste in the construction industry can be minimized by taking waste preventive measures during the design phase. This is because; design phase is a major phase that has implication on project result. Waste can also be reduced through design out construction waste. Saheed et al. (2016) discussed about five competency categories that are important and requisite to design out construction waste. The five competencies include design task proficiency, low waste design skills, behavioural competence construction-related knowledge, interprofessional collaborative competency (see appendix 5). The first four competencies are requisite for designing out waste, and inter-professional collaborative competency is required for design manager. This, in turn, contributes to effective waste minimization and management Competency for designing out waste can also be determined by incorporating design with site topography and considering reusable elements on site (Saheed et al., 2016). Understanding site topography also helps to minimize excavation waste.

Furthermore, according to Teo and Loosemore (2001), to reduce the waste level in the construction industry, it is important to give priority to waste management in relation to other project goals, and managers should reveal commitment toward waste management activities and provide the necessary resources.

Waste minimisation strategies

Osmani (2012) as cited in Richardson and Springer (2013) defined waste minimization as mitigation of waste at source (i.e., designing out waste) through comprehending the main factor of waste and redesign present processes and practices to reduce waste generation. waste minimization includes any process, method or activity that minimizes or eliminates waste from its source or enable reuse by permitting recycling (Richardson and Springer, 2013). Li (2012) mentioned that waste minimisation should be considered at first in waste management effort, and reuse and recycling can be used if the wastes are unavoidable.

Different scholars discussed about waste minimisation strategies. For instance, Lu and Yuan (2011) discussed the five methods/strategies for waste minimization, and these are minimizing waste by government legislation; reducing waste through design; establishing an effective waste management system and use of low waste technologies and improving practitioner's' viewpoint toward waste reduction. Mendis (2011) argued that planning and controlling are the two waste minimisation strategies. Planning strategies include procuring material, design, construction scheduling and site layout. Controlling strategies involve delivery and handling of materials, security, storage waste accounting, recordkeeping, safety, education and maintenance of machinery. Proper materials management plays a great role in reducing waste on-site (Mendis, 2011).

Furthermore, different scholars explained about methods for waste minimisation. For example, Mendis (2011) argued that waste can be minimised by using durable, recyclable and used materials as well as materials with lower environmental impact. Li (2012) argued that cooperation/collaboration and effective management of project stakeholders (such as clients, designers, head contractors, and subcontractors) throughout the construction supply chain, as well as incentive measures, contribute to minimization of waste. Additionally, Sezer (2017) argued that collaboration between site managers and waste contractors is crucial to reduce waste.

Moreover, in order to come up with practical waste minimization and management strategy, it is vital to understand the root causes of waste. Waste minimisation strategies require the concerted effort of all project participant such as client, government contractors, and the whole supply chain (Richardson and Springer, 2013).

Beside the waste management and reduction strategies, Wang et al. (2014) discussed about three design strategies that can help the management of waste. The first design strategy focused on the use of prefabricated components in construction project mitigate different construction wastes (Wang et al., 2014). According to Wang et al. (2014), waste *reduction investments,* is the second design strategy, and deal with incentives (special motivational and reward programs) for participants of a construction project to execute construction waste management. The final strategy is design Modification: design change produces a large amount of waste if performed at the finishing stage of a building. Therefore, avoid design modification at the accomplish of a building is crucial to be able to manage construction waste effectively (Wang et al., 2014). On the contrary, Udawatta et al. (2015) argued that effective construction waste management can be achieved by changing attitude rather than changing techniques. Incentives to implement the practices, equity distribution of the benefits of waste management as well as education and raising social awareness on issue regarding waste management practices plays a crucial role in the process of changing attitudes and behaviours of construction practitioners towards waste management. This in turn contributes to the improvement of waste management practices in a construction industry (Udawatta et al., 2015). In addition, having knowledge about the attitude and behaviours of construction project's stakeholders towards waste management play a greater role in management of construction waste in a better way (Udawatta et al., 2015). Seneviratne et al. (2015) argued that identified the source of waste and proposing waste auditing system is essential for effective construction waste management. Effective waste management at each phase of a building material life cycle is vital to attain sustainability in construction (Richardson and Springer, 2013).

2.1.4. Challenges in Managing waste of Construction Project

To improve waste management practices, construction clients and developers are increasingly attempting to set waste management requirements (Kareem et al., 2015). Udawatta et al. (2015) argued that clients and other construction project participants have a less positive attitude and behaviour toward waste management practices. There are different reasons that contribute to the difficulty of waste management practice in the construction industry. Some of the reasons are an inability to predict production environment; unique characteristics of each project; time pressure and cost limitation (Kareem et al., 2015; Teo and Loosemore, 2001). Additionally, building material can end up as waste due to improper handling and misuse as well as less management attention. For instance, if a building material has an impact on project cost, more management attention will be given to expensive building material, and less attention will be paid to wastage of other materials. Waste management activities were considered as unimportant to contractor work (Udawatta et al., 2015). Such negative thinking regarding waste management efforts has become a hindrance for the adoption of positive attitudes (Kareem et al., 2015).

Additionally, Kareem et al. (2015) and Teo and Loosemore (2001) discussed major challenge/obstacle to waste reduction in a construction industry particularly in the developing world. One of the challenge is a lack of managerial commitment and support on an issue regarding waste reduction has affected operatives' attitude toward reduction of waste and this contributes to the shortage of resource, manpower and time for waste management activities in relation to other project goals. The second challenge is that non-existence of performance standard for managing waste. The third challenge is that resistance to change the existing work trends in the construction industry. The fourth is waste reduction activities are predominantly profit motivated. In Canada, challenges for CDWM are that waste is bulky, difficult to compress and occupies more space in municipal landfills (Yeheyis et al., 2013).

A positive attitude and perception regarding waste management activities can be attained through training and incentives to operatives in order to develop knowledge and participate in less wasteful practice respectively (Kareem et al., 2015).

2.1.5 Communication and Information Flow regarding Waste Management

Communication is most often described along three dimensions: content, form and direction. Any of these dimensions can have some barriers which disturb the messages. These barriers vary from the language-barriers to lack of understanding the context (Sandhu and Ajmal, 2012). Sandhu and Ajmal (2012) argued that communication among different actors at the initial project phase is very crucial as there are lots of activities take place. Communication has various forms such as oral, written (e.g. textual, drawings, and graphics) and nonverbal communication.

Effect of communication and information flow to waste management

Terje and Morten (2007) as cited in Li (2012) mentioned that information flow is considered as crucial parts of construction supply chain that facilitates the united efforts of stakeholders in waste management. Having adequate knowledge and data on the occurrence of waste and its causes helps to understand and address the problems (Seneviratne et al., 2015). However, lack of data and poor communication have a negative effect on waste management. For instance, Li (2012) argued that lack of data is a barrier which prevents effective handling and management of construction waste. In addition, Gavilan and Bernold (1994) as cited in Li, (2012) noted that poor communication among project team members has resulted in craftsmen's error and mishandling of materials at the construction phase. For this reason, policies should be developed to give emphasis on 'stakeholders' awareness of Demolition Waste Management (DWM)', 'developing and promoting knowledge and communication among stakeholders with issues regarding environment and waste management concepts and practices (Ding et al., 2016). Understanding about waste management can also be improved through training (Kareem et al., 2015). To prevent waste, design managers are expected to be skilled in both design coordination and 'inter-professional collaborative competencies' such as communication. (Saheed et al., 2016).

2.2. BIM and CDWM

The Architecture, Engineering, and Construction (AEC) industry is in the middle age of a technology revival. As a part of this fast-growing innovation, Building Information Modelling (BIM) acts as the antecedent catalyst (Hardin & McCool, 2015) which has a promising advancement in this industry (Eastman et al., 2011; Rogers and Preece, 2015). This advancement leads the majority of world's prominent AEC firms changing their preceding drawing-based CAD (Computer-Aided Design) technologies into BIM for almost all of their projects (Eastman et al., 2011). BIM has been widely used to minimize cost and time and enhance productivity within AEC industry in the last ten years (Won et al., 2015). In addition, current studies show that BIM has also been enthusiastically promoted as a solution to Construction and Demolition Waste Management (CDWM) (Lu et al., 2017; Won et al., 2015), and is potential to help architects to reduce waste produced during the design phase (Akinade et al., 2016; Liu et al., 2015b). Hence, this section covers the BIM concept and definition, its benefit in the AEC industry as well as its potential to be applied in Construction and Demolition Waste Management (CDWM) practice.

2.2.1 Building Information Modelling (BIM): Concept and Definition

Although BIM concept has existed from the 1970s (Eastman, 2011), the term "Building Information Model" appeared the first time on the paper written by van Nederveen and Tolman in 1992. Besides, the term "Building Information Model" or "Building Information Modelling" along with its acronym "BIM" was not popularly used until ten years later, in 2002, which was proposed by Autodesk (Zhou et al., 2015).

Regardless its popularity for more than 15 years in today's AEC industry, no single uniform definition of Building Information Modelling is widely accepted (Liu et al., 2015a). One of the most used definitions is from U.S. National BIM Standard (Version 2, *page 21*), which defines BIM as:

> "*a digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onward.*"

A simpler definition is proposed by Kensek and Noble (2014) who defined BIM as a fundamentally changing mode of design practice and standards of a building from design, delivery, to operation. Porwal and Hewage (2012) argued that BIM is a tool in the AEC industry that is utilized to design, document, and improve communication among all project stakeholders.

BIM covers a variety of areas: from interacting policies, processes, and technologies applied to modelling, visualization, analyses, simulation, to documentation (Kalinichuk, 2015). According to Kalinichuk (2015), the entire concept of Building information modeling consists of three interlocking BIM Fields of activity: Process, Technology, and Policy fields along with each two sub-fields: players and deliverable. This concept, according to Kalinichuk (2015), was originally introduced by (Eastman, 2011; Succar, 2008) and illustrated in *Figure. 1*

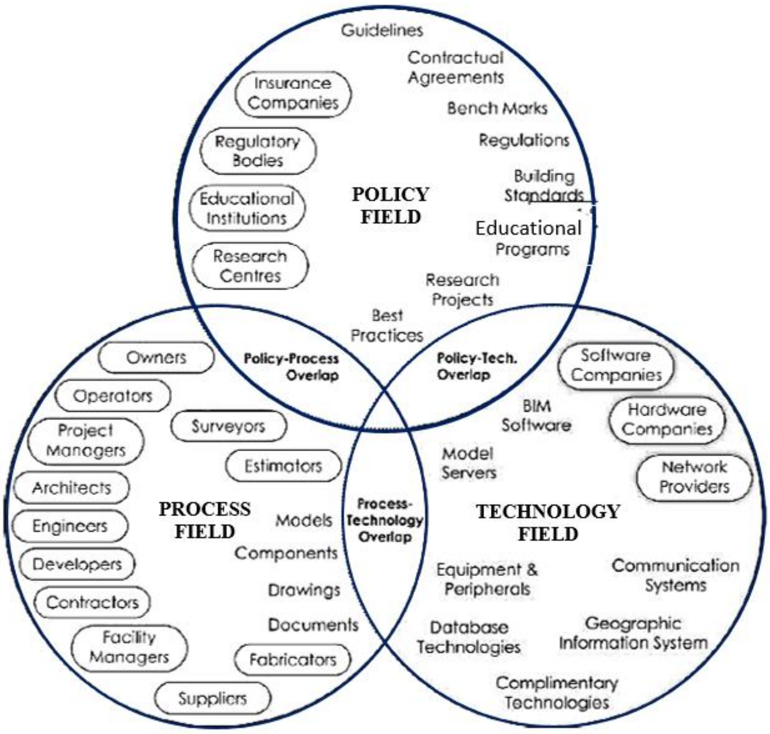

Figure 2.5: BIM Fields. Source: Kalinichuk (2015: page 25)

Eastman et al. (2011) emphasized that BIM does not only change the technology used in AEC industries but also change the process. It does not only change how visualizations and drawings of a building are created but also drastically transforms the entire key processes implicated in assembling a building. As mentioned by Kalinichuk (2015), current studies tried to examine how information is exchanged between different areas.

2.2.2 Benefits and Challenges of BIM Implementation

AEC firms progressively implement BIM in the whole building's lifecycle (Wong et al., 2015). The majority of the world's prominent AEC firms have changed their preceding drawing-based, CAD technologies, into BIM for most of their projects (Eastman et al., 2011). To illustrate, the level of BIM adoption in North America has increased significantly from 28% in 2007 to 71% in 2012 (McGraw-Hill Construction, 2012). Besides, research conducted by Jung and Lee (2015) has found that its adoption in this country increased to 82.1% by 2015, which made North America in the top ranked, followed by Oceania, The Middle East/Africa, Europe, and Asia with 81.8%, 80.0%, 75.0% and 46.3% respectively.

The significant interest in BIM use in the AEC industry seems to be the result of such early researches that prove obvious project benefits. According to the study conducted by Bryde et al. (2013), the most frequent project benefit of BIM reported was related to cost reduction followed by time reduction, communication and collaboration improvement, and quality through the project lifecycle. Ghaffarianhoseini et al. (2017) have also highlighted additional advantages of BIM such as technical benefits, knowledge management benefits, standardization benefits, diversity management benefits, building LCA benefits, and decision support benefits. BIM benefits have also been presented in number. For example, Shin (2017) has outlined the Return on Investment (ROI) when utilizing BIM, as illustrated in the figure below:

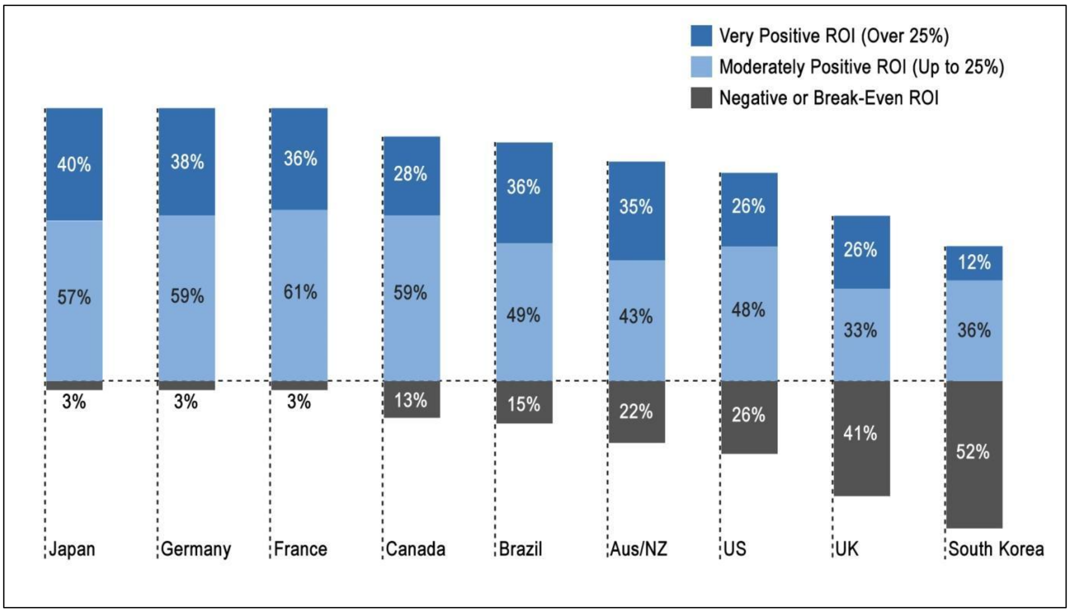

*Figure 2.5***.** Return on Investment on BIM. *Source: Shin (2017: pg. 206)*

BIM has also benefited in visualization and consistency of design, cost estimations, clash detection, lean construction implementation or enhancing stakeholder collaboration (Volk et al., 2014). It can also be used for monitoring construction progressively, building renovation, building system analysis, as well as energy system simulation (Wong et al., 2015).

On the other hand, along with its inherent advantages, BIM has been indicated to have shortfalls. These negative benefits, however, are outweighed by its advantages (Bryde et al., 2013; Ghaffarianhoseini et al. 2017). The negative benefits are mostly associated with software and hardware issues, which are related to technical difficulty (Ghaffarianhoseini et al. 2017). For example, the employees are not trained well and are not used to a new way of working with this technology. This, in turn, causes to low return of investment faced by many BIM users worldwide (Ghaffarianhoseini et al. 2017). Therefore, to tackle these challenges, the AEC firms need to invest more significantly in software, hardware, or training for employees.

The significant improvement of BIM implementation leads the researchers to expand the BIM use for further application, such as, constructing more sustainable building.

This seems to be the results of the awareness of the AEC stakeholders about the importance of sustainability in the construction for the past few decades (Akbarnezhad et al., 2014). One of many other possibilities of BIM implementation for sustainable building is for CDWM.

2.2.3 BIM Use for CDWM

Besides its potential to improve performance on construction management (Bryde et al., 2013), BIM has also been enthusiastically promoted as a solution to CWDM (Lu et al., 2017). BIM has been studied extensively to CDWM in some industrialized countries like Hong Kong, the UK, the USA and South Korea. Recent studies have found its benefits in minimizing waste generation in the construction industry. For example, Won et al. (2016) proved that 4.3-15.2% waste generation in the construction phase in South Korea can be prevented by using BIM.

There is a growing but limited body of literature researching how BIM can be implemented for CDWM (Lu et al., 2017). Therefore, the way how BIM is applied for construction and demolition waste management is still debatable. BIM utilization to support CDWM varies. It can be utilized as a modern design tool to help designers ponder various design options, prefabrication option for example, or to help contractors to evaluate different construction and demolition schemes (Lu et al., 2017; Won et al., 2016).

Preventing the waste from the design phase seems to be the best solution in construction waste management. Some researchers claim that clash detection and design validation during design phase are potential to reduce the amount of waste generated during construction (Cheng et al., 2015; Liu et al., 2011). According to Won et al. (2016), improper design and unexpected changes in the design and construction stages are the main contributors of construction waste generation. This waste, therefore, can be reduced with BIM since, in many cases, BIM is effective to reduce the amount of construction waste during the design phase (Won et al., 2016). For instance, BIM is considered as an effective tool to detect errors and validate building designs. This ability, according to Won et al. (2016), was able to minimize the design mistake, rework and unplanned changes, therefore has been proved to prevent waste by 4.3-15.2% from the construction projects in South Korea. Similarly, Porwal and Hewage (2012) established a BIM-enabled analysis to reduce the rebar waste of structural reinforcement in the design phase. In their study, a BIM model, which contains project data from AEC disciplines, was used as a communication centre among various design teams, and then minimized the potential reinforcement waste by optimizing the algorithm. The design teams can make necessary changes to the designs so that the rebar waste can be reduced.

Whilst the aforementioned studies are yet to convincingly link BIM to prevent the waste from the design phase, other studies have attempted to manage waste during demolition since most construction waste is from this phase. Earliest study was conducted by The Associated General Contractor of America (AGC) which developed BIM as a digital visualization tool to estimate and identify construction and demolition waste materials. The practitioners could establish a material recycling plan more cooperatively and efficiently prior to actual demolition and renovation. Cheng and Ma (2013) have also established a model in BIM to estimate the waste material from the demolition by extracting the information on volume and materials from every selected building element in BIM. From this information, the practitioners can calculate how much waste generated after demolition, so that they can predict the number of trucks needed as well as the cost to deliver the waste. Similarly, Hamidi et al., (2014) introduced a BIM-based demolition waste management system. BIM was used to provide reliable material information prior to demolition by either reviewing material properties or taking off material quantities from schedule/quantity sections. In addition, Park et al. (2014) have also established a BIM-based database system for demolition waste (DW). Here, BIM material information libraries were used to analyse the construction material categories.

The abovementioned studies have raised the benefits of BIM in preventing waste during construction as well as managing waste during demolition waste. Another study focused on benefiting BIM in favour of the waste at the end of building lifecycle, like deconstruction or renovation. Similar to demolition project, deconstruction and renovation also contribute to the huge amount of waste compared to new construction. According to Ding et al. (2016), BIM can be used as an application for deconstruction. For example, to examine the deconstruction scheme, the designers can integrate a "*de-constructability assessment score*" with a BIM model during the design phase. As many of the building components can be reused from the deconstruction or renovation project, the expected waste generated can be reduced. For example, to handle the deconstruction waste, Akbarnezhad et al. (2014) have developed a BIM-based model for assessing various options in deconstructing building in favour of the economic and environmental benefits. This model was intended to achieve a balance from such benefits because not all building components can be reused or recycled. By enhancing the BIM implementation in this way, renovation or deconstruction waste can be minimized (Akbarnezhad et al., 2014).

Different from conventional architectural and structural drawings which often use only combination of lines, without any information attached, to show the visualization of a building, every component of a building in BIM model has its own information attached (Akbarnezhad et al., 2014; Eastman et al., 2011; Wang et al. 2012). This information is typically about building geometry and its relationships; geographic, quantity, the material used, and property information about the building components. In addition to this information, with current BIM software, any other new customized information or variables can be added to the objects/elements by designers, owners, and contractors. This information, which consists of various characteristics, may have an effect on reusability and recyclability of its components (Akbarnezhad et al., 2014). Therefore, in order to make a good recycling and reusing strategy at the end of the building life cycle, it is important to add any information about this issue to the BIM model. Akbarnezhad et al. (2014) proposed some attributes based on previous studies that can be put in the BIM model so that it will be useful for the reusing and recycling strategy at the end of the building lifecycle. The first attribute that can be added is *recyclability*, which provides the information of whether the materials used for building are suitable for recycling or not. The second is the *reusability* attribute which determines whether the building component can be reused at the end of lifecycle based on components' life service and disassemble-able connections availability. The third is the *structural* attribute which provides data of structural capacities, such as shear and moment, from various elements. The next is *handling, installation, and disassembly* attributes which can be used to provide information of the required procedures on how to handle, install and disassemble elements. The fifth is *geographic coordinates* attributes which give the information about the nearest recycling and reuse plants and its distance to the construction sites. The last attribute is *condition-related* attributes which may be applied to store the results of several condition assessment tests.

2.2.4 BIM as a Communication and Collaboration Hub

According to Zurita et al. (2008) as cited in Park and Nagakura (2014), utilizing wireless and IT technology to improve communications is considered as necessary factor in maintaining the collaboration quality. "Communication tools have been revolutionised with the explosion in information technology, as a multitude of methods and software programs have become available for business" (Sandhu and Ajmal, 2012).

Collaboration is necessary for saving the investments and enhancing the competitiveness of the AEC industry (Shin, 2017). In addition, information sharing can also enhance to efficiency of working. One of new technologies that can be utilized in collaboration and communication among project parties is Building Information Modelling (BIM). Although the main element of BIM is about data sharing in a single and distributed platform, it is usually presented as a platform of collaboration (Forgues, 2016). In addition, BIM is an efficient tool for asynchronous communication, such as modelling and drawings (Knotten et al., 2015).

3 Methodology

This chapter discusses the reasoning behind selecting the methodology and delineates the stages taken to pursue the research questions. Several methods and approaches have been evaluated in regards to time, strength and practical consideration. The selected methods are observations, interviews, and questionnaires. Furthermore, the description of each selected method and tool are demonstrated. Research quality which is assessed by its reliability and validity is also outlined. In addition, to warrant respectable research practice, this chapter ends with a research ethics section.

3.1 Research Approach

Before deciding what type of study that is going to be performed, quantitative or qualitative, it is important to select whether to use an inductive or deductive view. According to Saunders et al. (2016), an inductive approach is selected when the researchers aim at exploring a topic or developing a theory through collecting and analysing the data (data-driven), On the other hand, a deductive approach is used when the researchers aim to test a theory (theory-driven) through data collection.

Different ways of data collection methods can be applied such as observations, interviews, and questionnaires. However, the core element is whether it is a quantitative or qualitative approach. According to Bryman and Bell (2015), a quantitative research is characterized as requiring the collection of numerical data which are evaluated in regard to statistical interpretation. On the other hand, qualitative research deals with qualities, meanings, and processes that are not tested through experimentation, or measured in terms of quantity (Hogan et al., 2009). In other words, a qualitative approach stresses the words instead of numbers in data collection and analysis (Bryman and Bell, 2015).

Mixed-methods research which combines quantitative and qualitative approach may be used in the research strategy. According to Basu (2010), this approach is considered as an outstanding research strategy as it has an inherent self-correcting element which strengthens the credibility of the research in academia. However, combining these two approaches is not without controversy. Bryman and Bell (2015) discussed that practical difficulties associated with this combination approach may happen, and not all writers agree that this approach is feasible and desirable. For instance, it has a risk in data collection and is considered as time-consuming, which makes it not applicable option (Denzin, 2012; Ma & Norwich, 2007). In addition, Basu (2010) suggests that mixed-method approach can be a preferable solution if it is applied properly.

From the description above, this study has decided to employ an inductive view which further performed qualitative approach. A qualitative emphasizes the generation and establishment of the theory. Furthermore, with an inductive view, the theory is the outcome of the research which is obtained from observations/findings (Bryman and Bell, 2015). From this theory approach, the data is usually analysed to generate theory. It breaks down the current practice of CDWM to offer areas of improvements.

3.2 Research Design

Research designs are associated with the research method. It correlates with the criteria employed when evaluating business research and gives a framework for collecting and analysing the data. Some research designs that may be applied are experimental design, cross-sectional design, longitudinal design, case study design, and comparative design (Bryman and Bell, 2015). Case study design is chosen in this master thesis due to its ability to combine several qualitative methods. This enables the authors to observe the current situation, connecting theory to practice.

3.2.1 Case Study Design

The case study encompasses the detailed and comprehensive analysis of a single case (Bryman and Bell, 2015). It enables the researcher to observe the current situation, connecting theory to practice (Levine, 1996). This approach is very prominent and widely applied in the business research. The cases used can be a single organization, a single event, a single location, or a single person (Bryman and Bell, 2015). The examples of a single location can be a factory, office building or even a construction site, which was used in this dissertation.

A case study design enables the authors to combine several qualitative methods, therefore avoiding to rely greatly on a single approach (Bryman and Bell, 2015). It may involve either several cases or a single case. Although some writers prefer the generalization of some cases, some other researchers tend to use a single case. For instance, according to Lee, Collier, and Cullen (2007) as cited in Bryman and Bell (2015), particularization constitutes the main strength of the case studies than generalization.

As Bryman and Bell (2015) said, it is suggested to select the cases based first and foremost on the anticipation of the opportunity to gain knowledge, so that the learning will be greatest. A construction site, which is a new children's hospital project (ÖstraBarnsjukhuset), has been chosen as a case area because the project site is quite big and has various construction activities that might have effects to CDWM. Furthermore, the site also has a huge ambition to achieve a sustainable goal through *miljöbyggnad guld,* which is the highest level of green building certification in Sweden, issued by Sweden Green Building Council. This ambition may affect how the CDW is treated. In addition, there are subcontractors, site workers and site manager with different cultural backgrounds. This, in turn, might have influence management of case area's CDW.

3.3 Data Collection Methods

This section describes the methods used to collect data during the case study. Primary and secondary data are collected qualitatively. The primary data included site observation of the study area as well as semi-structured interviews conducted with an environmentalist, researcher, recycling company as well as project member of studied project. In addition, a close-ended questionnaire was distributed to six site workers of the study area's construction site. The secondary data included reports and a brochure which were collected from the study area.

3.3.1 Observational Method

Different from interview and questionnaires, direct observations provide more clear information about what happens in the real-world situations (Ritchie et al., 2013). According to Farenga et al. (2003), observation is an effort to recognize the patterns by doing an empirical process directly based on the initial knowledge of the researchers. Furthermore, Farenga et al. (2003) argued that good scientific observing consists of these following components: as presented in table 3.1 below.

Table 3.1: Elements of good scientific observing. Source: Farenga et al. (2003: p.57)

Component	**Description**
Plan	Use a plan to guide the obervation to avoid skipping useful information or do repetation
Senses	Use all appropriate senses and instruments which extend the senses of collecting extensive and obvious information
Measurements	Make measurements of important variables complement qualitative observations when it matters
Changes	Identify natural changes existing in the objects or system of interest. When applicable, make some changes in this system and identify the responding changes.
Questions	Keep an open mind and be curious while observing. Raise more questions that can lead to new observations and new information.
Communication	Report the observations clearly by using descriptions, charts, diagrams, drawings, and other appropriate methods

Direct observation was done by investigating directly the construction and demolition waste management practice on the case area's construction site. The open observation was used which means that the participants were aware that they were being studied (Bryman and Bell, 2015). These observations were carried out twice in the site office as well as on the construction site. In the site office, waste management plan along with its related information that could be seen directly was gathered. In addition, the process of how the waste handled on the construction site was observed.

Since the information gathered by doing observation may be limited due to external factors, additional reports and documentations were used to build and strengthen research foundation. The work environment, as well as the process of waste handling of the construction site and site office, were captured by using a camera. It gave a clear picture of the real situation of waste management on sites as well as every component used to handle the waste. Moreover, a checklist was used to underpin the data collections. The checklist contains critical issues regarding CDWM that can facilitate the collection of data at the construction site and its office (site office) (see appendix 3).

3.3.2 Interview Method

Several interview methods may be used for collecting data in both quantitative and qualitative research. However, the interviews employed in qualitative research are often far less structured compared to those in quantitative research (Bryman and Bill, 2015). One of the most popular interview methods applied in qualitative research is the semi-structured interview (Bryman and Bill, 2015; DiCicco and Crabtree, 2006), which was employed in this dissertation. This interview style has a flexible nature, so it is possible to raise new questions based on the dialogue between interviewer and interviewee (Duignan, 2016; Louise et al.,1994). DiCicco and Crabtree (2006) argued that besides emerging questions during the dialogue, the semi-structured interview also includes an open-ended questionnaire. In addition, a semi-structured interview is also used to explore opinions of interviewees regarding specific issues, which can be complex or sensitive (Louise et al., 1994).

Semi-structured interviews were conducted with concerned bodies involved in CDWM in the study area. These consisted of an environmentalist and project members of the contractor company involved in the project, as well as the recycling company that handles the wastes in the case area. The interviewees were selected based on their expertise and responsibility. The environmentalist was chosen as she is responsible for environmental ambition including CDWM at the case company. The project members, including a logistic person, is selected due to his knowledge and responsibility for waste at the construction site. The market and sales manager from a recycling company was chosen as he is responsible for collecting and recycling the waste from the case areas of a construction site. In addition, to have a broader perspective and understanding of CDWM in the Swedish construction industry, the interview was also done with a research expert in this field.

The current work process and practices of CDWM and its challenges as well as information flow and communication were discussed with the aforementioned actors. The possibility of BIM usage in CDM was also discussed. The questions raised were about what information would be needed to put in BIM model in order to support waste management issues in construction and demolition project. The interviews were conducted in English and took about 30 minutes to one hour per interview. These interviews were recorded and then transcribed to avoid misinterpretation or mixing of data from various interviews.

3.3.3 Questionnaires

One of the main ways of collecting data is a questionnaire. Usually, questionnaires are self-completion questionnaires or self-administered questionnaires which mean the questions on the questionnaires are answered and completed by the respondents themselves (Bryman and Bell, 2015). As a method, it can come in different forms such as electronic or postal mail. In the business method, questionnaires are very similar to a structured interview. The clear difference is that in the self-completed questionnaires, the respondents need to read the questions themselves.

Self-completion questionnaires have some weaknesses and strengths compared to structured interviews. According to Bryman and Bell (2015), self-completion questionnaires are cheaper and quicker to administer, the absence of the interviewer (which can usually affect the answer of the interviewees), no interviewer variability, and convenience for respondents. On the other hand, self-completed questionnaires also have some disadvantages such as the interviewer cannot help the respondents to answer the question, or even ask the respondents to elaborate more, etc. (Bryman and Bell, 2015).

In addition to the aforementioned data collection methods, this dissertation employs a questionnaire. The purpose of distributing this questionnaire is to give additional information about CDWM at the study area based on site workers' perspective. Site workers were chosen because they are directly involved in managing waste on site. By doing a questionnaire, it is also possible to understand how information about CDWM is practiced by the site workers as the recipients.

The questionnaire was randomly distributed to some site workers in the study area. The questions were designed to be simple and were translated to the Swedish language in order to be easily understood by the respondents. The questions types were not multiple choice but rather multiple answers which allow the respondents to choose more than one answer and/or add more answer based on their experience. The questionnaire covered five big questions related to the thesis topic, including waste sorting, information flow, and challenges of waste management practice. These topics were carefully chosen in regards to the research questions.

3.4 Data Analysis

Although there are various methods of analysing qualitative in the scope of academia, only a few acknowledged and established guidelines exist (Bryman & Bell, 2015). The traditional method of analysing the data consists of collecting, evaluating, and structuring the data iteratively. This method is able to tailor the interviews and incorporate important factors found during the observations.

The data gathered from both primary and secondary sources were analysed qualitatively. In general, qualitative analysis will also be obtained by interpretation of data obtained from interviews, observations and questionnaires.

The observations, interviews, questionnaires and documentation were reviewed to assist creating an understanding of current situation of CDW practice in order to accurately identify possible area of improvements.

3.5 Research Quality

Assessing and establishing the quality of the study are important in the business research. Most prominent criteria for evaluating the business and management research are Reliability and Validity (Saunders et al., 2016). In qualitative research, the meaning of reliability and validity needs to be adapted from its meaning in quantitative. For example, validity seems always to have a connotation of measurement which is not a big issue in qualitative research. Therefore, in qualitative research, as cited in Bryman and Bell (2015), Mason (1996) argues that the term validity refers to 'whether you are observing, identifying, or "measuring" what you say you are'. On the other hand, Saunders et al. (2016) have a somewhat different meaning of reliability and validity, which were used in this study. They divided into external and internal of either reliability or validity. While external reliability measures the degree to which the research can be replicated, the internal is more about how much agree the observers hear and see something and has the same perceptions. Internal Validity means that how correlated between the researchers' theoretical ideas which they developed with the observations they do. Whilst the external validity refers to the degree of generalizing findings across social settings.

3.5.1 Reliability

This study had chosen specific case area which applied construction and demolition waste management. To avoid bias and errors either from researchers or the site workers, collecting data was carefully done. For example, when observing, note taking and capturing pictures were done carefully. Interviews were taped and transcribed to avoid misinterpretation. In order to improve current practices of CDWM, this study tries to come up with waste strategies as well as integrate BIM in CDWM by considering perceptions of different scholars. Therefore, if other researchers would like to do the same method, the same answers will be derived if the research objects are the same. However, since the authors only used single case study, the findings cannot be generalized with other cases.

3.5.2 Validity

As indicated earlier, research quality does not only depend on its reliability but also its validity. In this study, several data collection methods were carefully selected to enable the researchers to answer the research questions. The interviewees were selected in accordance with their expertise and knowledge. On the other hand, since the questionnaires were distributed randomly, the findings might be slightly affected since the participants were from various background, which leads to different answers on questionnaires. However, since there were still other data collecting methods employed, which had a bigger influence in this study, the findings are believed to be valid and are possible to be applied in other similar projects.

3.6 Research Ethics

The interviewees such as researcher, environmentalist and project members as well as the respondents of the questionnaires are only anonymous with name but not with their role. If the interviewees and respondents explicitly agree to be listed with name in this dissertation, written request will need to be filed, which is reviewed in regards of applicable rules and regulations from Chalmers University of Technology.

Confidential information may be encountered due to the nature of a case studies. However, it will not be included in the final dissertation and observational notes. Therefore, all primary and secondary data written in this dissertation were reviewed by the company, interviewees and respondent involved by sending them the copy of dissertation ahead of deadline. If any important information that needs to be included in this dissertation but is confidential, an open dialog between the researchers and the involved parties are done.

As the primary data collected may be sensitive to the individual or organizations involved, storing this information have to be carefully done to reflect the importance.

All the data gathered including interview records and transcribe, and documentations are kept by the researchers, and supplied to Chalmers University of Technology. If this data is considered to be obsolete in terms of research validity, it may be removed in the future.

4 Contextual Review and Case Study

This chapter is divided into two sections. The first section provides the information about current practice of CDWM in Swedish AEC Industry, including regulations and current state of Sweden's waste. The second section describes the case study used in this master thesis.

4.1 Current Practice of CDWM in Swedish AEC Industry

In Sweden, CDWM represents the largest waste stream, mining waste excluded, with a volume of 8 million tons generated annually (SEPA, 2014). In waste prevention program, Sweden has pointed out that CDWM are priority areas. It is also emphasized that it is important not only to dispose of the waste in an environmentally friendly manner, but also to reduce the waste quantity and its hazardousness.

According to the official statistics, the recycling rate in Sweden range between 50-60 %, (SEPA, 2015). It indicates that more effort is needed in order to reach the recycling target and move beyond this level. Therefore, in 2020, it is targeted by EU's member states including Sweden, to fulfil the directive regarding waste which states that non-hazardous construction and demolition waste will be recycled for a minimum of 70%. To reach the target, The Swedish Government has published "Resource and Waste Guidelines during Construction and Demolition", which purpose is to increase resource management towards the construction and demolition industries. These guidelines are a tool intended to fulfil the requirements of the Swedish Environmental Code (Kretsloppsrådet's guidelines, 2015).

According to *Resource and Waste Guidelines During Construction and Demolition,* the containers of waste should be signed with different colours:

a. Hazardous waste (Sign colour red)
b. Electrical waste (Sign for colour red/white)
c. Wood (Sign colour yellow)
d. Plastic for recycling (Sign colour purple)
e. Combustible materials (Sign colour orange)
f. Scrap metal (Sign colour grey/white)
g. Aggregates (Sign colour brown)
h. Landfill after sorted (Sign colour black)
i. Mixes for post-sorting as alternative fraction to landfill (Sign colour yellow/black)

4.2. Case Study

4.2.1. Company's Profile

The company that has responsibility as the main contractor for our study case is NCC. With turnover of SEK 53 billion and 17000 workers in 2016, this company has become one of the prominent construction and property development companies in Northern Europe (NCC 2016, 'About NCC'). As a construction and property development company, NCC is also active around the value chain - building and developing residential and commercial properties, constructing public building, industrial facilities, roads civil engineering structures and other kinds of infrastructure. Furthermore, materials used for paving and road services are also offered by NCC as one of its projects (NCC, 2016).

4.2.2 Project Description

One of the biggest ongoing projects constructed by this contractor company is a new children's hospital, the extension of Queen Silvia's Children's Hospital, which is located in the city of Gothenburg, Västra Götaland County, Sweden. The company is also commissioned to make connections to the existing hospital nearby as well as to build an attractive site environment (NCC 2015, 'NCC to construct a new children's hospital in Gothenburg'). This project, which is under the Design Bid Build Contract, was started in 2015 and is targeted to complete in 2020. Situated in the west of the old building, this new hospital is estimated to have value of SEK 850 million with construction costs around SEK 1.6 billion.

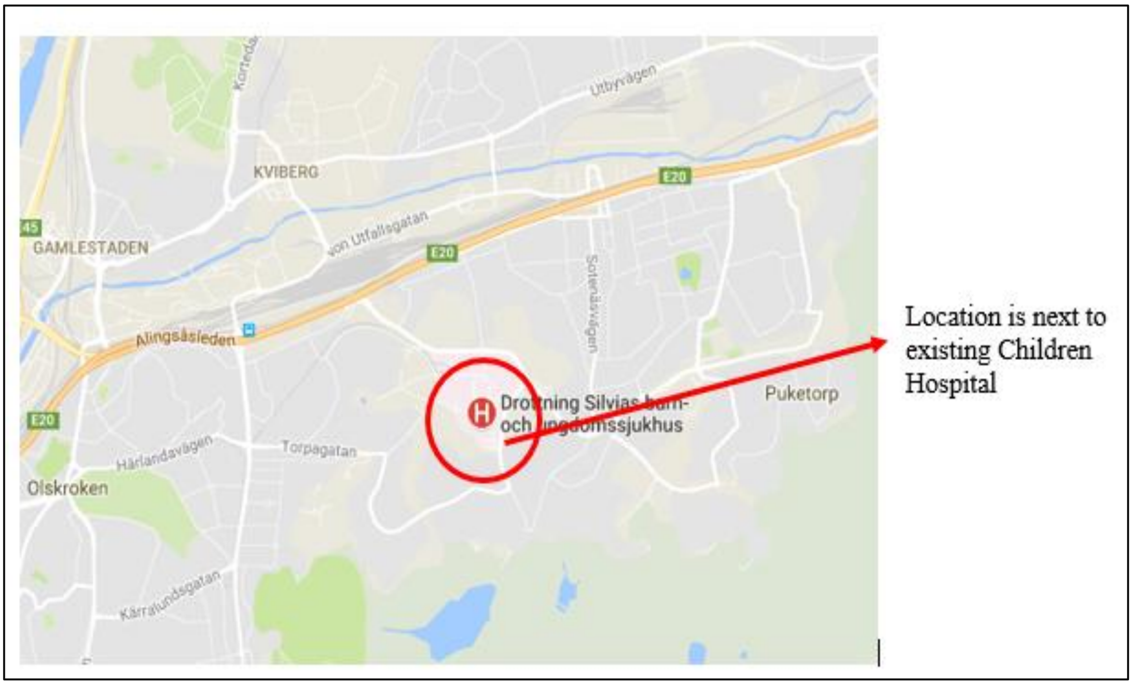

Figure 4.1 Location map of the project

This hospital will be one of the world's foremost children's hospitals with high standard of facilities such as children care, clinical research and education. Moreover, it will also be equipped with places for operation, intensive care, rehabilitation, nursing wards and administration. This nursing wards will offer improved care environment for patients and their close relations (NCC 2015, 'NCC to construct a new children's hospital in Gothenburg').

Business Area Manager for NCC Construction Sweden, said "NCC strives to achieve a Gold environmental rating from Sweden Green Building Council, which is the highest classification and demonstrates the building's environmental performance with respect to energy, indoor environment and material," (NCC 2015, 'NCC to construct a new children's hospital in Gothenburg').

5 Findings and Result

In this section, results and findings were discussed based on observation, semi-structured interviews, and questionnaires of the case area. The results were explained at case area, company and multi-project level.

5.1 Current Practices of CDWM

5.1.1 Current Practices of the Case Area's CDWM

The case area's construction site was big in size. It was paved with asphalt in order to keep the site clean as mentioned by a logistic person. In addition, in the case area's construction site, different types of construction wastes were generated. The logistic person who was in charge of waste management on site said that at least there were eight different fractions for wastes on site. These wastes were earth, concrete, foams, plastics, cardboards, wood, papers as well as hazardous wastes. In addition, most site workers who responded to the questionnaires considered earth/soil as the main waste generated during construction, followed by wood/timber and scrap metal.

Waste sorting was carried out on site. There were rooms/containers to sort waste materials such as electric, gases, chemicals and hazardous wastes (see figure 5.1 and 5.2). These rooms/containers were labelled based on waste types. Suppliers were responsible for taking care of the toxic/hazardous wastes as described by the logistic person. The logistic person also mentioned that the recycling company took the waste material to their station and the recycling company's chemist analysed everything.

In addition, the interviewee, who works in the recycling company, discussed that the recycling company is responsible for collecting and recycling the waste from the construction site. The interviewee mentioned that the recycling company has attempted to provide waste containers as many as possible and the construction company decides where to locate the waste containers based on waste management plan of the construction site.

The waste materials that are brought to the recycling company were still sorted a little more to have clear fractions. The mixed and combustible wastes were sorted carefully using waste sorting vehicle. Any wastes that were suspected to be harmful were tested before treated for further process. Some wastes were treated differently. For example, wood was crushed into small pieces and then sold to the energy recovery plant to produce heat. More than 95% of the waste went to energy recovery. On the other hand, metal was sent to other recycling company which took care of metal. This metal was melted and moulded to make a new metal and used in the industry. Plastic was also recycled and exported to other country like China and Indonesia for other purposes. In other words, the recycling company sold these wastes as raw material for further purpose.

Figure 5.1 Room to sort hazardous wastes such as chemicals, electronics

Figure 5.2 Room/container to sort gases

The waste containers were put in a row, and clustered in the same place (see figure 5.3). In addition, the waste containers were near to one side of the building, which was under construction but the containers were far from the other side of the building. The other side of the building, which was under construction, had only one or two waste containers.

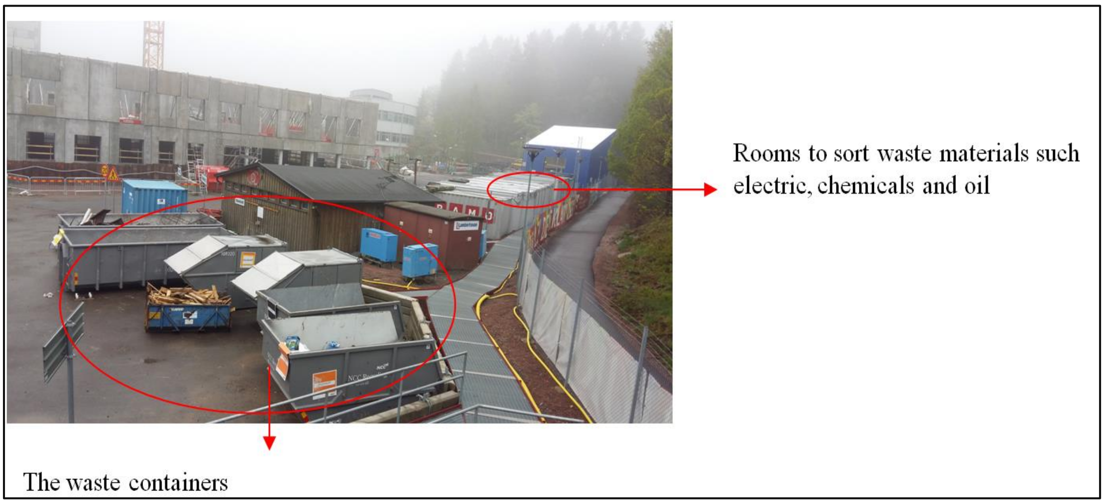

Figure 5.3 The location of waste containers

On the construction site, the waste containers were signed with different colours in order to easily distinguish the various types of construction wastes as well as to avoid mixing of the wastes. For instance, orange colour was used as a sign for combustible materials; black colour was used as a sign for landfill; red colour for hazardous wastes and yellow for wood. However, some of waste containers contained mixed waste (see figure 5.4, 5.5, 5.6, 5.7, 5.8 ,5.9 and 5.10). The colour codings are the same with those shown on the brochure.

Figure 5.4 containers with orange and red colour tag for combustible and landfill wastes

Figure 5.5 Waste Container is signed with red colour for hazardous wastes

Figure 5.6 Waste container with yellow tag for wood

Figure 5.7 Waste containers with light brown tag for cardboard

Figure 5.8 Waste container for foam ('cellplast')

Figure 5.9 Mixed wastes: foam, plastics, carton, etc.

Figure 5.10 Combustible Waste materials: plastic carton, paper, etc.

As it is mentioned above, the construction wastes were disposed in containers. However, some of the wastes, such as earth and concrete, were not disposed in the waste containers. Rather the wastes were dumped on the construction site (see figure 5.11 and 5.12).

Figure 5.11 Earth that is disposed on the construction site

Figure 5.12 Concrete waste

In addition to waste containers, in the construction site, there were two blue tents that were used to store steel. In one of the tents (tent-1), there were safety materials and few steel bars, and the other tent (tent-2) contained equipment that were used to cut and bend the steel bars (see figure 5.13 and 5.14).

Figure 5.13 Tent-1

Figure 5.14 Tent-2

The steel bars were temporarily stored at upplag 2. Upplag 2 was a sign that is used to easily identify the place where steel bars were stored temporarily. Moreover, there were places where different types of construction materials were placed temporarily. In order to easily identify the place and type of materials that should be stored in a specific place, signs are used. There were 5 signs that are used to store construction materials temporarily after goods moved from trucks. These signs were called ‘upplag 1’, ‘upplag 2’, ‘upplag 3’ ‘upplag 4 ’ and ‘upplag 5’ (see figure 5. 15). Additionally, on the site, there was also LP1 and LP2 that were signs for smaller delivery. Construction materials were ordered when needed (refer figure 5.16).

Figure 5.15 Temporary storage

Figure 5.16 LP 1 (A sign for smaller delivery)

5.1.2. Current Practices of CDWM at Company Level

The environmental expert discussed that they set up goals for their waste. i.e. reduce mixed waste, combustible waste as well as minimize waste materials that went to landfill, in less than 30 %, in 2020. The goal was at department level of the company in Gothenburg. The expert mentioned that the company was influenced by the EU target. EU target calculated waste in terms of volume. In addition, according to the environmental expert, the other goal was to work with two waste contractors (i.e. NCC recycling and external contractor) in order to reduce waste materials and improve sorting. This was because; the waste contractors had knowledge and experience regarding waste management as it could be understood from the interview with the expert. Currently, the waste contractors were responsible for recycling the waste materials of NCC's construction project. The interviewee mentioned that they were measuring how the department was working with waste and sorting of waste. The environmentalist explained that:

> *"Every quarter, I measure every department and they get the statics of the wastes and get down to project level, look which project is good and not very good and can learn from that and take the good stories and help another project"*

The expert discussed contractor firm got all statics about waste materials from waste contractors, that was responsible to collect waste materials from the firm's construction site, and measure the weight of construction waste in kilo or tone. Therefore, the waste contractors reported to the environmental department of the company about the amount of wastes (such as mixed waste, wood fraction, gypsum fraction and the like in number, and recorder calculated the wastes in all project and get the exact number at the department level. However, the expert described that when calculating percentage of mixed waste, landfill and combustible fraction, inner mass, soils, hazardous waste was not included. The expert mentioned that the department obtained the hazardous wastes in numbers but such wastes were not calculated every quarter but dangerous wastes was calculated once a year.

The department is responsible to have knowledge on how projects are handling the sorting of waste to be able to identify projects that may require education. The company tries to sort the waste materials. The expert mentioned that the company would like to reuse the building materials. Therefore, it needs to make sure the materials are not dangerous. However, it is a costly process to look into the quality of the materials when there is a lack of information on the content of building materials. The company also tries to work with purchasers and suppliers of building materials to take back the spillage from a building site as it can be understood from the environmentalist.

Moreover, the expert explained that the company is looking into a method to build up a digital platform to visualize the material left on a building site and enabled sharing of construction materials. For instance, gypsum, which is in one building site, could be used in another building site. The company is looking into a new digital platform, and it is not a logistic site. Nowadays, in the new digital platform, it is possible to visualize that the existing construction materials, and to reduce waste materials. The company uses internal internet site called 'starnet', which has been used as a place where to put in any question but it is difficult to find questions since it has a lot of questions not only about wastes. For this reason, the company wants to take out questions related to the existing construction materials and builds a platform that is easy to find information and user friendly. It is planned and the company begins to work with the new digital platform. The name of the digital platform is Loop Rocks.

The environmentalist mentioned that the company has clear waste management guidelines in their internal system that shows how to deal with waste in terms of legislation. Moreover, the expert discussed the company has not updated the guidelines. The interviewee mentioned that the company would like to improve the guidelines and documentation in order work more on waste management.

In addition to guidelines, the environmentalist also explained about logbooks. According to the expert, the logbook is used by all building industry of Sweden, and this is line with the recommendations of Swedish Environmental Protection Agency (SEPA). The industry has decided to use this, and made declaration on their products in terms of chemical content and material content information.

> *"If we buy products, we get declaration of the chemical content that is used in both "*Byggvarubedömningen*' and 'miljoledare' as one indicator which is called logbook, which means need to list all building product and information around the chemical content."*

The reason why it is required to list all product information regarding chemical content is that chemical legislation is slow process and is not easy to know the negative effect of chemicals, which are used currently.

5.1.3. Current Practices at Multi-Project Level (Viewpoints of the Researcher)

The researcher explained that unlike new construction projects, in a renovation project, there may be a high proportion of waste and different types of wastes such as concrete, electric cable, steel, etc are present. Reducing, reuse and recycling are carried out by waste contractors, which is the third party. Waste sorting was conducted on the construction site. However, according to the researcher, sorting of waste may depend on space and client demand. For example, there may be many containers on the construction site if there is space. However, on site, they may have two waste containers if the client wants to separate the construction wastes using two waste containers that are used to dispose of aggregate and mixed. The reasons why a client prefers to have two containers is the amount of space on the site, as well as the clients, are ready and willing to pay for the mismanagement of waste materials. Besides, some clients did not want separation of construction wastes as clients did not know about waste management. Moreover, clients may have no intention to do better waste management since they do not receive an incentive for this.

Like clients, subcontractors did not receive an incentive for CDWM, according to the researcher. For this reason, subcontractors had low performance in managing waste materials. According to the researcher who was interviewed, some site manager was not willing to include waste issues on a contract as site manager believed that it may cost more and consume time to separate waste materials. However, some site managers were environmental friendly and willing to have a contract regarding waste management.

According to the researcher, the site manager is responsible for waste management on a construction site. Site managers take all responsibilities and tasks and also take responsibility when subcontractors make mistakes. However, most of the time, site managers focused on finishing the project on time, within budget as well as satisfying clients and not disturbing tenants. In addition, site managers did not pay attention to waste management in studied renovation projects and this contributes to the generation/production of the waste in construction industry.

Furthermore, the researcher explained that no one controlled the site manager as the project manager focus on administrative work, the project manager may say something about the existence of waste management regulation. The researcher described that, instead of the project manager, site supervisors seems to advice/consult the site manager on issues regarding waste management.

5.1.4 Challenges in Managing Construction Wastes

5.1.4.1 Challenges at Case Area's Construction Site

As mentioned above, waste materials of the study area were sorted on site and the recycling company is responsible for collecting and recycling the wastes. However, there are challenges in managing construction wastes in the study area. According to the interview with project members, these challenges are cultural differences and space shortage. Since most workers are from another country, Poland, the interviewee said that language and legal differences between Sweden and Poland makes it more difficult to communicate and instruct to the site workers. The interviewee mentioned that space shortage also become a hindrance. This is because the space on the construction site has to be used also to store the construction materials temporarily. This, in turn, makes the waste containers clustered in one place, which sometimes become far away from the workers work location.

In addition, most questionnaire respondents thought that unclear understanding about sorting wastes, location of waste containers as well as lack of information regarding how to sort the wastes are their main challenges in managing waste on the construction site.

5.1.4.2. Challenges at Company Level

In addition, there are challenges in managing wastes at a company level. For instance, an environmental expert discussed that it is difficult to sort and reuse waste materials of aged buildings, especially in renovation projects. For instance, it is difficult to reuse waste materials of old buildings as it was difficult to know its chemical content. Bad waste management plan and lack of knowledge regarding waste management are also the hindrances for the management of CDW.

The expert also mentioned it is needed to start planning for waste earlier, and this is more difficult in terms of logistic. That is to plan where the waste containers should be placed as well as to plan earlier in order to identify the different types of waste; and how to handle the wastes. In this case, it was not easy to begin earlier.

5.1.4.3. Challenges at Multi-Project Level

According to the researcher, there are several challenges. Nowadays, at Swedish construction sites, there are challenges in managing CDW. The challenges are the shortage of space (or lack of adequate space); language and cultural barriers: and lack of awareness of CDWM. Additionally, non-existence of color containers; shelter for waste containers, as well as an *absence of an agreement with subcontractors regarding waste management:* Some of the aforementioned challenges at a multi-project level are described by the researchers as follows:

Lack of adequate space: The interviewee described that it was difficult to manage the waste materials in renovation projects since there might be a lack of adequate space to sort waste materials due to the availability of space around the existing building. In addition, in such projects, there might be an intensive amount of waste materials such as concrete, electric cable, chemicals, and the like. The other challenge was a shortage of space for recycling in the construction site as there is often no space for both recycling equipment and waste containers. In addition, recycling has a lot of dust and noise, and if there are neighbours or tenants that are living near to the site, they would complain. This was also the reason why recycling companies are located far from the construction site.

Absence of shelter for waste containers: According to the researcher, some waste materials get heavier as the waste containers have no shelter. Thus, the materials will become difficult to move or lift. For example, the interviewed person described that if you have gypsum board, it allows rainwater to penetrate and get heavier. For this reason, it is difficult to move the gypsum board easily, and you have to pay more for the waste material, gypsum. The interviewee believed that waste containers need to have shelter in order to protect the waste materials from rain and snow so that the materials will become easier to move.

Lack of agreement with subcontractors regarding waste management: it is difficult to control the waste materials if there was no contract or agreement with subcontractors according to the researcher. This is because; there are a lot of subcontractors on site especially, in refurbishment projects. It is not only the main contractor but there also are other subcontractors (such as electric subcontractors). Subcontractors do not always have their own waste containers. The subcontractors shared waste containers provided on site by the contractor. In view of this, it is difficult to identify or know the subcontractor who produced the extensive amount of waste and less waste except the electric subcontractor.

According to the researcher, it is not easy to sort waste materials if the waste is mixed. For instance, the researcher gave an example when a waste contractor came and picked the containers, they noticed that the waste was not only concrete but also electric cables or other waste materials. As a result, the construction company had to pay extra for the mix of waste. However, nowadays most site managers know about waste management problems and challenges. They know it costs a lot. Therefore, they sort waste materials to save money as it could be understood from the interviewee with a researcher. Unlike a site manager, subcontractors were not responsible for waste management as subcontractors did not get any incentives if they worked on waste management in good way.

Lack of awareness: according to the researcher, there can be a lack of awareness among lower level construction workers. Especially if they come from different countries, they do not know about the Swedish regulation regarding waste management.

Furthermore, It will be difficult to eliminate waste for the contractors if architects design buildings with errors. However, site managers did not think that architects are responsible for this but the project managers take all the responsibilities. There is a little opportunity to reduce waste.

5.1.5 Information Flow and Communication

5.1.5.1 Information Flow and Communication at Case Area's Construction Site

The workers got the information of how to sort the waste from the brochure provided by the recycling company. As the interviewee said:

> *"It's a small book that you can put in your pocket. We have it in Polish, Swedish and English..... So, there they (the workers) can look at by themselves and see where they should put the garbage".*

This small guideline book is available in three different languages: English, Swedish and Polish (see figure 5.17). The reason is the workers came from different country, so they do not speak Swedish.

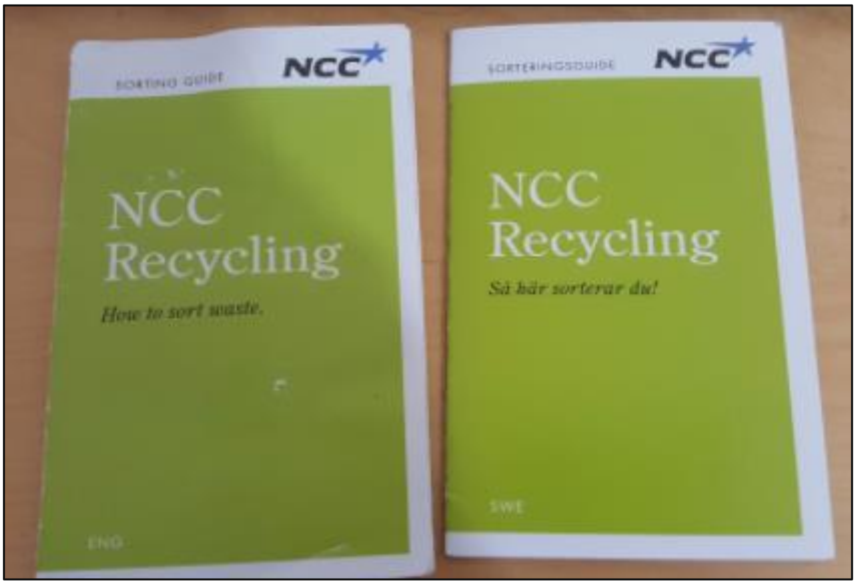

Figure 5.17 Brochure that is distributed to the workers

The waste sorting guideline is also attached on the information board (see figure 5.18). Colour code from each type of waste showed in the brochure was also put in the site containers.

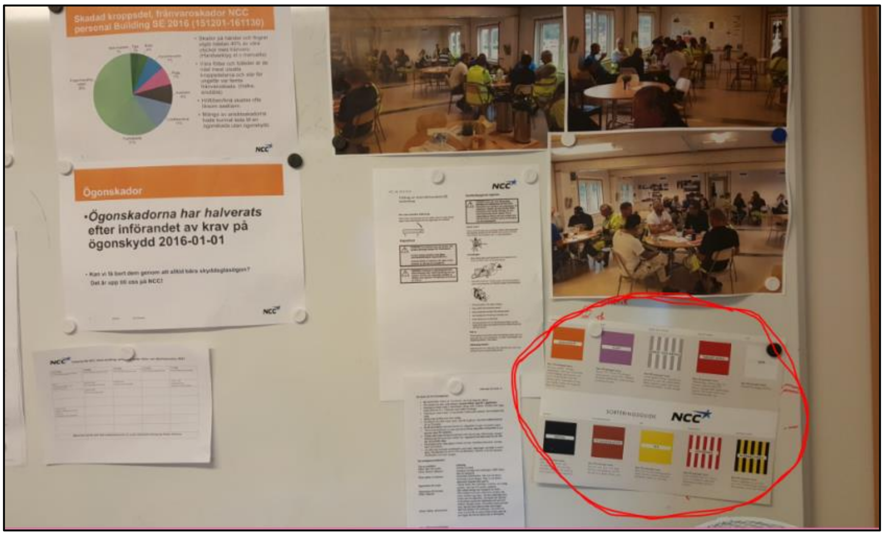

Figure 5.18. Waste sorting guidelines attached on the information board

In addition, the recycling company sometimes visits the construction area to have a meeting with the project members, and has a presentation on a big screen. The presentation and meeting was a 30-minute information about waste handling, explaining what the workers should do regarding waste, why they should do this, and how their actions can affect the environment. Place for meeting and presentation is shown on figure 5.19.

Figure 5.19 Place for meeting and presentation

The subcontractors were also informed in the same way, using brochure and a short presentation from the recycling company. However, the interviewee also mentioned that sorting the waste was the obligation of every subcontractor since it has been written in the contract.

> *"Yes, everything is written in the contract, ... they have to sort everything and another thing is that dangerous wastes have to be put in the special*

containers, like chemical. Those subcontractors are responsible for themselves. ……… They have to handle that, and take care waste with those products (the products that the subcontractors use).”

5.1.5.2 Information Flow and Communication at Company Level

At the company level, statistics of the waste materials are reported and presented to the contractor's annual account overview as described by the interviewee, an environmental expert. In order to inform the contractor’s workers about waste management practice, the expert described that the company starts to work on a waste handling plan as well as carrying out start up meetings for the projects. Additionally, in this year, the contractor firm also conducts two meetings with the waste contractors to acquire knowledge and experience on issues regarding waste management. The expert explained the information flow among site workers, subcontractors, waste contractors as follows:

“The waste contractors have a project start-up meeting and then it is the organization around the building sites that needs to ensure that everyone gets the right information, and the waste contractors have a lot of information (material) All information packages that we get from our waste contractors should be used.”

5.1.5.3 Information Flow and Communication at Multi-project (Viewpoints of the Researcher)

According to the interviewee (researcher), the site manager informed issues regarding waste management to construction/site workers and subcontractors through informal communication, often orally. However, the researcher discussed that the existence of different cultural and language barriers can affect the flow of information. For example, the researcher explained that *“you cannot really explain them why and how they should sort wastes because it requires certain knowledge. You have to able to talk to them either in Swedish or English. Some of the site workers do not speak any of this language. It is hard to communicate”.* This, in turn, affects the flow of information regarding waste management. In addition, there can be a cultural barrier to communicate with site workers and subcontractors as they might have different views about waste. For instance, in Sweden, which is an almost *‘zero waste country’*, there are high regulations about waste, and understanding of waste among workers of a construction project. If site workers come from other countries like Turkey, or Poland, the workers do not really care about waste management as it can be understood from the interview. Training on issues associated with waste management is not conducted in refurbishment projects discussed by the researcher. Moreover, there is no formal communication among site workers, subcontractors and site managers and most of the time, site managers do not have an agreement/contract regarding waste management with subcontractors on refurbishment projects as studied by the researcher.

According to the researcher, site managers were people who did not have time. Thus, they did not read their email and check the company's website as it took time. Site managers wanted someone to inform them about the regulation and the managers could easily understand the regulation with little time. Then they will implement it. The researcher explained about site manager as stated below:

> *"Site manager is also complaining that the information is very formal and they want someone come from the central organisation like an environmentalist, to talk to them face to face or call. No one controls the site manager. The site supervisor, who is lower than them, does check legislation, regulation, guidelines and comes up with solutions and informs the site manager and he/she will apply it."*

Generally, the presence of different site workers and subcontractors with different cultural backgrounds can have negative effect on the flow of information.

5.2 BIM

5.2.1 BIM at Case Area's Construction Site

The interviewee, the logistic person who is in charge of CDWM, said that the case area's construction project is using BIM. It could also be seen in the site office that 3D modelling, either in the employee's computer or on the big screens, was used. This indicates that they implemented BIM in this project. However, the interviewee had no idea about how this technology works, and it seemed that BIM had not been used for construction and demolition waste management.

5.2.2 BIM at Company Level

Environmental expert explained about the use of BIM in the future if it was applied at the company. For instance, the expert discussed planning of waste sorting was easy by using BIM as well as it was possible to get information about deconstruction.

BIM can give information about hazardous materials that were used during construction. The expert discussed that two pilot studies have been carried out to understand the positive aspect of BIM in the future. In the two studies, all specific product information is available in a BIM model. There was an ID number which was the same number as used in the material database, which was 'named as 'Byggvarubedömningen', which contained all information about the chemical content

An environmental expert described that the company has the information regarding specific building material on a different system. The expert believed that the company should put all information within one system and the information can be used in future.

BIM is used to get information in a 3D model. For example, building elements (such as wall, roof, etc.) could be seen directly from the 3 model. According to the expert, in BIM, it was possible, to add another attribute (like length of different building products), to do repairs or change some part or take some part away in a good way in end of building.

> *"You need to know how to deconstruct but first we need to have tractability and idea of the product. You have the information about reusability and, recyclability of product/ material. They have not put all that information together but now it is impossible and an efficient way because you need to go to another system and you need to get information out from that system and I want everything to be in one system. It is the future way of working."*

On the pilot study, the company has specific product information that has been built in with 'Byggvarubedömningen' (construction product assessment) ID. Then it needs to go to the material database, which was named 'Byggvarubedömningen', to find information about the chemical content, life length, and if the product was possible to reuse. The problem was that there was not much information on how to deconstruct. As an example, the expert described that *"you have identification ID for the specific product, normally you do not have information on the specific product. You have generic/basic information about a product if it is gypsum board you do not know which supplier it is, which means you do not know the chemical content"*.

To be able to know information about the hazardous of the material and the possibility if the material could be recycled and reused, it was important to know the supplier as suppliers do not have the same quality and chemical content in their product.

The expert explained that in a BIM model, there is a material database, which is called 'Byggvarubedömningen' ID (the supplier puts information about the product content in this system). Specific product information (such as chemical content, recyclability, and reusability of construction materials) is filled out in this database. The expert would like the company to use BIM in an efficient way.

BIM made waste sorting more efficient by using the 3D –model. For example, to look where different waste containers were located supported the logistic work with a waste contractor. BIM was helpful when working with purchasing order. For example, using BIM it is possible to get gypsum in the right size package in every flow.

5.2.3 BIM at Multi Project Level (Viewpoints of the Researcher)

The researcher described that BIM is a useful tool to estimate the amount and type of waste. Additionally, the interviewee mentioned that BIM can reduce waste as a project with a better plan does not produce that much waste, and plans can be checked. The interviewed person also described that BIM may be used for recycling and reuse.

However, it is expensive and hard to apply BIM in renovation projects because it is difficult and expensive to change old drawings into a 3D model. Therefore, most of the time, no one is willing to pay for BIM model for renovation projects as it can be understood from an interview with the researcher. On the contrary, according to the researcher, it was easy to start everything in BIM model in new construction as there is a new building. In the future, BIM will be more useful in managing waste of a particular project, especially in refurbishment projects since using BIM, it is possible, to know how much of waste can be sorted, reused and recycled. It can also be used to estimate the cost of a project in terms of percent. Moreover, BIM helps site managers and project teams to get information about the construction materials that are used for a specific project and its quality.

5.3 Summarized Findings

The findings are summarized in table as follows:

Table 5.1: Summary of current practices of case area's CDWM

Current practices	
Case area	- Different type of construction wastes such as earth/soil, wood/timber, and scrap metal generated on site. - Sorting of construction wastes has carried out on site - Waste contractors (recycling company and external firm collect construction wastes - use of prefabricated construction materials - After collecting the waste, waste contractors are responsible to recycle the waste - Construction wastes are disposed of in waste containers. - There are waste containers with different colour coding - Rooms, tents, and containers that are used to sort the different type of construction wastes - There are five signs that are used to store construction material temporarily (upplag 1-upplag 5) - Lp1 and LP2 are signs for smaller delivery - Construction material ordered when required - A waste management plan
Company level	- Set up goals (reducing mixed waste, combustible as well as minimize waste materials that go to landfill at department level - Minimizing waste materials and improving sorting by working together with waste contractors - Company tries to sort the waste materials

	- The company would like to reuse the building materials. - The company has developed a new digital platform, Loop Rock, to visualize construction material, which left on a building site and enables sharing of construction materials. - Have guidelines but it is updating now - Use of Logbooks in projects, to know chemical content of the construction materials and other information about the materials.
Multi-project level	- There might be a high proportion of waste and different type of wastes, especially in a renovation project. - Reducing, reuse and recycling are conducted by waste contractors - A client interest influences waste management practice - Space may have effect on waste sorting - Subcontractors and clients are not active participants in managing construction waste as they do not get incentives - Site manager is responsible for issues regarding waste management - No one controls the site manager except the site supervisor.

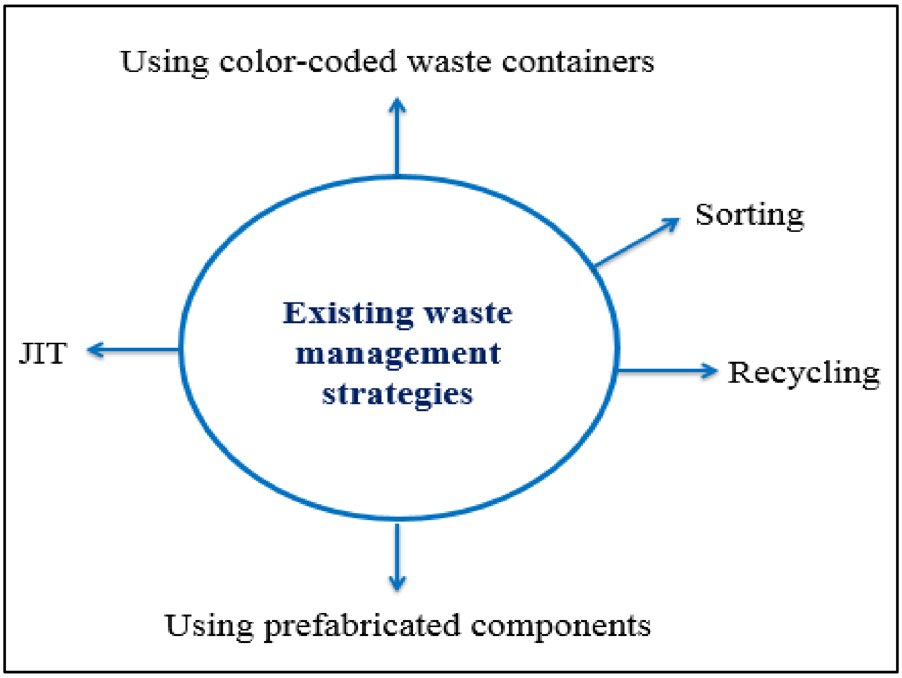

Figure 5.20 Existing waste management Strategies

Table 5.2: Summary of challenges

Challenges in Managing Construction Wastes		
Challenges at case area's construction site	**Challenges at company level**	**Challenges at multi project level**
Cultural and language difference; Unclear understanding of waste sorting; Lack of information Lack of adequate space	Bad planning and lack of knowledge regarding waste management; Begin planning for waste earlier, and this is more difficult in terms of logistic.	Lack of adequate space; Absence of shelter for waste containers; Lack of agreement with subcontractors regarding waste management; Site workers may not be aware of waste management; Language and cultural barrier;

Table 5.3 Summary of information flow and Communication

Information flow and communication		
Case area	**Company level**	**Multi project level**
Brochure Information board Short presentation Contract	Statistics of the waste materials reported and presented to the company's Årsredovisning waste handling plan as well as carrying out start up meeting to inform the workers Meeting with waste contractor to get knowledge and share experience	Informal communication among site manager, subcontractors and site workers

Table 5.4 Summary of BIM

BIM		
Case area	**Company level**	**Multi project level**
Has not used for CDWM	There is an effort to implement BIM for CDWM through two pilot projects The effort focus on putting more information regarding CDWM on BIM database The company has also tried to collaborate with the suppliers.	BIM is a useful tool to estimate the amount and type of waste. Better plan on using BIM could reduce the waste BIM is expensive to apply in old Building

	The company believed that by implementing BIM the work processes of CDWM could be improved	BIM will help site manager and project team to manage CDW, especially in refurbishment project.

6 Discussion

CDWM is a crucial issue for sustainable development that has environmental, social and economic benefits (Lu and Yuan, 2011). However, CDW may prevent the construction industry from attaining such benefits. This is because; the output of CDW has negative effect to the environment, economic and social value (Marzouk and Azab, 2014). Globally, an intensive amount of waste has generated from construction activities (Chinda, 2016; Teo and Losemore, 2001; Yuan and Shen, 2011). It seems difficult to manage waste throughout the construction phase but the case study's firm and construction site try to manage the construction waste using waste management strategies. There is also an effort at the case study's firm to manage CDW by applying the technology, BIM. However, in the case area's construction site, BIM has not used for the purpose of CDWM. It seems also that there is a lack of clear understanding about CDWM. However, the firm has started to carry out meetings with waste contractors to gain knowledge and clear understanding about CDWM. In the study area, that information regarding CDWM shared among the site workers, subcontractors and site manager through brochure, information board, presentation and meeting.

The discussion is structured in three main areas as it is stated below: current practice of CDW, information flow and communication as well as BIM. Structuring the discussion based on the areas above is intended to link back to the research questions and theoretical framework which gives the foundation of the study.

6.1 Current practices of CDWM

According to the research findings, the current practice of case area's CDWM has mainly three work processes. First waste materials are sorted on site, and second waste contractors collect CDW. Finally, recycling companies take the responsibility to collect and recycle CDW. This indicated that the case study has executed some of the waste management strategies such as recycling and sorting that are discussed in the theoretical section. For instance, sorting construction waste before disposal/dumped in landfill has viewed as good practice (Lu and Yuan, 2012). Similarly, in the study area's construction site, the major waste management strategy is sorting, and it can be considered as good practice of the case area's CDWM. In addition, it is possible to increase the reuse and recycling rate, mitigate the waste transportation cost and disposal and prolong the life of landfills through on-site sorting (Wang et al., 2010). In the case study, it is possible to achieve the aforementioned benefit as there is on-site sorting in the construction site. However, it seems impossible to reduce waste transportation cost as the case area's waste materials are brought to the recycling company in order to be sorted a little more to have clear fractions, and the case area's recycling company is far away from the construction site. The finding of the result showed that the recycling company is responsible to collect and recycle CDW to manage the wastes. Recycling is mentioned in the theory part, and it is one of the 3R principles of waste management as it is described by different scholars such as Kareem et al. (2015), Richardson and

Springer (2013) and Yuan and Shen (2011). Li (2012) mentioned that waste minimisation should be considered at first in waste management effort, and reuse and recycling can be used if the wastes are unavoidable. The result also showed that the company has started up to work with the new digital platform, Loop Rocks that enabled sharing of construction materials. For example, gypsum, which is in one building site, could be used in another building site. This indicated that the company has used reuse as a waste management strategy. This result is corroborated by Kareem et al. (2015), Richardson and Springer (2013) and Yuan and Shen (2011) who considered reuse as waste management hierarchy. In addition, the result is supported by Ajayi et al. (2015) who mentioned reuse as one of the waste management strategies. However, the case study seems to give more emphasis to recycling and sorting than reuse and reduce.

Besides sorting, reuse, and recycling, the result of this study showed that there are color-coded waste containers to sort and manage the waste in the construction site. This result is consistent with the study of Sertyesilisik et al (2012), which identified that use of color-coded containers as a method to manage waste. In addition, the colour codings are compliance with the *Resource and Waste Guidelines during Construction and Demolition*, which is mentioned in the Kretsloppsrådet's guidelines (2015).

Additionally, in order to manage waste, there are design strategies such as the use of prefabricated components in construction projects, waste *reduction investments* and design modification that can contribute to waste management (Wang et al., 2014). Prefabricated construction materials were used in the construction site but the finding of the study showed that there are no waste reduction investments. That means incentive measures are not practiced in the study area. Another important finding is that lack of incentive measures might limit the active participation of the subcontractor and clients in waste management practices. This result is aligned with the study of Udawatta et al. (2015) which found that most construction project participants are influenced by the profit-driven nature and competitiveness of the construction industry (Udawatta et al., 2015). On the contrary, the site manager is responsible for all issues regarding waste management. This supports previous research by Sezer (2017), who found that Site managers play a major role in waste management practice. This indicated that the site manager has a lot of tasks. This may have the negative effect to waste minimisation strategies effort as waste minimisation strategies require the concerted effort of all project participant such as client, government contractors, and the whole supply chain (Richardson and Springer, 2013). The result showed that the construction materials are ordered when needed. That means in the study area, there is strategy called 'Just in Time (JIT)'. This result is supported by Ajayi et al. (2015) who mentioned JIT as one of the waste efficient procurement strategies that reduce waste.

As it is mentioned above, the case study is trying to improve their CDWM practices through on-site sorting, reusing, recycling, JIT use color-coded containers and prefabricated components. In addition to such CDWM strategies, there are also different waste management strategies that are discussed. In the theoretical section, different waste management strategies are explained but in the study area, only few waste management strategies such as sorting, recycling, JIT, using prefabricated components and colour coded waste containers are implemented. Despite the fact that the waste management strategies that are stated in the literature part are effective construction waste management strategies that can minimize waste of the study area, it seems difficult and unrealistic to implement the strategies. This is because; the decision regarding waste management practices are made in construction industry based on financial profit (Udawatta et al., 2015). Clients also play a major role in processes of decision making regarding waste management practices as the client is the investor to the construction project (Udawatta et al., 2015). Therefore, clients have also the potential to influence the execution of the waste management strategies. This is true for the case study as well.

6.1.1 Challenges in Managing CDW

From the research findings, the case study has faced the following major challenges in managing CDW:

- *Lack of adequate space* has become a challenge to manage CDW as the construction site is not only used to put the waste containers but also to store construction materials temporarily.
- *Cultural and language difference* have negative effects on CDWM effort. This is supported by Ajayi et al. (2015), who stated that *culture of waste behaviour within the industry* contribute to the ineffectiveness of waste management strategies. In our point of view, - such a difference, may make collaboration among the stakeholder more difficult and sometimes it is impossible to communicate with the stakeholders.
- *Lack of information is* also a challenge for the management of the waste. This is supported by Li (2012), who found that lack of data is a barrier which prevents effective handling and management of construction waste.

However, the findings regarding challenges are not really the same with the challenges that are mentioned in the theoretical section. For instance, in the case study, the challenges in managing waste lack of adequate space and information as well as cultural and language difference. However, in the literature part, the challenges are less positive attitude and behaviour toward waste management practices; inability to predict production environment; unique characteristics of each project; time pressure and cost limitation ((Kareem et al., 2015; Teo and Loosemore, 2001; Udawatta et al., 2015).

6.1.2 Information Flow and Communication

Based on finding, the information flow and communication in the case area were done in many ways, such as using brochure, presentation, information board and meeting. These types of communication are therefore similar to what Sandhu and Ajmal (2012) mentioned as oral, written and nonverbal communication. However, the literature did not confirm how the information regarding CDWM should be shared.

The result shows that subcontractors in the study area also have an agreement with the main contractor regarding who is responsible for taking care of the waste. This is supported by Sertyesilisik et al. (2012) who mentioned that there should be agreement between contractor and subcontractors to identify who is responsible to take of the waste. This is an important way of communication since the agreement or contract binds both parties, which means there will be a consequence if the contract is not obeyed. However, there is still a few subcontractors who do not follow the contract as can be seen from the construction site. Some subcontractors still mixed the wastes although they have been informed. This indicates the subcontractors have less awareness regarding CDWM.

6. 2 BIM

The findings of this study indicated that BIM was used for various purposes without fully considering the benefits for CDWM. The result also showed that BIM is understood as a tool that shows the 3D model to visualize building and often the logistic person, who is in charge of waste management, did not know exactly how this technology works. It seems to some extent, there is lack of understanding about BIM usage for CDWM. However, it is reasonable since it can be understood from literature that BIM usage for managing waste have just got attention from researchers for the last few years, and the literature concerning is still limited (Lu et al., 2017).

As suggested from the interviews, BIM is possible to use in order to get information about deconstruction. This finding is supported by Ding et al. (2016) who stated that BIM can be utilized as a tool that can provide information for deconstruction. This is done by adding attributes to BIM model which show useful information for deconstruction project. These attributes, based on the finding, include *reusability* and *recyclability attributes,* which give information about the hazardousness or lifespan of the material or product. This finding is corroborated by Akbarnezhad et al. (2014) who mentioned these attributes as some of the needed attributes that can be added to BIM model to support the deconstruction project. The other attributes that need to be added to BIM model for deconstruction purpose, which were not mentioned in the results, are *structural* attribute; *handling, installation, and disassembly* attributes; *geographic coordinates* attributes; and *condition-related* attributes (Akbarnezhad et al., 2014).

The interviewee recommended that BIM is a useful tool to estimate the amount and type of waste, and this is supported by the literature. For example, the AGC developed BIM as a digital visualization tool to predict and identify construction and demolition waste materials. Additionally, Cheng and Ma (2013) used BIM to estimate the waste material. Similarly, Hamidi et al. (2014) used BIM to take off material quantities as well as Park et al. (2014) used BIM to analyse the construction material categories.

In addition, the interviewees suggested that BIM is a vital tool that can reduce waste generated during construction by making a better design plan or checking/validating the plan. This is confirmed by Cheng et al. (2015), Liu et al. (2011) and Won et al.

(2016) who found that clash detection and design validation during the design phase are potential to reduce the amount of waste. Based on the results, it is also clear that the project used prefabricated components to prevent waste. This is in line with the study conducted by Lu et al. (2017) which say that BIM can be used to prevent waste by pondering various design options such as using prefabricated components.

7 Recommendation

This chapter provides recommendations for the case area's current practices of CDWM, information flow and communication as well as BIM.

7.1 Current Practices of CDWM

- To improve the current practices of the company's CDWM in a good way, in addition to the above-mentioned attempt, the company should look to the different waste minimization and management strategies. The company and should enable to select the strategies that best fit (work) to a specific construction project. This is because waste management strategies that are applied in one construction project may not work in an effective way in another project.

- To address the CDW in an effective way, before recycling, it is vital to focus on reducing and reuse the waste materials

- It is recommended to change attitudes and behaviours of the stakeholders towards waste management practices to execute the above-mentioned strategies. In order to be able to change the current practices of CDWM, incentive measures (such as special motivational and reward program) should be provided to the stakeholders.

- Furthermore, it is vital to enforce the regulation in order to improve current CDWM practices until the waste management strategies and practices are adopted /accepted culturally in a construction industry throughout the supply chain.

- Involvement of construction project's participant in CDWM: it is recommended to inform clients and subcontractors the benefit of CDWM through training and workshop. The incentive to the clients, subcontractors, other construction participants (such as site manager and site workers) is necessary to implement waste management strategies. Additionally, education and creating awareness on issues issue regarding the waste management play crucial role in the process of changing attitudes and behaviours of the project stakeholders.

The following recommendations can overcome the challenges of the study area's CDWM

- It is advisable to use off-site sorting if a construction site has no adequate to space to manage

- It is suggested that the stakeholders with different cultural background should try to understand Swedish regulations associated with CDWM and be committed to following it. In addition, there should be representative actors who speak Swedish and other languages such as Polish, Danish, etc. As a result, misunderstanding among the stakeholders can be minimized.

- There should training and workshop about effective CDWM in the company, case study area, and different construction projects. This training should be conducted by different experts that have knowledge and experience about CDWM, for example, practitioners from the recycling company. However, such training and workshop may not be enough to acquire clear understanding about how to manage waste. In a view of this, stakeholders should be self-committed and eager to know and learn methods of waste management. Especially, architects or designers should learn and develop their low waste design skill, design task proficiency, and construction related knowledge in order to reduce waste at the design stage. To develop such skills and knowledge related to waste, there should be motivational or reward program for architects. This, in turn, might help construction industries to mitigate the extensive amount of waste at the design phase.

Practical Project Recommendation

SWMP should illustrate everything in detail including the location where to put waste containers/bins in the construction site, and this, in turn, might help the site workers or subcontractors to dump case area's CDW in a correct container or help not to mix the waste materials. In the study area, there are colour coded waste containers. However, it is not easy to distinguish the colour of one waste container with the other containers' colour from the distance because the colour of all containers is the same and coloured papers that have a name of the waste type is posted on one or two sides of the containers. Therefore, there should be coloured waste containers. So, site workers can easily see the containers and able to dispose of the CDW in a proper way, and this can help to minimize mixing of construction waste. In addition, some of case area's waste containers do not have shelter. As a result, the waste materials may become heavier and the company may need to pay more. Therefore, the existing containers should be covered to prevent the waste from further damage due to weather change. Besides the waste materials, the construction materials may be exposed to damage due to climate change as the materials are stored on the road temporarily without shelter. As a result, the construction materials should be stored in a tent or a room in order to prevent the materials from damage. This, in turn, might help to reduce CDW since it is possible to reduce the chance of construction materials to be damaged.

In addition to JIT, it is advisable to use the other waste efficient procurement such as minimizing packaging material and improved collaboration through the supply chains.

Although the construction site is clean, a small proportion of wastes such as concrete and earth are dumped on the construction site. Earth/soil are the main waste that is generated from construction activities of the case area. Additionally, some of the waste containers comprise mixtures of different types of waste. In a view of this, in the study area, to some extent, the construction wastes seem to be handled in an improper way. In order to reduce such construction waste especially soil during excavation, it is advisable to have knowledge about the site topography. To manage construction waste properly, training and workshop related to waste management or on how to manage the construction waste should be provided. However, providing training and workshop to the construction participants such as contractors, subcontractors, and site worker might need time, money as well as waste manager and site manager, who has good knowledge about waste management, this is because; a construction industry more focus on financial profit. Thus, it is not an easy task to provide a workshop to the participants. Therefore, the government should play a great role by enforcing legislation to improve waste management practices.

7.1.2 Information flow and communication

The information flow and communication among all stakeholders from the case area should not only focus on how to sort waste but also how to manage waste more efficiently. This means that the stakeholders should understand the occurrence and causes of wastes, waste management strategies, practices and benefits. This is because; sharing such information might help to increase awareness of the stakeholder on an issue regarding waste management. This, in turn, helps to reduce waste and manage construction waste in an effective way. Moreover, at the company level, it is important to encourage every project members, who are responsible for managing waste, to implement the waste regulation and policies made by the company.

In addition, as a communication hub, BIM can also be applied to improve collaboration among project stakeholders regarding waste management. It is also important to note that the recycling company, which has more knowledge about waste management, has to be involved in the early design to give suggestion about the best waste management practice. All project stakeholders should have access to the information stored in the BIM. This information has to be regularly updated so that the stakeholders know their waste management performance. By using BIM, the time needed to communicate and misunderstanding among project stakeholders could be minimized as well.

7.2 BIM and CDWM

In the study area, it is important to create awareness about the importance of BIM in such a big project specially to help managing waste. This is because BIM can have a great role in CDWM in many ways throughout building lifecycle, from design phase to the demolition or deconstruction.

During the design phase, it is suggested that BIM is implemented for CDWM. This is because the designers can prevent the waste in the construction by validating the design and making various design options to minimize the waste. Moreover, the designers could also add some attributes about CDW in the BIM model, so that it will be useful at the end of building lifecycle, i.e. deconstruction, and demolition. In addition, by Implementing BIM, the amount of various types of waste generated can be quantified from the design phase. This is important for the recycling company to decide how many waste containers needed. The location of each type of waste that will be generated can also be predicted. Therefore, both waste manager and recycling company can decide where to place their waste containers to the nearest waste source at the right time.

In addition, it is suggested that the company effort on implementing BIM for waste management must be continued and applied in the real project. Therefore, it is emphasized that to get optimum benefit of BIM for CDWM, the implementation should be done at the early stage so that the benefit of BIM for CDWM can be achieved throughout project life cycle.

8 Conclusion

This study presents the current practices of case area's CDWM and how information regarding CDWM shared with site workers, subcontractors and site managers. In addition, the aspects of current CDWM that could be supported/improved with the help of BIM is also discussed. The results are based on observation, semi-structured interviews, and questionnaires.

The current practices of case area's CDWM have mainly three work processes. The work process included sorting, collecting and recycling CDW. The finding of this study indicates that current practice of case area's CDWM focused on sorting and recycling. In addition, the case study has used colour coded containers and prefabricated components in the construction site in order to sort and manage the construction waste. Moreover, the study indicated that, in the study area, there are major challenges for CDWM. These challenges are lack of adequate space and information as well as cultural and language difference.

In the study area, the information associated with CDWM shared among the site workers, subcontractors and site manager through brochure and presentation, information board and meetings. In addition, the communication among the contractor and subcontractor was also done through an agreement. The information flow in the case area of CDWM could be improved by using BIM, due to its ability to increase collaboration among project stakeholders.

In the study area, there is a lack of BIM understanding for CDWM. However, there is an optimistic viewpoint from the company level to implement BIM for CDWM for future projects. BIM is crucial to improve the current practices of CDWM. Firstly, It can support the deconstruction and demolition project by providing material information from the design phase. Secondly, BIM can be used to estimate the amount and type of waste in the construction site. Lastly, the waste generation can be reduced with BIM implementation in the design phase by validation the design or pondering design options.

In order to obtain a successful outcome in CDWM, the current practices should be changed and improved. To bring improvement in the current practice, there should be an education, training, and workshop on the issue regarding CDWM, BIM and waste management strategies. Moreover, to mitigate CDW, execution of waste management strategies as well as BIM at the design stage in construction industries is crucial. This, in turn, helps to obtain economic, social environmental benefit from practices of CDWM. Therefore, future research should focus on how to implement waste management strategies and BIM in a construction industry to manage CDW in an effective way.

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Appendix 1 Interview Questions

Interview questions to project members

1. What is your role in this project? How long?
2. What types of waste do you have in the project?
3. What are the main waste generated in this project? And What are the major factors?
4. How do you deal with waste management in this project?
   a. What’s happening with the leftover material? / what do you do with the leftover materials? /do you recycle? If yes, how do you recycle the wastes? Explain the steps?
5. What tasks does the site manager take in terms of waste management in this project (strategy, plan)?
6. Are there any challenges in managing wastes in the study area? If yes explain the challenges.
7. How do you transfer information about sorting wastes and other issues regarding waste management to the site workers? Or to the subcontractors?
8. According to your experiences, how BIM model can help CWM?
9. Do you see any improvements for the future project?

Interview with Environmentalist

1. What is your role/task?
2. How do you work with waste management/recycling, reusing, reducing?
3. Are there clear policies, regulations and guidelines regarding waste management (sorting and different material handling) recycling and reuse at your company? If yes, please explain it?
4. How are these policies followed up on the construction site?
5. How do you document and monitor the information regarding waste management?
6. How does your company inform people about the waste management practices? Through information, training, visits etc.?
7. What are the reasons/ factors for the generation and/or increment of construction wastes?
8. Do you have guidelines on how to deal with different types of waste material?
9. Do you make a difference between new build and refurbishment projects?

Interview with Recycling Company

1. What is your role in this company?
2. Does NCC recycling company have contact with client, customers? If yes, what are your main clients? Contractors or real estate company?
3. How do you manage the Construction and Demolition wastes? Recycled, reused?

4. Does NCC recycling have waste management plan?
5. Does NCC recycling particular strategy where they put waste containers? (do you use colour coding?)
6. What is your main challenge managing this waste material? (space/information?
7. How do you inform the project members about sorting the waste? How often, and the follow up?
8. How many construction projects do you handle now? How about the children's hospital?
9. What kinds of contract do you have with them (children's hospital)?
10. Who are your customers regarding the recycled material you produced? (Does NCC recycling company have contact with client, customers?
11. Do you also communicate with the contractor's client (the owner of this project)?

Interview with Researcher

1. What is your experience regarding waste management in Swedish construction market?
   a. What was your PhD about and what were your main findings?
2. What are the differences between waste management of refurbish projects compared to new build projects? (examples?)
3. What are important factors for waste management on site in order to diminish waste, increase recycling and reuse? E.g., role of site manager, structure, policies etc.?
4. Who is responsible for waste management efforts in construction site?
5. How is information concerning waste management distributed on site to construction workers and subcontractors?
6. What is the current challenges in managing waste in a Swedish construction site?
7. Do you see any improvements for the future – what kind of things would need to be improved?
8. In your opinion, is it relevant to use BIM when dealing with CDWM?
   a. If yes, how can BIM contribute to waste management (Reducing, Reusing, and Recycling)?
9. What are the major factor for generation of waste in a construction industry?

Appendix 2 Questionnaires

1. How do you get the information about sorting wastes?
   a. From brochure/information boards
   b. From site manager
   c. From site engineer
   d. From training program
   e. others_______________
2. How do you sort/ handle the wastes on site? (how do you categorize the hazardousness of the wastes?)
   a. Sorting the wastes in different containers
   b. Collecting the wastes in one place and let waste contractors to do off-site sorting
   c. Others____________
3. What is the most common waste material in this construction site?

a. concrete	d. Wood
b. Earth	e. Electrical
c. Timber	f. Plastic
d. Scrap/ metal	g. Others_______

4. What are the major/main activities that contribute to the generation of wastes in this site?
   a. Concrete casting
   b. Unpacking the packaging of materials
   c. other_______________
5. What are the challenges in managing the waste materials? And what is the most challenge?
   a. Unclear understanding the types of waste
   b. Lack of information
   c. Separating hazardous material
   d. Location of the waste container
   e. Other______________________

Appendix 3 Checklist for observation

	Visualization of construction and demolition waste on site				
	Not implemented	Limited extent	50-57%	Fully implemented	comments
Site office:					
3D models					
2D drawings					
Information board					
CDW plan					
Time plan					
Safety poster/boards					
CDW info boards					
APD plan					
Logistic plans					
Quality standards					
Environment al standards posters					
Accident reports					
CAP to calculate the amount of waste					
On site					
Markings on material for CDW					
Safety signs					
Signage for CDW (what kind?)					
Material tags, stickers etc					
Color codes					
Hazardous waste signs					
Sorting waste signs					
Entrance (check points for trucks)					
Waste management					

issues					

Checklist for:

	Visualization of construction and demolition waste on site				
	Not implemented	Limited extent	50-57%	Fully implemente d	comments
Information flow on site on CDW					
Between top management and site managers					
Between site managers and construction workers					
Between various sub-contractors					
With external stakeholders					
Level of information available on CDW					
In the project					
About standards /quality					
Health and safety /risks					
Sorting waste					
Logistics and handling material					
Hazardous waste handling					
Types of waste? Inert Materials (earth, concrete, debris) Non-inert waste (timber, vegetation)					

Appendix 4 Questionnaire Result

Questionnaires	Respondents					
	Electrician 1	Electrician 2	Digger 1	Digger 2	Digger 3	Digger 4
Source of information						
a. Brochure	√	√	√	√	√	√
b. Site Manager						
c. Site Engineer						
d. Training Program						
e. Other:						
The way of waste sorting						
a. Put in different containers	√	√	√	√	√	√
b. Collecting the waste in one place and let waste contractors to do off-site sorting						
c. Other:						
Most common waste generated						
a. Concrete						
b. Stone	√	√				
c. Earth/Soil	√	√	√	√	√	√
d. Chemical						
e. Scrap/ Metal	√	√				
f. Wood	√					
g. Electrical						
h. Plastic						
i. Other:						
Major activity contributing to waste						
a. Digging	√		√	√	√	√
b. Concrete Casting						
c. Unpacking material	√	√				
d. Other:						
Challenges in managing waste						
a. Unclear understanding of waste types	√	√		√	√	√
b. Lack of Information			√			
c. Separating hazardous material						
d. Location of the waste container	√					
e. Other:						

Appendix 5 Components for designing out waste in construction projects *(Saheed et al., 2016: 475)*

A. Task Proficiency	
1	Aptitude in producing error free designs
2	Accomplishment in detailing of design elements
3	Aptitude in completing document error free design
4	Accomplishment in specification of materials to prevent inadequate ordering
5	Aptitude in producing coherent and comprehensive design information
6	Aptitude in identifying and integrating reusable elements into design
7	Accomplishment in design tools and vocabularies
8	Aptitude in producing legible design and its documentation
9	Aptitude in coordinating structural and planning grids to reduce off cuts
10	Aptitude in providing adequate information for subsequent trades
11	Aptitude in ensuring constructability of design
12	Aptitude in correctly integrating design with site topography
13	Aptitude in specifying waste efficient joint system
B. Low waste design skills	
14	Accomplishment in designing flexibility and adaptability
15	Aptitude in coordinating dimension of building elements & components
16	Accomplishment in designing for deconstruction and end of life
17	Aptitude in standardizing building spaces to industry standards
18	Aptitude in identifying design for preassembled components
19	Aptitude in studying, initiating and driving low waste techniques

20	Aptitude in optimizing design for waste efficiency
21	Designing to standard materials supply
22	Specification of secondary materials
C. Construction-related knowledge	
23	Knowledge of real life site layout
24	Knowledge of construction processes and sequence
25	Awareness of materials quality and durability