IMPROVING THE RECYCLING RATE OF CONSTRUCTION AND DEMOLITION WASTE IN SWEDEN – A REVERSE LOGISTICS PERSPECTIVE

A Master thesis conducted at Chalmers Industriteknik
Master's thesis in Production Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
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ABSTRACT

Sweden has been very successful in recent years in increasing energy recovery and reducing waste in the form of landfills. However, there is a great scope for improvement of the recycling rate of waste. The EU Waste Framework Directive (European Parliament and Council, 2008) requires all the countries within the EU to have achieved a minimum recycling rate of 70% for construction and demolition waste (CDW) generated, by 2020. The recycling rate of CDW in Sweden is currently 50-60%. Improving the reverse logistics of CDW could contribute greatly towards achieving this target. This thesis focuses on understanding the current state of identification, sorting, collection and logistics of CDW in Sweden, which is a part of the reverse logistics chain. Based on the current state analysis, some suggestions for improvement are given.

In this thesis, interviews and surveys are conducted with various stakeholders within the CDW industry. The surveys and interviews along with the help of a literature review are used to understand the factors that affect the identification, sorting, collection and logistics of CDW. Additionally, five cases of construction/demolition projects are studied. The analysis of the data collected in term of five case studies, interviews and a survey, has supported in answering the purpose. Based on the current state of operations and the factors affecting them, some suggestions for the improvement are provided. The suggestions are – i) using the waste management plan throughout the chain, ii) improving the waste management plan and iii) using additional waste coordinators on-site. Application of these suggestions could lead to improvements in the reverse logistics of CDW and help in increasing the recycling rate of CDW in Sweden.

KEYWORDS:
Construction and demolition waste (CDW), recycling rate, waste management plan, on-site sorting, reverse logistics

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Gothenburg
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1 Introduction

This chapter starts with a background describing the problem of construction and demolition waste (CDW) recycling. In the next section, the general flow of CDW is explained, followed by listing the possible ways of improving the CDW recycling rate. Then, the research project Constructivate within which this study is performed is introduced. The purpose of the thesis is stated, and the scope of the thesis is defined. Next, two research questions are framed, which aid in fulfilling the purpose of the thesis. The chapter ends with an outline of the contents of all the subsequent chapters in the report.

1.1 Project background

The term construction and demolition waste (CDW) refers to the waste arising from construction and demolition activities within the construction sector (Shen et al., 2004). CDW is often a complex waste stream since it is a mix of many different types of materials like soil, concrete, wood, metals, plastic, bricks, paper and cardboard, gypsum based materials, packaging materials, insulation materials, waste electronic and electrical equipment, chemicals etc. (Manfredi et al, 2011). Approximately, 30% of the waste generated within the EU is caused by CDW (Fischer and Werge, 2009). CDW can cause adverse effects on the environment like air pollution, surface and groundwater pollution, public health risks, depletion of natural resources and additional use of land for waste landfilling (Dixit et al, 2010). Hence, to curb the negative impacts of the construction and demolition activities on the environment, management of CDW is of high importance.

The EU Waste Framework Directive (European Parliament and Council, 2008) requires all the countries within the EU to have achieved a minimum recycling rate of 70% for CDW generated, by 2020. According to Hotta et al. (2013), recycling rate is often presented as a "proportional value (%) and reflects the proportion of materials recycled or recovered from waste or the rate of inclusion of recycled materials in products." In 2010, 75% of CDW produced in the EU was dumped in landfills (Ortiz et al., 2010). While some countries within EU, like Denmark, Netherlands and Germany, have reached 80-90% CDW recycling rate, the CDW recycling rate in Sweden is currently between 50-60% (SEPA, 2015). Sweden has been successful in increasing energy recovery and reducing waste in the form of landfills, however in terms of reducing, reusing and recycling CDW, Sweden has not been very successful (Resource and waste guidelines during construction and demolition, 2015). The construction and demolition sector accounts for the largest amount of waste in Sweden and since only about half of the waste is currently recycled, there is a huge potential for increasing this recycling rate (Michaud et al, 2010). It is expected that the construction activities are going to increase in the coming years making it important to increase knowledge within CDW management to achieve sustainable recycling. Hence a lot more work must be done to reach the minimum target level of 70% by 2020.

1.2 Project Introduction

Figure 1. demonstrates the general CDW flow and management waste processing in a construction/demolition project. In the case of a demolition project, the process starts with a pre-demolition audit, which contains an identification of the hazardous wastes on the site, their quantity and location. This is followed by a waste management plan, which contains an inventory of all the different waste fractions that will be generated and where this waste will be sent. After this, the actual process on the site begins, with the first step being the careful removal of the hazardous waste. Thereafter, the structure is demolished, by either selective demolition or total demolition (see section 2.2). Many different types of wastes are generated, which are then sorted into different fractions. These waste fractions are then transported for further processing, which could be either for re-use, recycling, energy recovery or for disposing into landfills. The recycled and re-used material can then re-enter the supply chain of raw material required for new constructions. The same process follows in a construction project, except there is no pre-demolition audit and construction takes place instead of demolition.

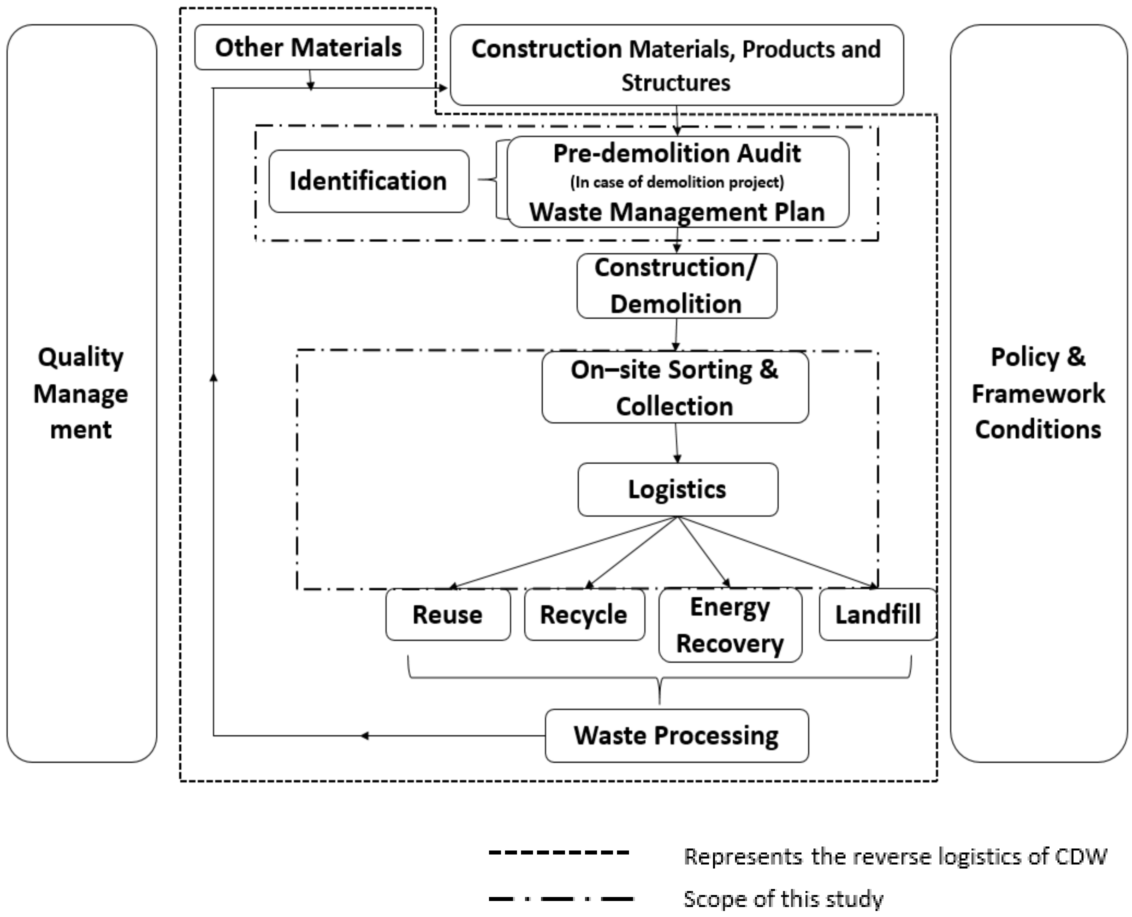

Fig 1. General CDW flow and management (adopted and simplified from EU CDW management protocol)

According to the EU Construction & Demolition Waste Management Protocol (2016), there are five main ways to achieve improved recycling rates of CDW:

1) Improving the waste identification, sorting and collection.
2) Improving the waste logistics to the point of receipt of waste for further treatment
3) Improving the waste processing
4) Improving the quality management
5) Implementing appropriate policy and framework conditions

Waste identification deals with issues like an estimation of the different kinds and volumes of waste that will be generated during the construction/demolition project. This is done by identifying the different waste streams and listing them in the pre-demolition audit and the waste management plan. The sorting and collection deals with the on-site sorting of the waste that is generated. The waste logistics deal with the flow of material from the waste generation site i.e. the construction/demolition site to the waste receiver i.e. the recycling company or the landfill. Waste processing refers to the physical treatment of the waste using different recycling, re-use, energy recovery or landfill methods. Quality management and policy and framework conditions have more of a horizontal nature. They are applied throughout the first three measures to improve their implementation. In this study, the focus will be on the first two ways of improvement i.e. improving the waste identification, sorting, collection and improving the waste logistics.

The Constructivate research project, within which this study is performed, is an applied research project by Chalmers Industriteknik (CIT) started in 2015, with the aim to increase the recycling rate of CDW in Sweden. Constructivate is divided into certain main areas, one of which focuses on reverse logistics part of the supply chain. The terms 'supply chain management' and 'reverse logistics' are explained below.

"Supply chain management (SCM) encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers" (CSMP, 2017). SCM in construction is defined as "all construction processes from the initial demands by the client/owner through design and construction, to maintenance, replacement and eventual demolition of projects" (Albaloushi & Skitmore, 2008). The supply chain consists of two parts - traditional or forward logistics and reverse logistics. "Traditional logistics (i.e. forward logistics) represents the activities of organizing, managing and controlling the flow of materials from the points of raw materials extraction up to its use in a construction site" (London, 2007). "Reverse logistics concentrates on the movement of materials from the points of consumption back to the market" (Rogers and Tibben-Lembke, 2001). It is not necessary that the materials that return back, go exactly to the points of origin (Brito and Dekker, 2004). The materials that return back could be used for different purposes or in different markets.

Many authors have explored the role of reverse logistics in effective management of

CDW. The study and modification of reverse logistics of supply chains can facilitate effective reuse, recycle and recovery of materials (Sundarakani et al., 2014). Supply chain solutions in reverse logistics, like forming alliances with suppliers and recycling companies, are some of the most effective waste management solutions (Dainty et al, 2004). Some authors talk about the importance of transport distances between the recycling plant and the construction site and how it influences the decisions taken to deal with the waste, (Blengini and Garbarino, 2010; Chong and Hermreck, 2010; Chowdhury et al., 2010). Some authors have proposed optimization models to plan the CDW recycling network (Hiete et al, 2011). According to Tennant and Fernie, (2014), commercial exchange of goods and services in a construction project typically account for approximately 75%–90% of the total project cost. Hence, it can be seen that there is enormous potential for improving recycling by applying theories and practices within reverse logistics.

Applying the definition of reverse logistics on Fig 1, the general CDW flow and management, reverse logistics of CDW could be described as below (shown within dotted lines in Fig.1):

1) Waste identification, sorting and collection
2) Waste logistics till the point of receipt of waste for further treatment
3) Waste processing (which could be either re-use, recycling, energy recovery or landfill disposal)
4) Movement of treated waste to the point of consumption.

This project focusses on the first two parts i.e. waste identification, sorting and collection and waste logistics till the point of receipt of waste for further treatment.

To summarize, the CDW recycling rate needs improvement not only for environmental reasons, but also to achieve the EU target of 2020. As demonstrated by previous studies, one of the major ways of achieving the improvement in recycling rates is by improving the reverse logistics of CDW, in particular the identification, on-site sorting, collection and logistics of CDW.

1.3 Purpose

The purpose of this thesis is to contribute towards improving the identification, on-site sorting, collection and logistics of CDW in order to increase the recycling rates in Sweden.

1.4 Scope

As discussed above, there are 5 main ways to achieve improved recycling rates of CDW. The focus will be on following two ways (as shown in Fig.1):

1) Improving the waste identification, on-site sorting and collection.

2) Improving the waste logistics

The remaining three ways of improving the recycling rate, namely improving the waste processing, improving the quality management and implementing appropriate policy and framework conditions will not be addressed. The suggestions for improvement will not be detailed implementation plans, but rather they will be brief descriptions. These suggestions will be described in the discussion chapter.

The European Commission's Waste Framework Directive 2008/98/EC, recommends a priority order for action to reduce and manage waste, known as the waste hierarchy (Fig.3). Waste prevention, as the preferred option is followed by reuse, recycling, recovery including energy recovery and as a last option, safe disposal. According to the waste management hierarchy, explained in detail in section 2.1, prevention of waste is the best practice. However, this project will not focus on the causes and prevention of waste. Rather, only the management of CDW after it has been generated will be studied.

1.5 Research questions

Two main research questions (RQ) were framed, which would aid in fulfilling the purpose of the thesis.

It is necessary to know the current state of any process before attempting to make improvements in the process. It would be beneficial to know who are the actors involved in the CDW management process and how they are involved. Waste management practices could also differ greatly based different project conditions and also between different countries. Hence, the first question was framed to provide a general understanding of the current practices of CDW management within Sweden.

RQ 1. *What are the current practices of waste identification, sorting, collection and logistics used by the construction and demolition companies for the management of CDW in Sweden?*

In any construction or demolition project, some factors might drive good waste identification, sorting collection and logistics while some other factors might hinder them. It is helpful to know the factors that affect these waste handling practices, in both positive and negative ways. Hence, the second question was framed to understand the factors that lead to decisions regarding waste identification, sorting, collection and logistics by the construction and demolition contractors.

RQ 2. *What are the main factors that affect the waste identification, sorting, collection and logistics of CDW?*

1.6 Outline of the thesis

This thesis is divided into seven chapters that are briefly described below:

Chapter 2 Theoretical framework

This chapter describes and define the key concepts used in the thesis and lays the foundation for the theory used in the analysis and discussion

Chapter 3 Research Methodology

This chapter discusses the methodology of performing the study. The research approach is explained and an analysis model is presented. A brief description is provided of how the selected research approach was followed, how the data was collected and for what purpose.

Chapter 4 Empirical data

This chapter contains a description of the case studies and the information gathered from the case studies, which is presented with the aid of maps. The salient points from the interviews and survey results are then shown.

Chapter 5 Analysis & Results

In this chapter, a cost analysis is performed on the cases. In the second part of the chapter, the research questions are answered.

Chapter 6 Discussion

The first part of this chapter contains an analysis of the problems observed from the results obtained in the previous chapter. In the second part of this chapter, suggestions are provided which could help to increase the recycling rates in Sweden, which is the purpose of the project.

Chapter 7 Conclusion

This chapter summarizes the results and the important results are highlighted. Suggestions are made about possible future research areas.

2 Theoretical Framework

In the first part of this chapter, concepts like waste hierarchy, basic levels of sorting and waste management plans are introduced. This is followed by a description of the situation of CDW recycling other countries within the EU. The second part of the chapter explains the way of calculation of recycling rate of CDW in Sweden.

2.1 Waste hierarchy

In order to promote circular thinking and reduce the amount of waste landfilled, the EU has developed a waste policy. In any system or industry, the waste management options can be classified into certain categories. The European Commission's Waste Framework Directive 2008/98/EC, recommends a priority order for action to reduce and manage waste, known as the waste hierarchy (Figure.2). Waste prevention, as the preferred option is followed by reuse, recycling, recovery including energy recovery and as a last option, safe disposal. The waste hierarchy is also adopted in the Swedish Miljöbalken (Swedish Environmental Code).

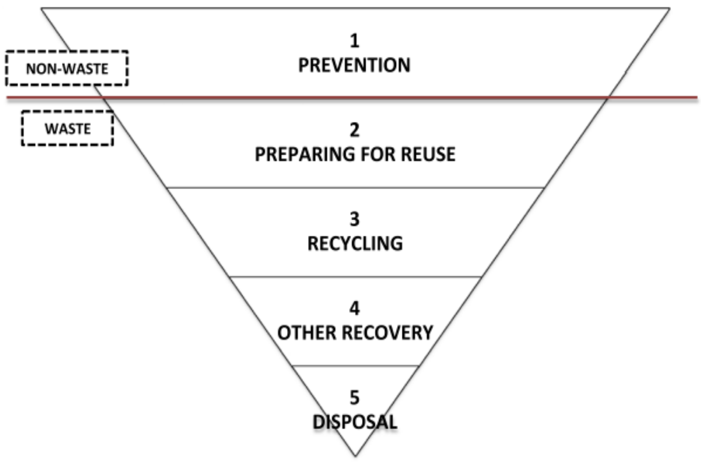

Figure 2. Waste management hierarchy (Waste Framework Directive 2008/98/EC)

The terms used in Figure 2. are defined as below:

Prevention: Prevention means measures taken before a substance, material or product has become waste, that reduce the quantity of waste, including through the re-use of products or the extension of the lifespan of products; the adverse impacts of the generated waste on the environment and human health; or the content of harmful substances in materials and products;(Council 2008).

Preparing for Re-use: Preparing for re-use means checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing (Council 2008).

Recycling: Recycling means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels (Council 2008).

Other Recovery: Recovery means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy (Council 2008).

Disposal: Disposal means any operation that is not recovery even where the operation has as a secondary consequence other than he reclamation of substances or energy (Council 2008).

As mentioned before, the scope of this project is only limited to the management of waste after it has been generated. Prevention of waste will not be a focus.

2.2 Demolition methods

This section provides information about the two methods that are generally used for the demolition process.

Selective demolition

Selective demolition is a process where the demolition activities are sequenced in such a way that it enables the separation of building materials and then sorting them out. The demolition is planned to initially take away all the nonstructural materials such as furniture, ceramic tiles, frames and electrical equipment and then to tear down the structural materials such as bricks and concrete. The goal of selective demolishing is to make it possible to re-use or recycle as much material as possible. The selective demolition method makes sorting of the waste easier. However, this method consumes significantly more time, advanced equipment to handle hazardous waste, labor, and space (Guidelines for selective demolition and on-site sorting, 2004).

Total demolition

This is a process where the entire building or a structure is demolished in one go using heavy equipment. The result is that all the waste material gets mixed up. This mixed waste then must be sorted off-site if it is to be re-used, recycled or energy recovered. This method is easy, simple to execute and saves time for the demolition activity. However, the sorting becomes more difficult since all the waste is mixed (Demolition with Brokk, 2000).

2.3 Resource and waste guidelines during construction and demolition

This section provides information about the Resource and Waste Guidelines during construction and demolition, which is a document intended to improve the management of waste according to the waste hierarchy and the Swedish Environmental Code's general rules of consideration.

In 2007, Resource and Waste Guidelines during construction and demolition were drawn up by the Kretsloppsrådet, as one of the measures in order to reduce the amount of landfill in Sweden. In 2013, The Swedish Construction Federation took over the responsibility for updating the guidelines and a new revised version of the guidelines was drawn up. The aim of the guidelines is to improve the resource management in the Construction and demolition industry of Sweden, in order to fulfill the requirements of the Swedish Environmental Code. However, in a few cases, the guidelines also exceed the requirements in the legislation.

The Resource and Waste Guidelines provide normative industry texts, which are the construction and demolition industry's agreement about how resource and waste management should take place during construction and demolition projects. These normative industry texts include pre-demolition audit, waste management plan and basic levels of sorting, which will be discussed further. The guidelines also contain recommendations about prevention of waste in construction projects and handling of waste in both construction and demolition projects.

2.3.1 Pre-demolition audit

The purpose of a pre-demolition audit is to document the hazardous substances along with their quantities and locations, so that they can be handled in a correct manner during the demolition. However, according to the Resource and Waste Guidelines, the pre-demolition audit should include not only hazardous wastes, but also materials that can be reused, recycled or energy recovered.

The Resource and Waste Guidelines also provide recommendations about how the procurement of the pre-demolition audit should be carried out. Details regarding the contents of tender specification, competence requirement of the pre-demolition audit consultant and contents of the pre-demolition report are mentioned in the guidelines.

2.3.2 Waste management plan

A waste management plan is a document that must be drawn up for all construction and demolition projects according to the Resource and waste guidelines during construction and demolition, 2015. However, it is not a legal requirement to have a waste management plan, but it is recommended by the guidelines to fulfil the Swedish Environmental Code's general rules of consideration and the waste hierarchy.

During the procurement of a contract, a waste management plan should be submitted as a part of the tender specification. This means that the waste management plan should be drawn up before the construction or demolition project can begin. The waste management plan should contain information about the planned management of hazardous waste and also information about the types and estimated quantities of other wastes and how they will be managed.

According to the Resource and Waste Guidelines, the waste management plan should contain:

- "Information about materials and products which will be hazardous waste: position, estimated amount, waste code (as far as this is possible) and an overall description of handling
- Information about products and materials for reuse, material recycling and energy recovery and how they will be handled.
- Information about other waste divided into fractions, estimated amounts, waste codes (where applicable) and the handling of the waste
- Headings or table columns so that the latter can be completed with information about the amount removed, transports, recipients, the amount received and references to the verification of transport and reception."

The current guidelines for a waste management plan according to the Swedish Construction Federation provide a good template for waste management (see appendix 1). The current format starts with a description of the status of the project and some administrative information. This is followed by identifcation of the hazardous waste, the way it will be handled, the quantity, the transporter, receiver along with verifications. Details about decontamination, storage and risks are also specified here. This is followed by identifcation of all the other non-hazarous wastes, the way it will be handled, the quantity, the transporter, receiver along with verifications. The waste management plan can serve as a document to audit or inspect the waste management activities, but more importantly, it can help to formulate a plan of action for waste management, starting with the identification of wastes.

2.3.3 Basic fractions of CDW

A large variety of wastes fractions are obtained during any construction or demolition activity. This makes the construction and demolition waste stream very complex. Hence there needs to be some sort of guideline for the sorting of the waste, so that a standardized practice of sorting is followed in all construction and demolition sites.

The basic levels of sorting in any construction/demolition project are as follows (Resource and waste guidelines during construction and demolition, 2015):

- Hazardous waste (different types are separated)
- Electrical waste (different types are separated)

- Wood
- Combustible materials
- Plastic for recycling
- Plasterboard
- Scrap metal
- Aggregates
- Landfill (sorted)
- Mixed waste – for post-sorting

The legislation states strict requirements for handling of hazardous waste and electrical waste. The legislation also states certain specific requirements for combustible, organic and plasterboard wastes regarding their disposal. However, the level of sorting in basic fractions of CDW is decided by an agreement between the client and the construction/demolition contractor. The amount of non-hazardous mixed waste sent to the waste receiver is not subjected to any legal requirements.

However, according to the Resource and Waste Guidelines, if fewer fractions are sorted than the ones prescribed in the basic levels, then specific justification must be provided. When the waste generator, in this case the construction or demolition contractor, sends the waste to any recycling company or to a landfill, they have to pay a certain gate fee. This gate fee depends on the waste fraction that is received and its quantity in terms of weight. Table 1 shows the gate fees for the different waste fractions aggregated from different interviews (refer section 3.3.1).

The gate fee can also vary within a certain type of fraction, depending on the quality of the waste fraction. For example, the gate fee for pure concrete aggregates is different from the gate for concrete aggregates containing re-enforced steel. Note that the gate fees for metal scrap and corrugated waste are negative, which means that the construction/demolition contractor receives money from the waste receivers, for these materials.

Table 1. Gate fees for different waste fractions (aggregated from interviews (section 3.3.1))

Material	Receiver Fee (SEK//Ton)
Waste for Sorting (Unsorted)	1300
Combustible Waste	1130
Hazardous Waste	8000
Concrete & bricks	400
Wood	300
Electronic Waste	4000

Metal Scrap	-600
Pure concrete	150
Reinforced concrete	250
Unreinforced concrete	390
Light unreinforced concrete	200
Insulating material	915
Asbestos	8000
Corrugated	-600
Landfill	980
Plaster	750
Plastics recycling	1200
Mineral wool	950

2.4 Calculation of recycling rate

This section explains the method of calculation of CDW recycling rate in Sweden. Since the main goal of the Constructivate project is to increase the recycling rate of CDW in Sweden, it is important to know the exact formula used to calculate this recycle rate.

While the figure of 50-60% recycling rate of CDW in Sweden, is fairly well known in the industry and academia, the mechanism of how this rate is exactly calculated is not very clear. There is no specific standard that is followed for the calculation of the recycling rate of CDW. In fact, due to this reason, different countries within the EU have different methods of calculating the recycling rate of CDW. No literature was found during the study which showed a specific formula or method which could be used to calculate CDW recycling rate. Hence, it was important to find out how the CDW recycling rate was calculated in Sweden.

An analysis of Table 2 and 3, along with an interview with a statistics expert from Swedish IVL was used to find out the exact method used to calculate the recycling rate of CDW in Sweden. This is explained in the following text.

Tables 2 and 3 provide a brief summary of the CDW treatment in Sweden for the year 2012. (Palm et al., 2015)

Table 2. Amount of resulting primary waste from construction and demolition, and its treatment. (Palm et al., 2015)

Waste disposal	Amount of resulting primarily waste (tons)	Conventional recycling	Construction, landfill cover, backfill	Energy Recovery	Landfill disposal	Sorting	Unknown treatment
06 Metals, source-separated	140,000	140,000					
07.1 Glass wastes, sorted	2,000	2,000					
07.4 Plastic, source sorted	200	200					
07.5 Wood waste, sorted	300,000			300,000			
10.2 Mixed waste, source-separated combustible	25,000			25,000			
12.1a drywall, separate waste for recycling	24,000	24,000					
12.1B Mineral waste from construction and demolition, construction	676,000		404,800	11,900	87,500	187,400	129,200
12.1C Mineral waste from construction and demolition, other industries	144,800						
12.1 D asphalt (not reported in the Start / ASP) *	900,000	900,000					
Total	1,312,000	166,200	404,800	336,900	87,500	187,400	129,200

Table 3. Construction and demolition waste that goes to the central sorting, and the secondary waste generated by sorting, as well as the secondary waste treatment (Palm et al., 2015)

Waste Disposal	Amount in (t)	Amount of the secondary waste (tons)				
	For sorting plants	conventional recycling	Construction, landfill cover, backfill	Energy Recovery	Landfill disposal	TOTAL out
12.1 Mineral waste from construction and demolition (construction and other industries)	187,400					
06 Metals		35,400				35,400
07.1 Glass wastes,		200				200
07.2 Paper and cardboard wastes		1,700				1,700
07.4 Plastic,		500				500
07.5 Wood waste,				3,300		3,300
10.3 Sorting residues, flammable				82,500		82,500
10.3 Sorting residues, residual landfill			14,800		16,200	31,000
12.8 Mineral waste from waste treatment			32,800			32,800
TOTAL	187,400	37,800	47,600	85,800	16,200	187,400

The CDW generated directly after the construction or demolition activity is known as primary waste. As can be seen from table 2, some parts of the primary waste, are sorted on-site into different fractions like metals, glass, plastic, wood, drywall (gypsum) and combustible mixed waste. Out of this, wood and combustible mixed waste is used for energy recovery. However, there is also a major fraction called mineral waste from construction and demolition. This fraction can contain both mineral wastes (e.g. plaster, concrete, brick, etc.) which are combustible or recyclable materials (e.g. metals, plastics, wood, paper, etc.). Parts of this waste end up as landfill cover and backfill, energy recovery, dumping and a certain fraction goes for further sorting. The fraction that goes to sorting is called secondary waste, which is shown in Table 3. In 2012, 1,87,400T of mineral waste went for sorting in Sweden. Table 3 explains the treatment of this secondary waste that is sent for sorting, which is then sent of recycling, energy recovery, backfill and dumped in landfills.

While calculating the recycling rate, the waste that is used as backfill and landfill cover is considered as recycled (downcycled). The recycling rate of CDW is calculated as follows:

Recycling rate =

$$\frac{\begin{array}{c}\boldsymbol{Primary\ waste\ used\ for\ conventional\ recycling} \\ +\ \boldsymbol{Primary\ waste\ used\ for\ landfill\ cover}\ \&\ \boldsymbol{backfill} \\ +\ \boldsymbol{Secondary\ waste\ used\ for\ conventional\ recycling} \\ +\ \boldsymbol{Secondary\ waste\ used\ for\ landfill\ cover}\ \&\ \boldsymbol{backfill})\end{array}}{\boldsymbol{Total\ CDW\ generated}}$$

(Eq.1)

= (166,200 + 404,800 + 37,800 + 47,600) / 1,312,000 = 50.1%

Using the above formula, there are two ways to increase the recycling rate by increasing the numerator of the fraction:

1) *Increasing the Primary waste used for conventional recycling + Primary waste used for landfill cover & backfill*: This could be done by increasing the on-site sorting of the mineral waste (mixed waste) so that the waste can be sent in different fractions from the construction or demolition site itself.

2) *Increasing the Secondary waste used for conventional recycling + Secondary waste used for landfill cover:* This could be done by improving the sorting of mixed waste at the recycling company which involves improvement in the sorting technology. Since improving the technology of waste sorting is out of the scope of this project, the efforts will be focused on how the on-site sorting of waste can

be improved.

Note that out of the 1,87,400 tons of the secondary waste which was sent for sorting, (37,800 + 47,600) = 85,400 tons of waste was recovered for conventional recycling or landfill cover. Hence, on an average, it can be said that the secondary waste recovered in Sweden is 85,400/1,87,400 = 45.6%. This percentage is used in section 5.1 in the economic calculations.

Also note that the 900,000 tons of asphalt that was generated was not included in the calculations, even though all of it was recycled or re-used. This situation is peculiar to Sweden, since asphalt is included in the recycling rate calculations in other countries. If this quantity of asphalt is included in the calculations, the figure of the recycling rate changes to 70%, which means the EU target might already have been achieved. However, in spite of this, the environmental reasons to increase recycling and re-se remain unchanged.

2.5 Sorting of waste on-site

This section provides examples of some studies which show that good sorting of waste decreases the cost for waste treatment. It provides a validation for the purpose of the thesis.

From section 2.4, it can be seen that sorting CDW on-site leads to better recycling rates. Many previous studies have also talked about the benefits of on-site sorting of CDW. According to Poon et al. (2001), on-site sorting not only results in increased recycling and re-use rates but also reduction disposal costs. CDW is generally a mixture of various material fractions and mixed waste is generally disposed of at landfills, instead of being recycled or re-used (Shen et al., 2004).

Certain companies have also tried to investigate the benefits of on-site sorting from a cost perspective. The company SUEZ, previously SITA AB, made an analysis of the cost for treatment of CDW by comparing situations where different degree of waste sorting was done on-site as shown in Fig 4. It can be seen that when more sorting is done on-site, the cost for treatment of CDW decreases. For example, when 90% sorting is done, the CDW treatment cost is nearly half of the cost when no sorting is done.

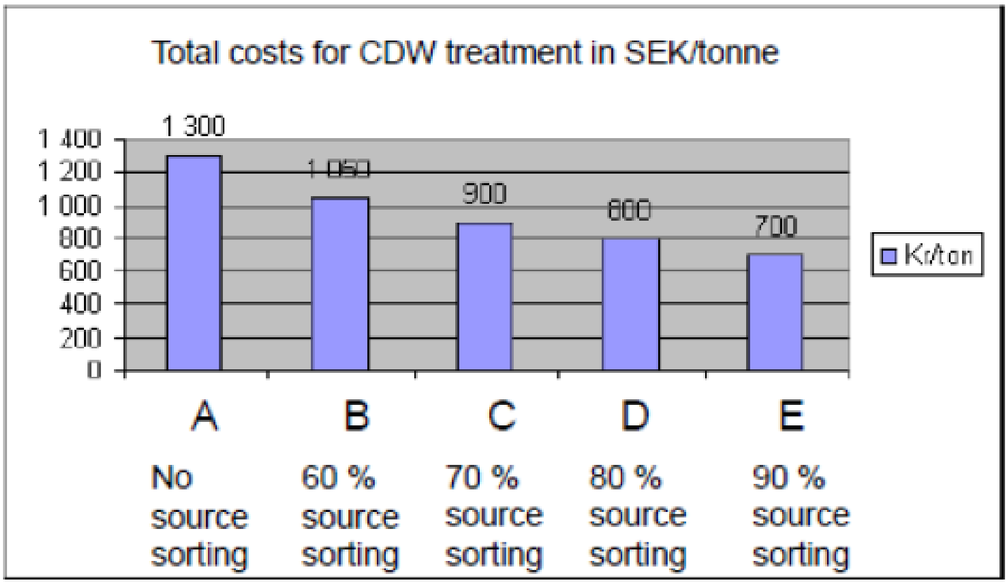

Figure 3. **Cost saving in on-site sorting at site according to SITA**

A similar study to the one made by SUEZ, was of waste also conducted by the company NCC Recycling (Table 4). Again, it can be seen that the cost per ton for the waste generator when 90% of the waste is sorted, is nearly half the cost per ton, when no sorting is done.

Table 4. Comparison of cost using different degrees of sorting

Types of waste	Cost of 0% sorting (SEK)	Cost of 60% sorting (SEK)	Cost of 80% sorting (SEK)	Cost of 90% sorting (SEK)
Mixed waste	11,395 SEK (10 ton)	3,418 SEK (3 ton)	2,275 SEK (2 ton)	1,142 SEK (1 ton)
Combustible waste	-	1,843 SEK (3 ton)	1,229 SEK (2 ton)	1,229 SEK (2 ton)
Metal	-	-1,344 SEK (2 ton)	-1,344 SEK (2 ton)	-1,680 SEK (2.5 ton)
Gypsum	-	1,718 SEK (2 ton)	1,718 SEK (2 ton)	1,718 SEK (2 ton)
Wood	-	-	58 SEK (2 ton)	58 SEK (2 ton)
Cardboard and paper	-	-	-	-182 SEK (0.5 ton)
Rent	1,344 SEK (10 ton)	1,344 SEK (10 ton)	1,421 SEK (10 ton)	1,421 SEK (10 ton)
Transport	4,042 SEK (10 ton)	4,042 SEK (10 ton)	4,042 SEK (10 ton)	4,042 SEK (10 ton)
Cost (10 ton)	16,781 SEK	11,021 SEK	9,399 SEK	7,748 SEK
Saving (SEK)	-	5,760 SEK	7,382 SEK	9,120 SEK
Saving (%)	-	34%	44%	54%

Given the method of calculation of recycling rate of CDW in Sweden, and taking into account the well documented benefits of on-site sorting, the second research question of the study was framed to find out the factors which affected the on-site sorting of waste. Since the activity of on-site sorting is generally performed by the construction or demolition contractors, the reasons for their sorting practices were to be investigated.

2.6 Factors affecting on-site sorting of CDW

This section describes the factors affecting the on-site sorting of waste. Some of these factors are used as questions in the surveys conducted (see section 3.3.1). Some of these factors are used to define the conditions of the different cases (see section 3.3.2)

According to (Wang et. al, 2010), the following are the factors that determine the success of on-site sorting of CDW:

- **Construction duration:** Extra time will be required for conducting construction waste sorting activities. This may cause time delay to the project.

- **Site space:** This factor refers to the limitation of original site space, the layout and the space for handling construction waste, especially for the poisonous ones. Since specified site space should be needed for sorting, less space would lead to less willing of contractors to implement on-site sorting.

- **Interference with normal construction activities:** Implementation of on-site construction waste sorting, particularly the use of equipment for waste collection, transportation and sorting will interfere with other site activities.

- **Market for recycled materials:** The markets for recyclables should be mature to make good use of the recycled materials. If contractors do not get economic benefits in on-site sorting, the 'short-term profits' oriented contractors would not take this practice into consideration.

- **Environmental considerations:** This factor mainly refers to two aspects. One is the pollution caused by on-site waste sorting activities, typically including noise and dust. The other is the limitation of external environment. For example, roads and time selected for waste transportation should abide by the local regulations.

- **Better management:** To promote the effectiveness of on-site sorting of construction waste, it is important to coordinate among various practitioners involved. This in turn calls for better construction management.

- **Waste sortability:** It means that whether it is possible or easy to sort a material manually out from the mixture. It is the genera view that he better way is to separate wasted materials when they were generated.

- **Manpower:** This refers to the extra labor arranged for performing the waste sorting work.

- **Equipment for sorting of construction waste:** This mainly includes two aspects: one is the storage equipment for sorted waste; the other is the use of some professional equipment for on-site sorting of construction waste.

- **Cost factors:** The construction/demolition contractors usually take decisions like where to send the waste material and how much to sort, by comparing the costs of the different scenarios.

- **Governmental policies:** There are governmental policies that specify the way in which the waste has to be handled, sorted and disposed of.

Out of all these factors, manpower, equipment and management are the factors that are within the control of the construction/demolition contractor. The other factors like construction duration, site space, market for recycled materials waste sortability and external environmental conditions are not within the control of the contractor. In other words, they are circumstances that are specific to each project and cannot be changed.

According to (Gangolells et. al, 2014), the following are the main factors that motivate construction and demolition companies to properly manage CDW

- Meet current legislation
- Improve the company's public image
- Increase our commitment to environmental sustainability
- Reduce costs
- Improve health and safety work conditions

2.7 Waste collection and logistics

This section provides information about waste collection and waste logistics during the management of CDW.

2.7.1 Waste collection

Waste collection refers to the process in which the sorted waste is collected and stored on-site. Precautionary measures must be taken to minimize risks while collecting and storing CDW. Generation of dust, potential fire hazards, odour emissions, run-off of contaminants etc. are the possible risks of improper waste collection. Hence, the waste should be stored in separate containers. According to the EU Construction & Demolition Waste Management Protocol, the containers and bins should be marked uniquely so that unintended mixing of waste is reduced

2.7.2 Waste logistics:

Waste logistics deals with the flow of CDW material from the generation site to the waste receiving site. According to the EU Construction & Demolition Waste Management Protocol, some important aspects connected to waste logistics are as follows:

- The waste receiving facilities should be selected to minimize the distance travelled by the CDW as much as possible, while considering the waste management hierarchy.
- The logistics of CDW need to be managed in such a way that there is good traceability throughout. This should be done by keeping a thorough record of the waste transported. Traceability and transparency are important to build trust in the CDW management process.
- Road networks should be utilized in the optimum manner so that transport distances are minimized.
- It is important to know what type of CDW is expected to be generated. But it is equally important to ensure that the waste has been handled according to plan.

2.8 Mapping model:

This section describes the mapping model that was developed, part of which was borrowed from literature. The purpose of this model is to provide an easy and visual representation of the waste flow.

The green lean philosophy states that visualization helps to understand processes better (Kurdve et al., 2015)**.** According to Shen et al. (2004) a waste management mapping model is a simple tool to assist with waste management planning and to compare different waste management practices at different sites. The mapping model is shown in Fig 4. All waste is generated at some source. The waste then undergoes some process, which could be waste collection, waste transportation by hand, loading the waste, sorting the waste, storing the waste etc. This processing of the waste is carried out by one or more waste facilitators, which could be labour, handcart, waste bins or waste containers. The waste finally reaches its destination, which could be for recycling, energy recovery or a landfill.

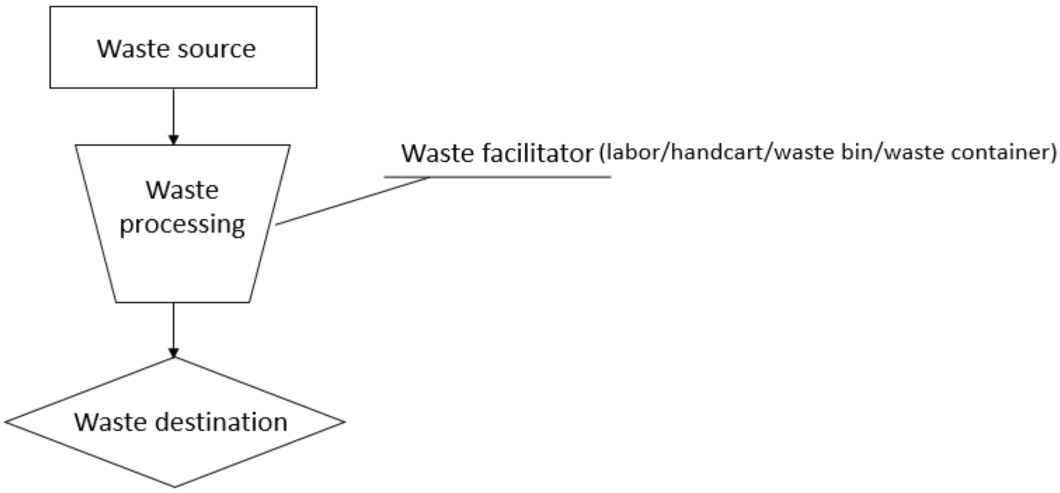

Figure 4. **Mapping Model (Shen et al., 2004)**

Using this model as a base and modifying it to include the variables required for the total waste handling cost calculation, a new mapping model was developed as shown in Figure 5. A symbolic representation of the different phases like waste transportation, waste facilitators and waste destination have been added. The only purpose of this model is to provide an easy and visual representation of the waste flow.

The customer initially gives the contract to a construction/demolition company. Further, the construction/demolition contractor drafts the waste management plan which contains expected material waste inventory and expected waste material volume. The demolition contractor also calculates the number of machines and equipment, workers and working hours required. The contractor then assigns work tasks and describes the plan and situation of the demolition building to the rest of the team after which the project begins. The waste that is generated is then sorted, collected and stored by the workers using some equipment. The waste is then finally transported to the waste receiving facility.

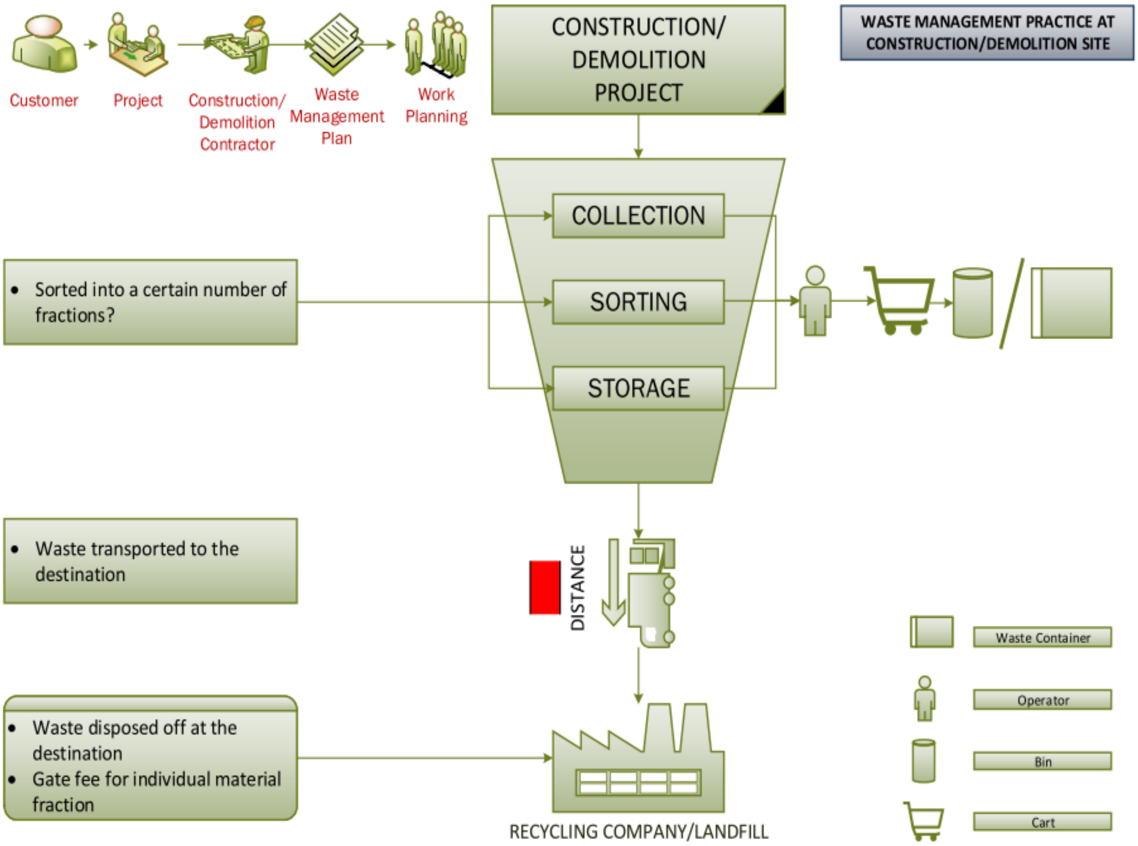

Figure 5. Analysis Model (Adopted from Shen et al., 2004)

2.9 Cost for waste generator

This section describes a mathematical model constructed to provide an economic analysis of the different cases that are studied (refer section 5.1).

According to (Duran et al., 2006)**,** the cost incurred by the generator of waste to dispose of the waste at recycling company is the sum of i) Cost of transporting the waste to the recycling center ii) Cost of bringing or dumping the waste at the recycling center, also known as the gate fee iii) Extra cost incurred by the waste producer for separation of waste on-site i.e. on site sorting costs.

Total cost = On-site sorting cost + Transportation cost + Receiver gate fee (Eq.2)

On-site sorting cost = Cost of collection and on-site transportation of waste + cost of sorting the waste material on-site + cost of storing the waste material on-site using bins

Through the interviews conducted (refer section 3.3.1), it was discovered that the storage cost was negligible since most of the times, the bins were owned by the construction/demolition company. Similarly, the transportation cost on-site was negligible because of the short distances, and because of the fact that transportation carts were used even to transport unsorted waste, so there was no extra cost. Hence, the simplified on-site sorting cost is given by:

On-site sorting cost = Number of man hours required for sorting x wages/hour (Eq.3)

The transportation cost consists of the fuel cost, which depends on the distance travelled and the wages of the driver.

Transportation cost = Driver cost + Fuel cost
= (No of hours for transport x driver wages/hour) + (Distance from construction/ demolition site to receiver x 2 x Fuel price/liter/truck fuel efficiency (Eq.4)

The dumping cost to the recycling companies depends on the type of waste fraction. Each waste fraction poses a different cost to the waste generator.

Total Receiver gate fee = Weight of waste fraction in tons x Gate fee/ton for that fraction (Eq.5)

The gate fee for mixed waste at the recycling company is always high, since the work of sorting this mixed waste will now have to be borne by the recycling company. This also demonstrates one great benefit of sorting, since sorting into several fractions will not only increase the recycling rate of the waste, but also result in less total waste dumping to the recycling companies. In this way, the total cost of CDW management was calculated for all the cases, the details of which are discussed in section 5.1.

2.10 CDW recycling rate performance of EU countries

This section provides a comparison of the performance of EU countries with respect to CDW recycling rate, providing some benchmarks to Sweden regarding the levels of recycling rates that are being achieved in the EU. Some examples good practices followed in Netherlands, Belgium, Luxemburg and Denmark are explained, which helped them achieve a good recycling rate.

Some countries in the EU have performed exceedingly well in the aspect of CDW recycling rates Some examples of the good practices followed are given below (EU CDW Management Protocol, 2016):

2.10.1 Netherlands

The Netherlands had set a goal of reaching 90% recycling rate by 2000, which was achieved in 1999 (Ministry of Housing, Spatial Planning and the Environment, 2001). In the Netherlands, customers prescribe a certification scheme (BRL SVMS-007) for demolition processes, which is controlled by the Council of Accreditation. The following four steps are followed for the certification:

1) Pre-demolition plan: The demolition contractor makes an inventory of the wastes that will be generated along with the potential occupational risks and the safety risks to the surroundings.
2) Waste Management Plan: In this step, the demolition contractor draws up a waste management plan describing the planned method of demolition and removal of the waste generated.
3) Execution: During the execution of the project, the waste management plan is referred to and strictly followed. Certified demolition contractors work with experts in environmental-friendly demolition.
4) Final Report: Upon completion of the project, the demolition contractor draws up a final report containing information about the flow of the waste generated. This report is then handed to the customer.

2.10.2 Belgium

Belgium had achieved a recycling rate of 75% by 1999 (Fischer and Werge, 2009). Tracimat is a demolition management organization recognized by Belgian public authorities. It issues a certificate of demolition for materials that have gone through their traceability system, which are classified as "low environmental risk materials". The certification ensures the waste receiver (the recycling company) of the quality of the received waste, for further processing. The "low environmental risk materials" can be treated separately from the other high-risk materials, which are not traceable and hence their quality cannot be ensured. The traceability system starts with a waste management plan containing the inventory of the waste that will be generated along with volumes. This waste management plan must be prepared according a specific procedure. This increases the trust between the waste generators i.e. the construction/demolition contractors and the recycling companies regarding the quality of the waste and ultimately, the quality of the recycled material.

2.10.3 Luxembourg

Luxembourg is one of the countries who are performing comparatively well in recycling the construction and demolition waste. The country has managed to recycle around 88.4% of its CDW in the year 2012. There is a legal obligation from the authorities to collect and sort the construction and demolition waste as much as possible and if not sorted, the mixed waste should be in such a form which can be handled by the inert waste treatment facilities. Within the countries' CDW management it is mandatory to carry out a waste management plan and a pre-demolition audit, including an inventory of materials and how each type of waste (hazardous and non-hazardous) will be treated as per the waste hierarchy.

SuperDrecksKëcht (SDK) is the public body that is responsible for supporting construction sector in minimizing waste and help them to improve the degree of sorting, apart from that SDK provides a free software access to the construction sector where waste handling can be controlled in a more efficient way. Many clients are interested in the certified buildings (BREEAM, HQE), this is also one of the driving factors for the construction companies to reduce and handle waste to be competitive in the construction market.

2.10.4 Denmark

Denmark had set a goal of reaching 90% recycling rate by 2004, which was achieved by 1997 (Waste Centre Denmark, 2010). In order to improve the CDW recycling rates, many action plans were implemented by the country such as identification and sorting of problematic substances, a stricter requirement for selective demolition and requirements regarding qualifications of demolition companies. “Dafoka” is an organization which is part of Danish waste competence center, who is mainly responsible for having effective communication between various stakeholders such as legislators, consultants, construction and demolition companies. The organization also plays a prominent role in promoting the sustainable construction and demolition waste management in Denmark. Dafoka is bringing all the above stakeholders involved within the CDW management by organizing workshops, conferences, and seminars to come up with a best practice to make the CDW management more sustainable and also to have better recycling rates. Danish waste resource management plan which constitutes all the information regarding requirements for handling construction and demolition waste and objectives that must be achieved with respect to CDW recycling rates. This plan emphasizes that “waste is a resource that has to be recycled”. Demark national legislation demands that construction and demolition waste should be sorted on-site or handled at the registered sorting facilities. In addition to this, a high tax rate for non-recycled waste is also levied in Denmark (Montecinos and Holda, 2006).

2.10.5 Other countries which have performed well

Germany achieved a recycling rate of 85% by 2002 even though it produces the maximum amount of CDW waste within the EU (Weisleder and Nasseri, 2006). The UK achieved a recycling rate of 65% by 2006, despite also being one of the biggest producers of CDW waste within the EU (European Commission, 2011). By 2006, Ireland and Estonia had achieved a CDW recycling rate of 80% (Fischer and Werge, 2009). According to Yoa and Shen (2010), Hong King, Australia, USA, UK, and Sweden have contributed the most to C&D waste management from 2000 to 2009.

2.11 Certifications

This section describes some of the certifications which are awarded to construction/demolition companies to promote sustainable practices and utilize resources in a more effective way, during the management of CDW.

2.11.1 BREEAM Certification

BREEAM (Building research establishment's environmental assessment methods) is one such international certification which is widely used in Europe and more 70 different countries. Sweden and other countries like Germany, Netherlands etc. have moved one step ahead in developing BREEAM certification system. In Sweden, BREEAM is operated by the Swedish green building council. BREEAM is the world's first sustainable rating scheme and leading assessment method for master planning projects, infrastructure and buildings to create a higher value. BREEAM's priority is to support all the actors to measure and reduce environmental impact. (BREEAM technical manual, 2014)

2.11.2 LEED Certification LEED

(Leadership in energy and environmental design) is a green building rating system which is significantly popular in Sweden. LEED system provides a package of facilities such as third-party verification, building design, construction, maintenance and operations in creating more sustainable buildings around Sweden. The certification system's aim is to simplify the complexity within the structures, reduce the environmental impact, improve public health and safety and to build structures by making use of resources in an effective way. This certification system is adopted by well-known companies such as Skanska and Vasakronan. The Sweden Green Building Council and many giant companies have been working along with LEED professional to continuously improve the rating system which can be easily adapted to Swedish standards (LEED in Motion: Sweden (2014)

3 Research Method

This chapter discusses the methodology of performing the study. The research approach is explained, and an analysis model is presented. A brief description is provided of how the selected research approach was followed, how the data was collected and for what purpose.

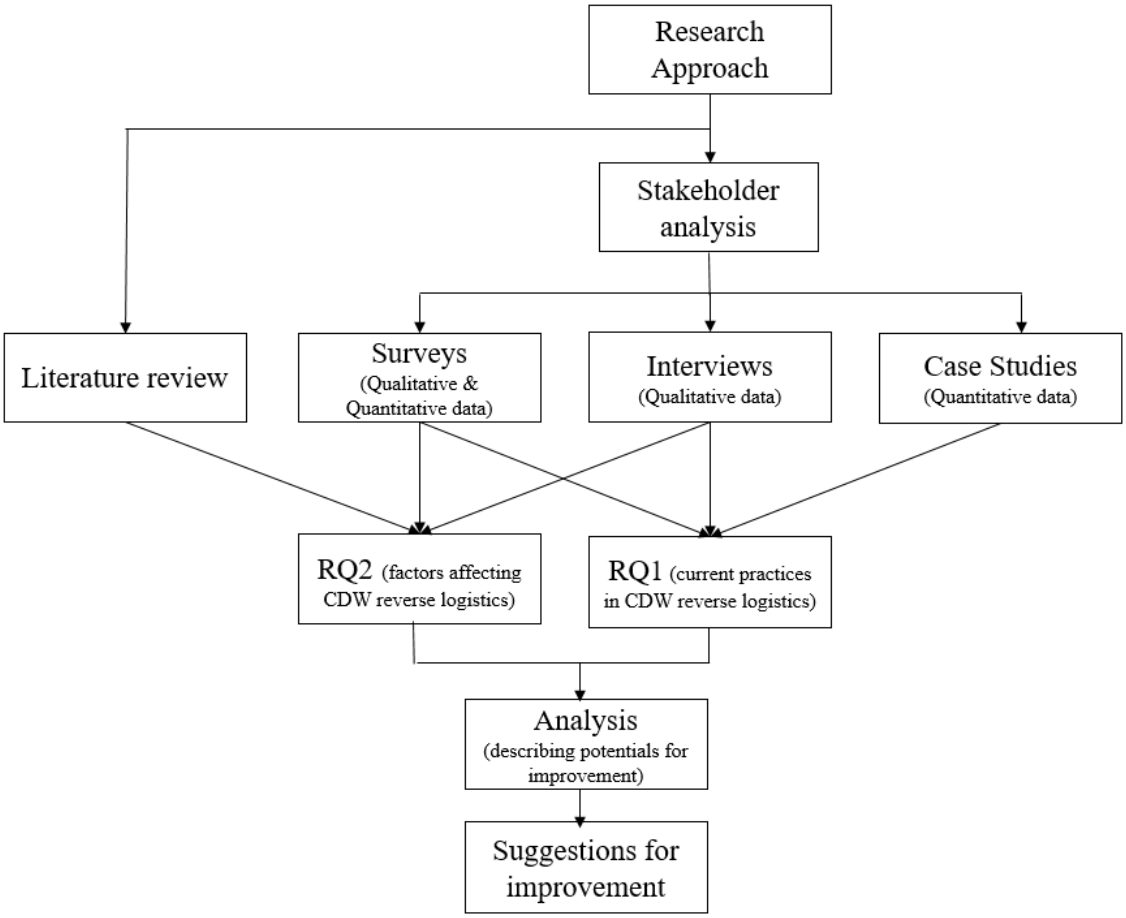

Figure 6. Research Process

The research process is described in Fig.6. A stakeholder analysis is performed to identify the people to be interviewed, surveyed and to obtain case studies. A literature review is performed in parallel. The surveys, interviews and case studies together are used to answer RQ1. The literature review, surveys and interviews together are used to answer RQ2. In this way, the factors affecting the identification, on-site sorting, collection and logistics of waste as well as the current practices of these processes are found out and then described.

Based on the observation of the factors and the current practices, an analysis about the potentials for improvements is made. Based on these potentials for improvement, suggestions for improvement are made.

3.1 Research approach

According to a study conducted by analyzing research papers related to CDW management from 2000 to 2009, there are four main types of research methods used (Yuan & Shen, 2011):

1) Survey: In this method, questionnaires are distributed amongst the stakeholders or interviews are conducted
2) Case study: In this method, real world construction or demolition projects are studied
3) Review: In this method, an analysis of the historic literature in the related topic is conducted.
4) Experiment: In this method, the process of CDW recycling is studied

For the purpose of this research, a mixed method of surveys and case studies was deemed appropriate. The large number of stakeholders in the CDW value chain meant that surveys and interviews would be needed to gain a better understanding. The case study method was used to analyze some of the current practices of construction and demolition companies for CDW management in Sweden. Of course, these case studies would not provide a complete picture of the current practices of CDW management in all of Sweden, but they would provide a small sample for studying.

There are two basic methods of research that could be used in any research project – method using quantitative data or numerical data and method using qualitative data or descriptive data (Yilmaz, 2013). In this study, the two methods of case studies and surveys would provide mostly quantitative data, but also some qualitative data. However, due to the nature of the topic of management construction and demolition waste, it seems that more qualitative data would also be required to gain a better understanding. Which is why, the qualitative method of conducting interviews with stakeholders was also required. This project uses a mixed method of qualitative and quantitative approaches. This kind of mixed model approach is gaining wider use and acceptance in academia (Bryman & Bell, 2011).

3.2 Stakeholder analysis

In this section, the stakeholders within the construction and demolition industry are identified. The main purpose of this is to identify the stakeholders to be interviewed and surveyed.

The construction and demolition industry involves a large number of actors or stakeholders. Hence, all the stakeholders must first be identified, after which an assessment can be made of how the different stakeholders are affected and can be utilized throughout the project. It also helps to identify the persons to be interviewed for the qualitative analysis in the project. Below are the stakeholders within the project:

Positive secondary	Positive primary
• Environmental policy makers • Building owners • SEPA, Swedish IVL • Recycling industry • Swedish Government	• CIT • Environment in general
Negative secondary • Landfill industry • On-site workers	**Negative Primary** • Construction /Demolition Contractors and sub-contractors • 3PL companies

Figure 7. A List of the different stakeholders in the project

- **Positive primary stakeholders**: These stakeholders are the ones who are affected directly in a positive way by the project. This thesis will help CIT for the Constructivate project and the general environment.
- **Negative primary stakeholders**: These stakeholders are the ones who are affected directly in a negative way by the project. The construction/demolition contractors and 3PL companies will have to put in extra effort, which could make them reluctant to apply the suggestions.
- **Positive secondary stakeholders**: These stakeholders are the ones who are affected indirectly in a positive way by the project. SEPA, environmental policy makers and Swedish IVL will benefit from the thesis since it will make them aware of the improvement possibilities in CDW management. The recycling industry will benefit from higher recycling. Reaching the EU target will help the Swedish government.
- **Negative secondary stakeholders**: These stakeholders are the ones who are affected indirectly in a negative way by the project. The landfill facilities will be negatively impacted since higher recycling rates will lead to lower disposal rates of waste. On-site workers also might have extra work to do which might make them reluctant for change.

The stakeholders were contacted by either site visits, interviews, surveys or meetings. Some of the questions in the surveys and interviews were framed with the help of literature in similar areas, discussed in section 2.6.

3.3 Research method

The following analysis model provides a simple explanation of the methodology used to answer the research questions:

Table 5. Research method

Research Question	Method used	Outcome
RQ1	Interviews, Surveys (Contractors/ Subcontractors, Recyclers), site visits, case studies	Visual map, description of the current practices
RQ2	Literature, Interviews, Surveys (Contractors/Subcontractors, Recyclers),	Description of the factors affecting the identification, sorting, collection and logistics.

3.3.1 Interviews and Surveys:

Due to the large number of stakeholders in the reverse logistics of CDW, a survey and interview approach was selected, to seek both quantitative and qualitative data.

Interviews

The table below shows the details of the people interviewed and surveyed and the main purpose of each interviews and survey. In total 11 interviews were conducted as follows: one waste statistics expert from Swedish IVL, one expert in plastic recycling, two experts in concrete recycling, one demolition contractor, one construction contractor, three recycling companies, one employee from the planning department of the municipality and one employee from the environmental department of the municipality. Concrete and plastic experts were interviewed because they were a part of the Constructivate project. The focus of this study however, was not was not limited to concrete and plastic. Each interview lasted between 40 and 80 minutes. Then answers to the interview questions and comments from the interviewees were noted down in documents.

Table 6. Details of interviewee and purpose

Interviewee	Main Purpose
Expert from Swedish IVL	To understand how the CDW recycling rate is calculated in Sweden
Plastic recycling expert, who was part of Constructivate	To find out what degree of sorting is desired for better recycling
Concrete recycling expert, who was part of Constructivate	To find out what degree of sorting is desired for better recycling

Demolition contractor	To seek cases to understand current CDW management practices
Construction contractor	To seek cases to understand current CDW management practices
Recycling companies	To understand the logistics of waste flows, costs involved in waste flows and their perspectives in terms of what can be improved
Planning department	To understand procedure involved in giving permits
Environmental department	To understand procedure involved in giving permits

Surveys

Initially, the interviews were conducted with the different stakeholders as mentioned in table 6, to gain a qualitative understanding of the subject. Based on these interviews, questions were formulated to construct a survey to understand the opinions of a larger population of stakeholders. A pilot survey was also handed out to the interviewees to gauge whether the questions included in the surveys were relative and easy to comprehend.

In addition, 763 total surveys were sent out, 685 to construction/demolition contractors, 21 to recycling companies and 57 to landfill facilities. The contact information of the recycling industries was readily available on the website of the Recycling Industries trade organization of Sweden (Industries, 2017). This list contained 67 recycling companies. However, only 21 of these companies accepted CDW. The contact information of the construction/demolition industries was not found readily available on any website. SverigeBygger provides researchers with database in exchange for a reasonable fee. Hence, the contact information of construction/demolition companies was obtained from a them. The contact information of the landfill facilities within Sweden was also readily available on the AvfallSverige website (Sverige, 2017). All the surveys were sent out in the second week of April 2017. A reminder e-mail was sent out again a week later. The number of responses received were as follows:

- Construction/demolition contractors: 80/685, giving a response rate of 11.7%
- Recycling companies: 12/21, giving a response rate of 57.1%
- Landfill facilities: 15/57, giving a response rate of 26.3%

It should be noted that there are nearly 8,000 construction/demolition companies and around 1,000 recycling companies in Sweden. Which means that the surveys were sent to less than 10% of the population. However, the results that were obtained from the surveys may not be a true reflection of the opinion of the entire population of these companies in Sweden.

Table 7. Details of stakeholders surveyed and purpose

Stakeholder	Main Purpose of survey
Construction/Demolition contractors	To understand the current CDW management practices, logistics of waste flows, what motivates them to increase recycling rates and their perspectives in terms of what can be improved
Recycling companies	To understand the logistics of waste flows, costs involved in waste flows and their perspectives in terms of what can be improved
Landfill facilities	To understand the costs involved in waste flows to landfills

3.3.2 Case studies

Case studies are the best ways to understand a phenomenon based on its context, which is why the case study approach has become a common method in scientific studies (Dubois & Gadde, 2002). To get an overview of the current waste handling process within construction and demolition waste industry in Sweden, different types cases were studied. This would aid in answering RQ1. In total, 5 cases were studied in this project. The construction and demolition contractors were asked for cases from the recent past, which they have been a part of. The case studies would also need to have all the necessary information in written records, so that they can be referred to when required for further analysis. The cases were selected to compare two extremes of the waste handling processes as well as to understand the typical practice. The contractors were asked for cases with different conditions of project duration, site space, management etc. (according to the factors mentioned in section 2.7), to represent the different conditions that could arise in a construction/demolition project, as well as possible. Hence, the criteria of selecting the cases can be stated as:

1) Degree of sorting performed
2) Project conditions

The five cases which were studied were:

- One demolition case, where on-site sorting was not performed well, resulting in low recycling rate
- Three typical cases of demolition, which represented the general degree of on-site sorting. However, these three cases had different project conditions (see section 2.6).
- One construction case, where on-site sorting was performed exceptionally well, resulting in high recycling rate.

The cases are described in detail in section 4.1. and are the later analyzed in section 5.1, for the total cost of handling CDW for the waste generators i.e. construction and demolition contractors. The aim is to compare the cost for the waste generator, when waste is sorted and when waste is not sorted.

4 Empirical Data

This chapter contains a description of the case studies and the information gathered from the case studies, which is presented with the aid of maps. The salient points from the interviews and survey results are then shown.

4.1 Case descriptions:

In this section, the five cases are described. A uniform structure is followed for the case descriptions. First, information about the site, customer, the construction/demolition contractor and the duration of the project are stated. Then the conditions of the project as described by the construction/demolition contractor, are shown in a tabular format. Then, some special features of each case are described, with the help of quotations from the contractor. A table showing the degree of sorting of the different waste fractions is shown and the expected recycling rate is calculated. Finally, map showing the flow of CDW in the case is displayed.

4.1.1 Case 1: Volvo PVD Torslanda (Bad Practice)

In this case, Volvo PVD as a customer gives the demolition contract to a demolition company called RIVAB AB, located in Gothenburg. The demolished building was located in Torslanda, Gothenburg. The demolition of Volvo PVD building took around 2 weeks to complete. Based on the environmental documentation in the initial phase of the demolition the hazardous material was taken out from the building and treated separately.

The manager for the demolition project at RIVAB was asked to rate the suitability of the conditions for on-site sorting of the waste for this particular case. His answers are as stated in table 8.

Table 8. Conditions for sorting of CDW for case 1, as stated by the site manager (1=fully disagree, 2=partially disagree, 3= partially agree, 4=agree 5=fully agree)

	1	2	3	4	5
Sufficient project time was available	○	◉	○	○	○
Sufficient site space was available	○	○	◉	○	○
Normal construction activities were not interfered with	○	○	○	◉	○
The waste was sortable comparatively easily	○	◉	○	○	○
Management during the project was good	○	○	○	◉	○
Sufficient manpower for sorting was available	○	○	○	○	◉
Sufficient equipment for sorting was available	○	○	○	○	◉

The manager of the demolition project added,

> *"This particular building was a special case. The entire demolition had to be completed within two weeks"*

As the customer demanded that the demolition project be completed in two weeks, the demolition contractor drafted a waste management plan which aimed to transport large amount of mixed waste fraction. Due to Volvo pvd building not containing large variety of material fraction, the demolition contractor felt that not sorting the waste completely would help in finishing the project on time. The demolition contractor mentioned that, due to good profit in receiver gate fee, they delegated the task of sorting the mixed waste fraction to the recycling company. The demolition project involved 4 excavators and 2 workers for sorting the demolished waste onsite. The waste generated from Volvo pvd building was sorted into unsorted waste, scrap metal, cables, copper, wood, fluorescent lamps, electronics, halogen bulb, small battery, smoke detectors, lighter, refrigerants, oil compressors, glycol, hydraulic oil and concrete.

In this particular case, the trucks arrived at regular intervals to pick up the waste containers from the demolition site and drop them off at the recycling facility. The waste containers were loaded and transported by trucks to different recycling facilities depending on the type and volume of the material fraction. The sorted waste was transported to five different recycling facilities they are RGS 90, Skrotfragg, Stena recycling, Sortera and Caverion for further processing.

Table 9. CDW generated in case 1

Fraction	Amount(ton)	Receiver Company
Waste to sorting (Mixed waste)	875.7	RGS 90
Scrap metal	96.1	Stena recycling
Cables	2.3	Stena recycling
Copper	3.7	Stena recycling
Wood	29.5	Renova
Fluorescent lamps	2014st	Sortera
Electronics	10kg	Sortera
Halogen Bulb	13st	Sortera
Small Battery	4st	Sortera
Smoke Detectors	88st	Sortera
Lighter	1953st	Sortera
Refrigerants	0.0506	Caverion
Oil Compressor	30ltr	Caverion
Glycol	1.602	Renova
Hydraulic oil	0.407	Renova
Concrete	272	Samgräv/Fläxhult
Total (tons)	**1281**	

The total amount of waste generated was 1,281 tons. Out of this, 875.7 tons of waste was mixed or unsorted waste. 405.1 tons of waste was sorted into different fractions before being sent to the recycling companies. Out of all the fractions, concrete & bricks and metal scrap are the primary waste that will be used for either conventional recycling or landfill cover. Wood and combustible waste will be utilized for energy recovery through incineration. The rest of the fractions are hazardous wastes and will be disposed of safely, but not recycled.

As discussed in section 2.5, the average recovery of secondary waste in Sweden is 45.6%. Hence, 45.6% of the mixed or unsorted waste, i.e. 399.31 tons of secondary waste would be recovered for conventional recycling or landfill cover. From Eq.1, stated in section 2.5, the recycling rate for this project is

$$= \frac{\begin{array}{c}(Primary\ waste\ used\ for\ conventional\ recycling + Primary\ waste\ used\ for\ landfillcover\ \ backfill + \\ Secondary\ waste\ used\ for\ conventional\ recycling + Secondary\ waste\ used\ for\ landfillcover\ \ backfill)\end{array}}{Total\ CDW\ generated}$$

$$= \frac{(272+96.1)+399.3}{1281}$$

$= 59.9\%$

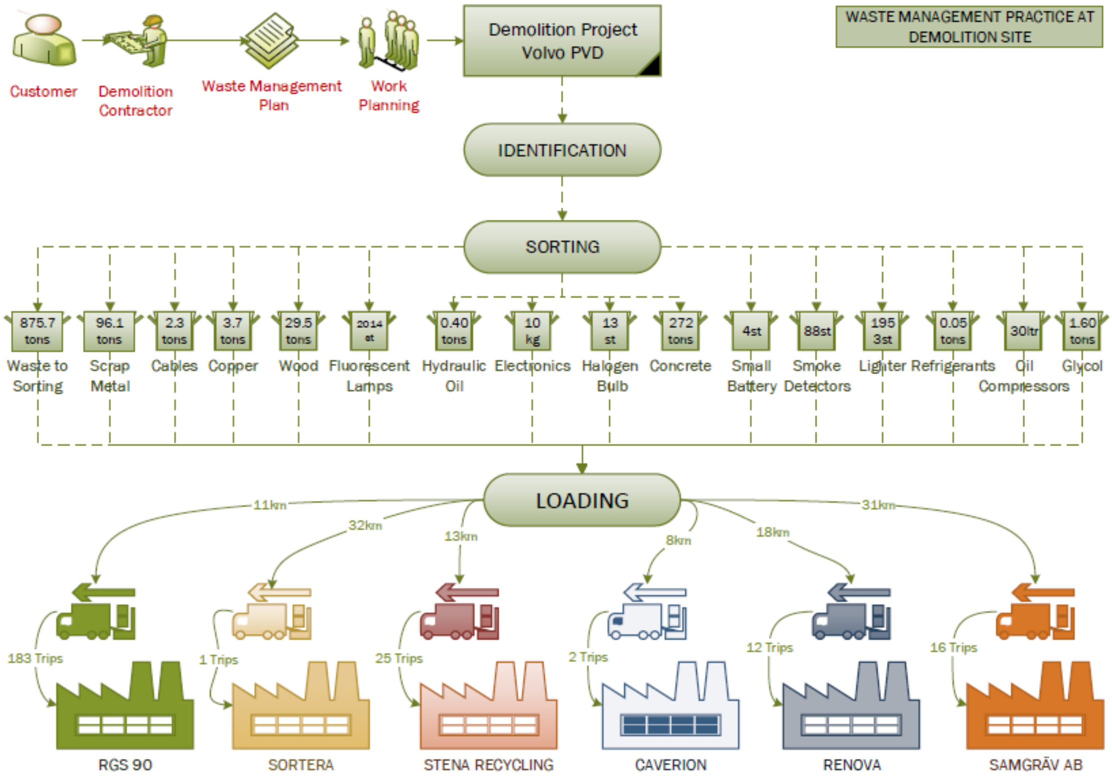

Figure 8. Process map of Case 1

4.1.2 Case 2: Rosendals School (Typical practice)

This case is a demolition project which was also carried out by RIVAB. The demolished building was called Rosendals school which was in Sörensensgata, Göteborg and the customer was Tage & Söner. The demolition project was initiated during mid of October and was completed by the end of November 2016. The documentation containing different material fractions, type of hazardous material and identifying locations, further handling of those hazardous waste was prepared by an environmental policy company. The demolition contractors' view about this case was that

> "T*he calculation was not done perfectly from the beginning of the demolition".*

The manager for the demolition project at RIVAB for this case was asked to rate the suitability of the conditions for on-site sorting of the waste for this particular case. His answers are as stated in table 10.

Table 10. Conditions for sorting of CDW for case 2, as stated by the site manager (1=fully disagree, 2=partially disagree, 3= partially agree, 4=agree 5=fully agree)

	1	2	3	4	5
Sufficient project time was available	○	○	◉	○	○
Sufficient site space was available	○	○	○	◉	○
Normal construction activities were not interfered with	○	○	◉	○	○
The waste was sortable comparatively easily	○	○	◉	○	○
Management during the project was good	○	○	○	◉	○
Sufficient manpower for sorting was available	○	○	◉	○	○
Sufficient equipment for sorting was available	○	○	○	◉	○

The Rosendals school building consisted of different hazardous waste fractions which were to be taken out first before the demolition process. According to the contractor,

> *"It was not a normal building case and sortability was not so easy due to its oldness and complexity of different materials. That is why, it was hard to control or predict different types waste within this particular building. We found some extra asbestos within the building which was not specified in the environmental report".*

The demolition was stopped in order to take care of the hazardous material. This resulted in the slowdown of the demolition process. In such case the demolition company will report to the environmental officers for further proceedings and after their clearance, the demolition resumed. The waste generated from the demolished building was sorted into different fractions such as, asbestos, waste for sorting, combustible, concrete bricks, wood, detectors, door closers with oil, paint waste, fluorescent, light sources, extinguishers, electronic scrap, air filters, color bases, hydraulic oil and metal scrap. During the demolition of Rosendals school, 2 excavators and 2 workers were involved to sort the demolished waste. Additional 2 workers were involved for a couple of weeks to handle waste. The contractor specified that

> *"We faced a problem regarding lack of manpower availability in the initial weeks but later there were enough workers to operate*

demolished waste".

This lack of availability of workers would also be another factor in decreasing the efficiency of on-site sorting. This could have resulted in increased volume of mixed fraction. By looking at the volume of the waste fraction, the demolition contractor calls the trucks to pick up the waste containers from the site and further dispose at the recycling company. The waste containers were loaded and transported by trucks to different recycling facilities depending on the type and volume of the material fraction. The waste generated was sent to these recycling companies for further processing such as RGS 90, Renova, Samgräv and Stena Recycling. The details of the amount of different waste fractions sent to different companies is shown in table 11.

Table 11. CDW generated in case 2

Fraction	Amount (Tons)	Receiver
Waste to sorting	275.2	RGS 90
Asbestos	4.4	Renova Tagene
Combustible	28.3	RGS 90
Concrete & bricks	2600	Samgräv/Fläxhult
Wood	69.12	Renova
Detectors	0.007	Renova
Door closers with oil	0.053	Renova
Paint waste	0.201	Renova
Fluorescent	0.120	Renova
Light sources	0.035	Renova
Low energy	0.033	Renova
Extinguishers	0.153	Renova
Electronic scrap	0.140	Renova
Air filters	0.012	Renova
Hydraulic oil	0.018	Renova
Colour bases	0.1	Renova
Solvent	0.03	Renova
Metal Scrap	75.7	Stena recycling
Total (tons)	**3053.64**	

The total amount of waste generated was 3053.64 tons. Out of this, 275.2 tons of waste was mixed or unsorted waste. 2778.4 tons of waste was sorted into different fractions before being sent to the recycling companies. Out of all the fractions, concrete & bricks and metal scrap are the primary waste that will be used for either conventional recycling or landfill cover. Wood and combustible waste will be utilized for energy recovery through incineration. The rest of the fractions are hazardous wastes and will be disposed of safely, but not recycled.

As stated in section 2.5, the average recovery of secondary waste in Sweden is 45.6%. Hence, 45.6% of the mixed or unsorted waste, i.e. 125.5 tons of secondary waste would be recovered for conventional recycling or landfill cover. From Eq.1, stated in section 2.5, the recycling rate for this project is

$$= \frac{\begin{array}{c}(Primary\ waste\ used\ for\ conventional\ recycling + Primary\ waste\ used\ for\ landfillcover\ \ backfill + \\ Secondary\ waste\ used\ for\ conventional\ recycling + Secondary\ waste\ used\ for\ landfillcover\ \ backfill)\end{array}}{Total\ CDW\ generated}$$

$$= \frac{(2600+75.7)+125.5}{3053.64}$$

= 91.7%

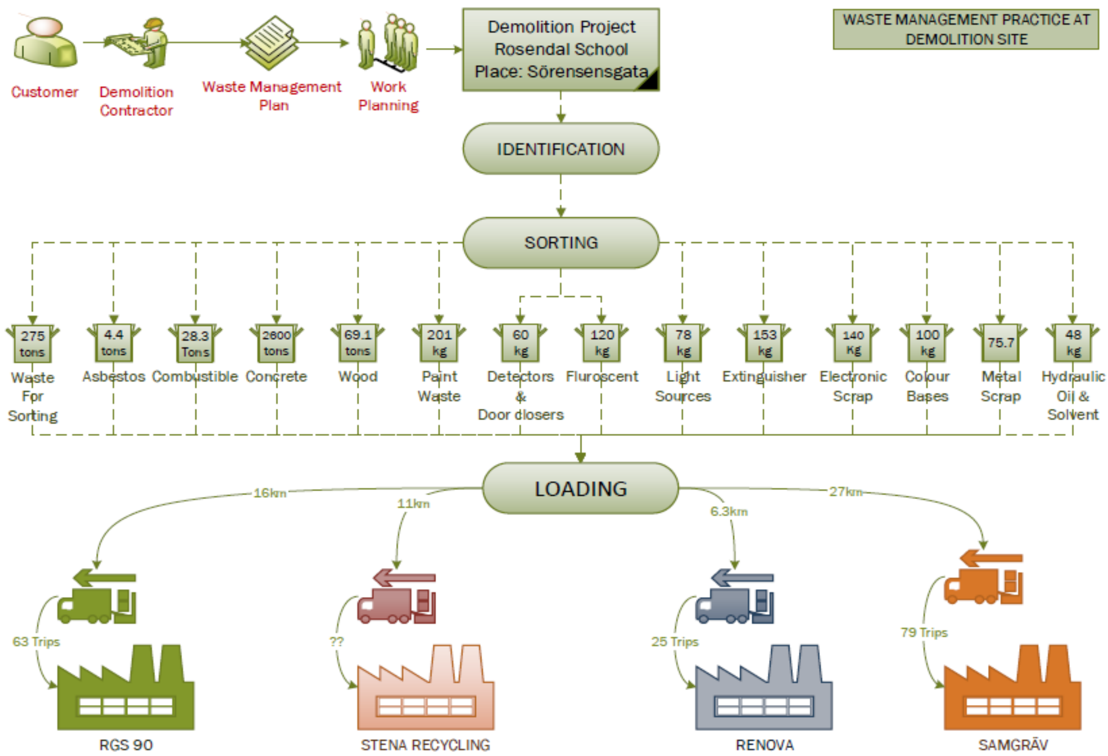

Figure 9. Process map of Case 2

4.1.3 Case 3: Volvo Penta (Typical practice)

Case 3 is a demolition project called Volvo Penta which was located at Gropegårdsgatan, Göteborg. The demolition was carried out by RIVAB AB and the customer was Betonmast. The Volvo Penta demolition was initiated in the middle of May 2016 and was completed in the beginning of March 2017. The documentation containing different material fractions, type of hazardous material and identified locations and further handling of those hazardous waste was prepared by an environmental policy company.

The manager for the demolition project at RIVAB for this case was asked to rate the suitability of the conditions for on-site sorting of the waste for this particular case. His answers are as stated in table 12.

Table 12. Conditions for sorting of CDW for case 3, as stated by the site manager (1=fully disagree, 2=partially disagree, 3= partially agree, 4=agree 5=fully agree)

	1	2	3	4	5
Sufficient project time was available	○	○	○	○	●
Sufficient site space was available	○	○	○	●	○
Normal construction activities were not interfered with	○	○	○	○	●
The waste was sortable comparatively easily	○	○	○	●	○
Management during the project was good	○	●	○	○	○
Sufficient manpower for sorting was available	○	○	●	○	○
Sufficient equipment for sorting was available	○	○	○	●	○

The contractor mentioned that,

> *"The planning was not done effectively before the project, which resulted in making critical decisions very shortly while the project was in progress. Also, for some reason the customer changed the order of the demolition planning itself, because they wanted another demolition company to operate first and then RIVAB had to come later and finish. Which resulted in delay of the project and a bad flow occurred for the demolition company."*

The Volvo Penta building consisted different kinds of concrete such as pure concrete, reinforced concrete, unreinforced concrete and light unreinforced concrete. According to the contractor,

> *"In this case light demolition was followed because some part of the building will be rebuilt. So, there was a customer demand to sort the*

concrete as much as possible in a clean state, so that the same concrete can be reused Demolition of Volvo Penta building consumed a long duration of time"

Based on the customer requirement light demolition was performed inside the building to take down concrete walls separately using various machines and hand equipment's. This resulted in different sorted concrete fractions rather than just one mixed fraction of concrete.

One of the reason behind prolonged duration of project would also have been due to change in demolition plan by the customer. The demolition project contained around 7 workers and variety equipment's were involved especially for sorting onsite operation. The waste generated was sorted into these many material fractions such as clean concrete, reinforced concrete, polluted soil, unreinforced concrete, insulating material, PCB contaminated concrete, Combustible sorting, unsorted, nickel cadmium battery, fluorescent and metal scrap

By looking at the volume of the waste fraction, the demolition contractor called the trucks to pick up the waste containers from the site and further dispose at the recycling company. The waste containers were loaded and transported by trucks to different recycling facilities depending on the type and volume of the material fraction. The waste fractions were sent to various recycling facilities for further processing such as Samgräv, RGS 90, Renova and Stena recycling.

Table 13. CDW generated in case 3

Fraction	Amount (Tons)	Receiver
Pure concrete	4965	Samgräv AB
Reinforced concrete	1037	Samgräv AB
Soil, oil pollution	0.95	RGS 90
Unreinforced concrete	300.85	RGS 90
Reinforced concrete	55.55	RGS 90
Light unreinforced concrete	147.55	RGS 90
Insulating material	11.75	RGS 90
PCB Contaminated concrete	11.2	RGS 90
Combustible sorting	82.25	RGS 90
Unsorted	675.65	RGS 90
Asbestos	3.51	Renova
Car battery	290	Renova
Fluorescent	7	Renova
Nickel cadmium battery	23	Renova

Metal scrap	548.3	Stena recycling
Total in (tons)	8160	

The total amount of waste generated was 8,160 tons. Out of this, 675.65 tons of waste was mixed or unsorted waste. 7,484.75 tons of waste was sorted into different fractions before being sent to the recycling companies. Out of all the fractions, concrete & bricks and metal scrap are the primary waste that will be used for either conventional recycling or landfill cover. Wood and combustible waste will be utilized for energy recovery through incineration. The rest of the fractions are hazardous wastes and will be disposed of safely, but not recycled.

As discussed in section 2.5, the average recovery of secondary waste in Sweden is 45.6%. Hence, 45.6% of the mixed or unsorted waste, i.e. 308.10tons of secondary waste would be recovered for conventional recycling or landfill cover. From Eq.1, stated in section 2.5, the recycling rate for this project is

$$= \frac{(Primary\ waste\ used\ for\ conventional\ recycling + Primary\ waste\ used\ for\ landfillcover\ \ backfill + Secondary\ waste\ used\ for\ conventional\ recycling + Secondary\ waste\ used\ for\ landfillcover\ \ backfill)}{Total\ CDW\ generated}$$

$$= \frac{(6505.95+548.3)+308.10}{8160}$$

= 90.22%

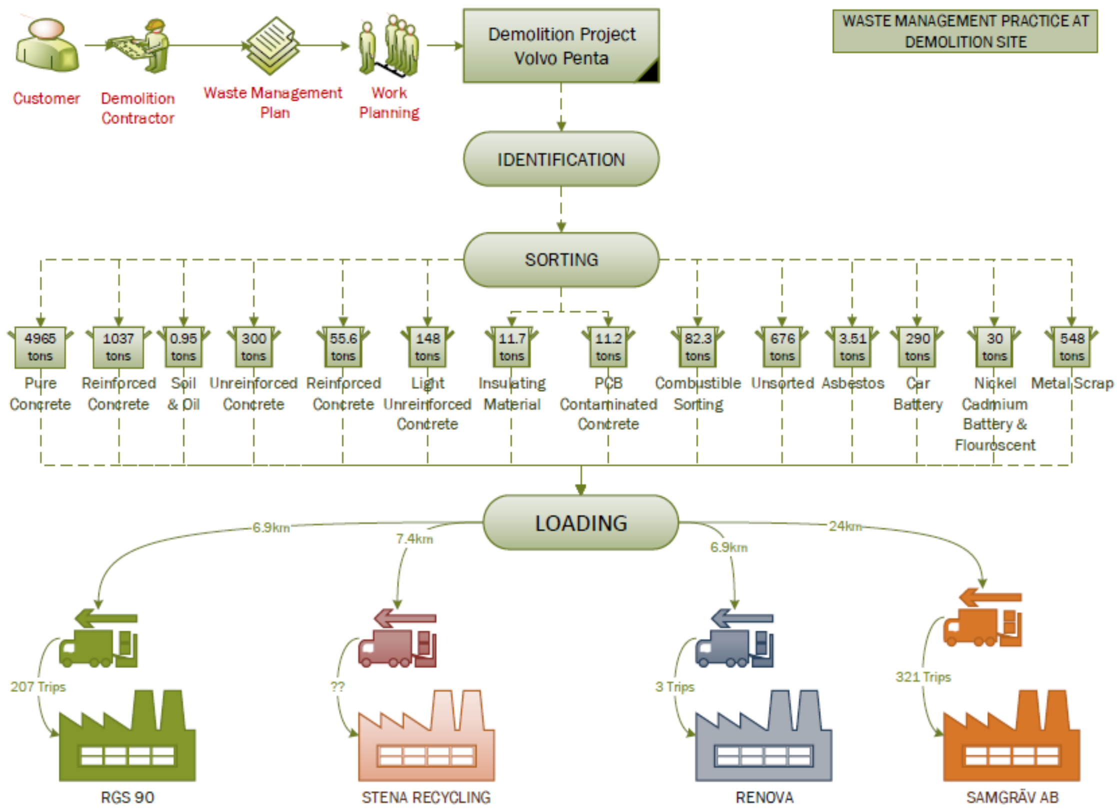

Figure 10. Process map of Case 3

4.1.4 Case 4: Ekodukt Case (Typical practice)

This case was a demolition project called Ekodukt located in Sandsjöbacka and was undertaken by RIVAB AB. The demolition project was assigned by the customer company called PEAB. The project was to demolish a part of the animal crossing bridge due to some designing errors. The bridge was under construction during the demolition project, so some part of the material fraction was reused as filling material onsite. The demolition project was carried out from January end till march end 2017. The demolition contractor mentioned that,

> *"It was an emergency case the customer informed us early in the morning and stated the problem about the bridge that was about to collapse in couple of days. The demolition job wasn't ordered to the demolition company in advance or planned accordingly, we just went to the site and planning phase took place later".*

The manager for the demolition project at RIVAB for this case was asked to rate the suitability of the conditions for on-site sorting of the waste for this particular case. His answers are as stated in table 14.

Table 14. Conditions for sorting of CDW for case 4, as stated by the site manager (1=fully disagree, 2=partially disagree, 3= partially agree, 4=agree 5=fully agree)

	1	2	3	4	5
Sufficient project time was available	○	○	○	○	◉
Sufficient site space was available	○	○	◉	○	○
Normal construction activities were not interfered with	○	○	○	◉	○
The waste was sortable comparatively easily	○	○	○	◉	○
Management during the project was good	○	○	○	◉	○
Sufficient manpower for sorting was available	○	○	○	◉	○
Sufficient equipment for sorting was available	○	○	○	◉	○

Since, the demolition company had enough machines and manpower to operate Ekodukt problem it didn’t cause any delay to start. As this was a special case demolition company didn’t have to go through procedure because the bridge was free from hazardous material. The demolition contractor also added that sortability of demolished waste was good.

The Ekodukt bridge composed of material such as concrete, some wood used for supporting and metal waste fraction. The maximum material fraction was crushed concrete which was around 3000 tons and was used for filling purpose on the demolition site.

During the demolition of Ekodukt bridge; 2 excavators, 1 worker for cutting and 2 workers were involved to sort the demolished waste into different material fractions such as wood and metal. The waste generated from the Ekodukt bridge was sorted into four different fractions such as waste for sorting, combustible waste, metal scrap reinforcement and wood.

By looking at the volume of the waste fraction, the demolition contractor called the trucks to pick up the waste containers from the site and further dispose at the recycling company. The waste containers were loaded and transported by trucks to different recycling facilities depending on the type and volume of the material fraction. The sorted waste was transported to three different recycling facilities they are RGS 90, Skrotfragg and Stena recycling for further processing.

Table 15. CDW generated in case 4

Fraction	Amount (Tons)	Receiver
Waste to sorting	31	RGS 90
Combustible waste	30	RGS 90
Scrap reinforcement	145	Stena recycling
Scrap reinforcement	45	Skrotfrag
Wood	54	Renova
Total (tons)	305	

The total amount of waste generated was 305 tons. Out of this, 31tons of waste was mixed or unsorted waste. 274 tons of waste was sorted into different fractions before being sent to the recycling companies. Out of all the fractions, concrete & bricks and metal scrap are the primary waste that will be used for either conventional recycling or landfill cover. Wood and combustible waste will be utilized for energy recovery through incineration. The rest of the fractions are hazardous wastes and will be disposed of safely, but not recycled.

As discussed in section 2.5, the average recovery of secondary waste in Sweden is 45.6%. Hence, 45.6% of the mixed or unsorted waste, i.e. 14.316tons of secondary waste would be recovered for conventional recycling or landfill cover. From Eq.1, stated in section 2.5, the recycling rate for this project is

$$= \frac{\begin{gathered}(Primary\ waste\ used\ for\ conventional\ recycling + Primary\ waste\ used\ for\ landfillcover\ \ backfill + \\ Secondary\ waste\ used\ for\ conventional\ recycling + Secondary\ waste\ used\ for\ landfillcover\ \ backfill)\end{gathered}}{Total\ CDW\ generated}$$

$$= \frac{(145+45)+14.316}{305}$$

= 70%

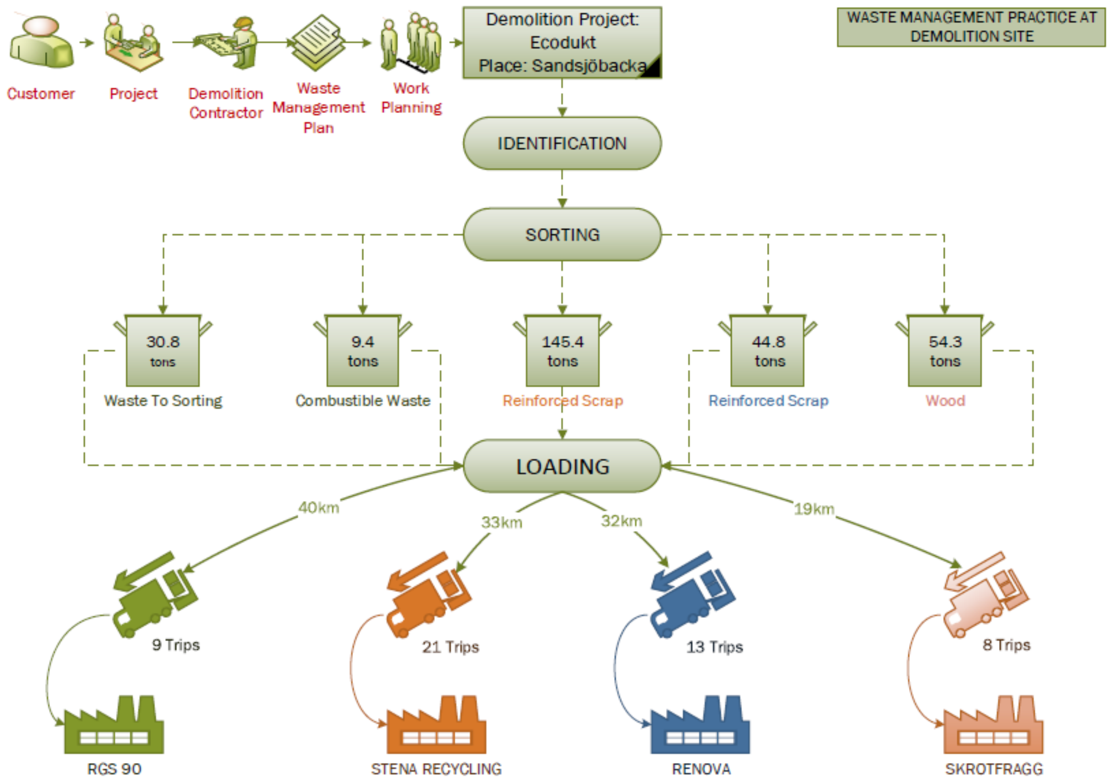

Figure 11. Process map of Case 4

4.1.5 Case 5: Mölndals Galleria (Good practice)

This case is an ongoing construction project called Mölndals Galleria, which is in a very close proximity to Mölndals central station. The Galleria Project was initiated in the beginning of august 2015 by NCC construction company and their customers are NCC property development AB. On the construction site, two recycling assistants are responsible for managing all documentations regarding waste management, recycling, waste handling activities and logistics operations both internally and externally. The construction building was certified under BREEAM. To get this certification, the building must earn points by reducing landfill, reusing the waste on the construction site and by reducing mixed waste fraction.

Table 16. Conditions for sorting of CDW for case 5, as stated by the site manager (1=fully disagree, 2=partially disagree, 3= partially agree, 4=agree 5=fully agree)

	1	2	3	4	5
Sufficient project time was available	○	○	○	●	○
Sufficient site space was available	○	○	●	○	○
Normal construction activities were not interfered with	○	○	●	○	○
The waste was sortable comparatively easily	○	○	●	○	○
Management during the project was good	○	○	○	●	○
Sufficient manpower for sorting was available	○	○	○	●	○
Sufficient equipment for sorting was available	○	○	○	●	○

The recycling assistant at the construction stated that,

"A lot of subcontractors are involved in this construction project and they keep on changing. Too many people to handle and it is hard to communicate with all of them because of the language and lack of time to guide them".

Since there are so many actors involved it was hard for the environmental site manager alone to reach all of them about onsite sorting procedures. Each floor of the construction site contains at least 5 -10 small bins to collect construction waste, but still many workers were not following the procedure perfectly. She mentioned that in order to tackle this problem, the recycling assistants were setting a plan to have weekly meeting with all the subcontractors to set some basic rules and regulation about degree of sorting.

In this case, most of the waste generated was sorted to the highest possible extent at the workplace itself. All the big containers were named with the type of material waste that it should contain. During the construction process; around 19 big containers, 200-250 small bins and 3 people working 8hours/day for collecting waste were involved. Most of the containers and small bins were owned by NCC recycling company and only a few bins were rented from other companies. The waste generated was sorted into different material fractions such as hazardous waste, electrical waste, wood, combustible, plastics for recycling, plaster, metal, corrugated, concrete, mineral wool, aggregate and mixed waste.

When the waste container volume reaches the threshold, the waste administrator makes a call to the truck driver and further waste containers are driven away to the NCC recycling site located in Utby for further processing.

Table 17. CDW generated in case 5

Fraction	Amount (Tons)	Receiver
Mineral wool	0.38	NCC Recycling
Hazardous waste	1.0096	NCC Recycling
Electrical waste	5.4935	NCC Recycling
Wood	81.78	NCC Recycling
Paper	3.22	NCC Recycling
Plastics recycling	1.89	NCC Recycling
Combustible	46.36	NCC Recycling
Plaster	8.36	NCC Recycling
Scrap & Metal	82.8	NCC Recycling
Mixed Waste for sorting	14.68	NCC Recycling
Landfill	0	NCC Recycling
Concrete	71	NCC Recycling
Aggregate	74,810.6	NCC Recycling
Glass	0	NCC Recycling
Corrugated	0.2	NCC Recycling
Total (tons)	75,127.8	

The total amount of waste generated was 75,127 tons. Out of this, 14.68tons of waste was mixed or unsorted waste. 75,113.12 tons of waste was sorted into different fractions before being sent to the recycling company. Out of all the fractions, concrete & bricks and metal scrap are the primary waste that will be used for either conventional recycling or landfill cover. Wood and combustible waste will be utilized for energy recovery through incineration. The rest of the fractions are hazardous wastes and will be disposed of safely, but not recycled.

As discussed in section 2.5, the average recovery of secondary waste in Sweden is 45.6%. Hence, 45.6% of the mixed or unsorted waste, i.e. 6.7tons of secondary waste would be recovered for conventional recycling or landfill cover. From Eq.1, stated in section 2.5, the recycling rate for this project is

$$= \frac{\begin{array}{c}(Primary\ waste\ used\ for\ conventional\ recycling + Primary\ waste\ used\ for\ landfillcover\ \ backfill + \\ Secondary\ waste\ used\ for\ conventional\ recycling + Secondary\ waste\ used\ for\ landfillcover\ \ backfill)\end{array}}{Total\ CDW\ generated}$$

$$= \frac{(74{,}881.6+82.8)+6.7}{75127.8}$$

$= 99.7\%$

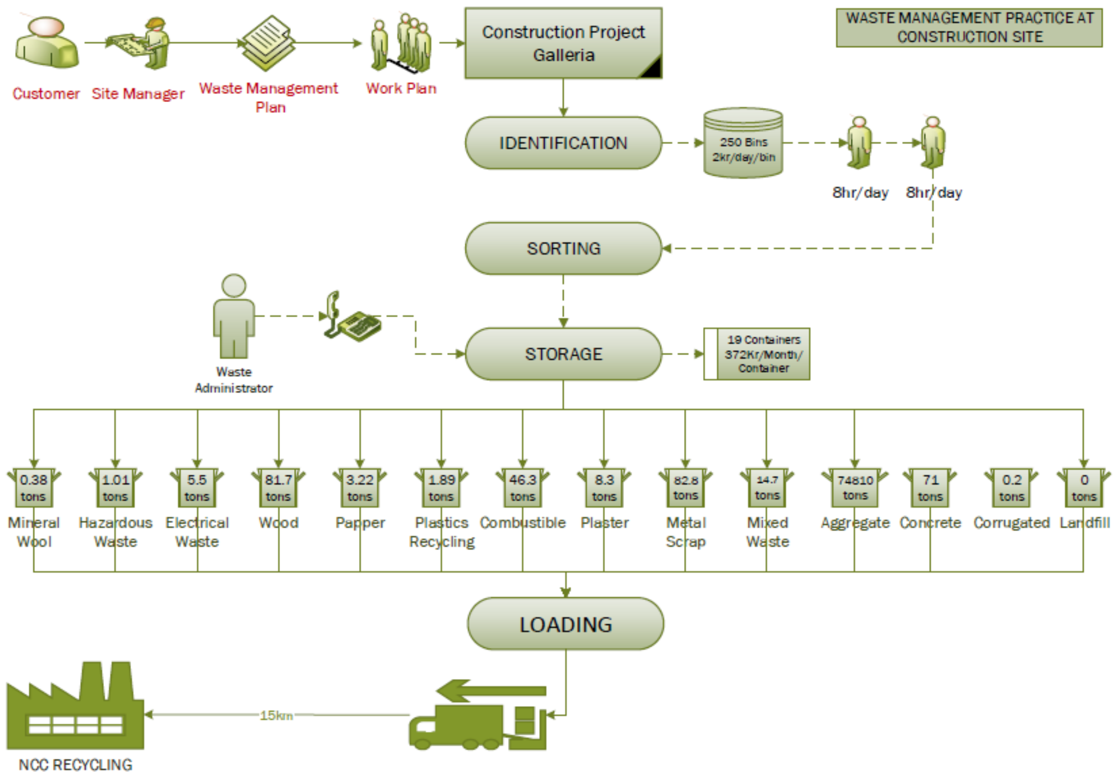

Figure 12. Process map of Case 5

4.2 Interviews

The interviews that were conducted gave an insight into the CDW management in Sweden. Some of the salient points of the interviews are discussed below.

Statistics expert from Swedish IVL: This interview helped to verify the method of calculating the recycling rate of CDW in Sweden. The reasons for using this method were also understood. There are around 8,000 construction and demolition companies in Sweden and less than a thousand recycling companies. Hence, the data regarding the wastes received is collected from the environmental reports of the recycling companies and not the waste generators i.e. the construction/demolition companies. Another important output from this interview was that different countries within the EU have different methods of calculating recycling rate of CDW. There is no standard method of calculating the recycling rate.

Plastic and concrete experts: The plastic expert claimed that presently, plastic is not sorted well. Some sorting does take place in construction sites, but during demolition, almost no plastic is sorted due to the difficulty in sorting. Some of the old plastic has to be incinerated since it is of poor grade. Most of the plastics can only be used for low quality products, so quality doesn't matter so much. Hence, there is no great benefit from sorting plastic into different grades. If all the plastic at the construction/demolition site is sorted into one fraction, it would serve the purpose. Concrete however should be sorted into different grades like pure concrete, concrete containing reinforced steel, impure concrete etc.

Recycling companies: The interviewees from the recycling companies claimed that sorting on-site will always lead to better recycling rates. They also claimed that cost calculation is the main factor that determines the degree of sorting on-site. Out of the three interviewees, one said that recyclers are not involved during the formation of the waste management plan before the start of a project, while the other two said that recycling companies are also involved in the formation of the waste management plan. One of the interviewees claimed that one of the major reasons for lower recycling rate is that end market is not well developed for the recycled materials. One of the interviewees felt that municipalities should have stricter rules and regulations, which could be a major factor to encourage recycling.

Construction/ Demolition contractors: Construction sites usually have a lot of subcontractors, meaning that there are always many people working on the site. They could speak different languages too and it becomes difficult to manage them. The environmental site manager claimed that the major barrier for sorting on construction sites is the lack of space, since big containers cannot be placed on every site.

The demolition contractor claimed that the future trend is to not sort the waste on-site, but on recycling company's site. The construction contractor however claimed that more on-sorting would be the future trend. However, both the construction contractor and the demolition contractor agreed that cost was the major factor that they considered while deciding the degree of sorting that would be carried out in any project. The cases required for the case studies were also received during these interviews.

4.3 Surveys

As described in chapter 4 (Method), three separate surveys were prepared for construction/demolition contractors, recycling companies and landfill facilities. In this section, the results of the surveys will be discussed.

The surveys were framed to gain an insight into three main areas - factors affecting the on-site sorting and collection of waste, the current method of forming a waste management plan and the logistics of waste flows. The interesting results received from the responses to the surveys are stated below.

4.3.1 Waste Management Plan

The interesting results regarding the waste management plan are:

1) 86% of the construction/demolition contractors make a waste management plan for every project. 14% do not make a waste management plan for all projects.
2) 31% of the construction/demolition contractors do not have a standardized format for making the waste management plan.
3) 70% construction/demolition contractors consult the recycling companies during the preparation of the waste management plan, but only around half consult the transportation/logistics companies.
4) 78% of the construction/demolition contractors do not contain the identification of the optimum transport route to the recycling company in the waste management plan and almost 64% do not contain Identification of optimum transport loads depending on the vehicle capacity. The EU guidelines (EU CDW Management Protocol, 2016) suggest that optimal transport routes to each destination company should be mapped in the start of the project and mentioned in the waste management plan.

4.3.2 Sorting

The interesting results regarding the waste sorting are:

1) 73% of the recycling companies said that waste coming sorted from the site would be better in terms of recycling capabilities, if that waste was sorted on-site at least according to the basic levels of sorting.
2) 97% of the construction/demolition contractors sort waste on site on at least some level very often. This level may or may not be the basic sorting level as recommended by the Resource and Waste Management Guidelines (2015).
3) The construction/demolition contractors were asked about what factors decided the degree of sorting for a certain project. The factor that received the highest amount of importance was cost. 82% of the respondents felt that cost was the most important factor when taking the decision of whether to sort and to what degree to sort. The next most important factor was site space, followed by environmental considerations. Site space is a factor that is not within the control of the construction/demolition contractor. It is also good to know that people are becoming increasingly aware of the environmental impact of their actions.
4) The construction/demolition contractors were asked to estimate the ratio of the different costs (cost of on-site sorting, cost of transportation, gate fee to dump the waste) in terms of the total waste management cost for them. 60% of the construction/demolition contractors feel that cost of on-site sorting is between 15-30% of the total cost. 60% of them feel that cost of waste transport to the destination is between 20-35% of the total cost. 55% of them feel that gate fee of dumping the waste is between 30-50% of the total cost.

4.3.3 Logistics of waste

The interesting results regarding the logistics of waste are:

1) 65% of the construction/demolition contractors said that transportation is arranged

by the recycling company. Most of the times, the transport rates are fixed per trip, irrespective of the weight and distances.

2) Almost all of the construction/demolition contractors said that waste is sent after some threshold quantity is collected on site.
3) 73% of the construction/demolition contractors report the waste generated to some authority. Mostly they are reported to the clients. The construction/demolition contractors get the information about the quantity of waste from the waste receivers who weigh the amount of waste that they receive.
4) The standard prices of the gate fees for dumping different waste fractions were received from some of the respondents including the recycling companies and landfill facilities.

5 Results

In this chapter, an economic analysis is performed on the cases. For the first case, detailed calculations are shown and for the other four cases, summarized results are shown. In the next part of the chapter, the research questions are answered.

5.1 Economic analysis

It can be seen from the results of the surveys that one of the major factors that affect the decision regarding the degree of on-site sorting of CDW is economic feasibility (i.e. sum of transport costs, sorting costs and gate fees).

In this section, the cost for the waste generator will be calculated, for each of the cases. Eq.2 will be used to calculate this cost. The aim is to find the difference in the cost for the waste generator, when waste is sorted compared to when waste is not sorted.

Assumptions: For the on-site sorting cost, the worker wage is assumed as 180SEK/hour, which was the figure provided by a construction contractor and confirmed by the demolition contractor. For the transportation cost, the truck driver wage is also assumed as 180SEK/hour. The truck fuel efficiency is assumed as 4 km/litre. Fuel price is assumed as 12 kr/litre. For the receiver gate fee, table 1 was referred.

5.1.1 Case 1: Volvo PVD Torslanda

On-site sorting cost = Number of man hours required for sorting x wages/hour

The duration for demolishing the Volvo pvd building was around 2 weeks. 2 extra workers, working for 8 hours a day were required for sorting the waste.

On-site sorting cost = (Number of extra workers x Number of man hours x Wages/hour x total Duration of the project) = (4 x 8 x180 x 14) = 62,720SEK

Transportation cost = Driver cost + Fuel cost

The distance from the demolition site to recycling facility was calculated using Google Maps. In this demolition project waste was sent to four different recycling facilities - RGS 90, Samgräv/Fläxhult, Caverion, Sortera, Stena Recycling and Renova.

Transportation cost = (No. of hours for transport x driver wages/hour) + (Distance from construction/demolition site to receiver x 2 (To and fro) x Fuel price/litre / Truck fuel efficiency)

Calculation example of the mixed waste fraction transported to RGS 90 Recycling facility from the demolition site = (1 x 180) + (11 x 2 x 12/4) = 206SEK/Truck load.
Transportation cost of mixed waste fraction = (Number of loads mixed waste fraction x

Transportation cost per load) = 183 x 206 = 37,698SEK. The transportation cost of all different material fractions transported to different recycling facilities in total is = 56,108SEK.

Now let us consider a scenario where the waste was not sorted i.e. the entire waste generated was sent to the receiver as mixed waste. In this case, the entire waste would be sent to RGS 90. The transportation cost of sending all the mixed waste to RGS would be 49,234SEK. Which means that (56,108 – 49,234) =6,874SEK extra is required when on-site sorting is done. This means that the transport cost increases when on-site sorting is done, since more transportation is required. However, from the data regarding transportation activities, it was observed that maximum utilization of trucks was not achieved during transporting waste to the recycling companies. Some truck loads would contain 8 tons of waste, while some would contain only 3 tons of waste. This meant that the full capacity of the trucks was not utilized. Further investigating this factor an optimum transportation cost was calculated. If all the truck loads were utilized to their maximum capacity for transporting the waste, the result would be a decrease in the number of loads to the recycling facility, from 239 to 115 loads in total.

The example shown below is mixed waste fraction:

Optimum number of truck loads for mixed waste= (Waste generated by material fraction in tons / Truck capacity in tons) = (875.7 / 12.35) = 71 Loads

The actual number of truck loads used to transport mixed waste was 183 and optimum number of truckloads required was 71 loads. Further investigation was carried to find out optimum transportation cost and to compare actual transportation cost with optimum transportation cost.

Optimum transportation cost = (Optimum number of truck loads for mixed waste x Transportation cost per load) = (71 x 206) = 14,626SEK

The optimum transportation cost of all the material fraction was = 30,267SEK. The difference between actual and optimum transportation cost was 25,841SEK. During the demolition process, the contractor could have planned transportation accordingly, so that each and every truck leaving to recycling facility should be utilized to full capacity. In that case, the demolition company would have saved 25,841SEK within the transportation itself. Hence, the money saved by utilizing the full transportation capacity could be used to employ one extra worker for sorting of waste. This extra worker could be used for sorting the mixed waste fraction on the demolition site itself. This would have promoted better recycling rates of demolition waste. In fact, the demolition company would save some money since the receiver gate fee for individual material fraction would be reduced.

Receiver Gate Fee:

Total Receiver gate fee = weight of waste fraction in tons x gate fee/ton for that fraction
In this case, Receiver gate fee is 1,278,185SEK.

If no on-site sorting would take place, the entire gate fee would have to be for mixed waste.
In this case, the gate fee would be 1,665,767SEK.

The table below gives a comparison of the different scenarios.

Table 18. Cost comparison of sorting vs not sorting for case 1

Type of Cost	Without sorting	Present scenario (with sorting)
On-site sorting cost (SEK)	0	80,640
Transportation cost (SEK)	49,234	66,828
Receiver gate fee (SEK)	1,665,767	1,278,185
Total cost (SEK)	1,715,001	1,425,653

The percentage savings in the cost to the waste generator is given by:

$$\%\ savings = \frac{Total\ cost\ without\ sorting - Total\ Cost\ with\ sorting\ (present\ scenario)}{Total\ cost\ without\ sorting}$$

$$= \frac{1{,}715{,}001 - 1{,}425{,}653}{1{,}715{,}001}$$

$$= 16.87\ \%$$

Hence, it can be seen that by sorting 59.9% of the waste, the demolition contractor made a cost saving of 16.87 %, compared to the situation where there would be no sorting.

5.1.2 Case 2: Rosendal school:

The duration for demolishing the school was around 3 months. 2 extra workers, working for 8 hours a day were required for sorting the waste. In this demolition project waste was sent to four different recycling facilities - RGS 90, Samgräv/Fläxhult, Stena Recycling and Renova. The table below summarizes the cost comparison between the present scenario (with on-site sorting) and the scenario where no sorting is done. (See appendix 4 for calculations)

Table 19. Cost comparison of sorting vs not sorting for case 2

Type of Cost	Without sorting	Present scenario (with sorting)
On-site sorting cost (SEK)	0	259,200
Transportation cost (SEK)	39,412	49,955
Receiver gate fee (SEK)	3,969,732	1,444,255
Total cost (SEK)	4,009,144	1,753,410

Hence, it can be seen that by sorting 91.7% of the waste, the demolition contractor made a cost saving of 56.26 %, compared to the situation where there would be no sorting.

If all the truck loads were utilized to their maximum capacity for transporting the waste, the result would be a decrease in the number of loads to the recycling facility, from 167 to 106 loads in total.
The optimum transportation cost of all the material fraction, if all the trucks were utilized to their maximum capacity, was = 27,366SEK. The difference between actual and optimum transportation cost was 15,910SEK. During demolition process, the contractor could have planned transportation accordingly, so that each and every truck leaving to recycling facility would be utilized to full capacity. In that case demolition company, would have saved 15,910SEK within the transportation itself.

5.1.3 Case 3: Volvo Penta

The duration for demolishing the Volvo Penta building was around 293 days. 7 extra workers, working for 8 hours a day were required for sorting waste. In this demolition project waste was sent to four different recycling facilities such as Samgräv AB, RGS 90, Stena Recycling and Renova. The table below summarizes the cost comparison between the present scenario (with on-site sorting) and the scenario where no sorting is done. (See appendix 4 for calculations)

Table 20. Cost comparison of sorting vs not sorting for case 3

Type of Cost	Without sorting	Present scenario (with sorting)
On-site sorting cost (SEK)	0	2,953,440
Transportation cost (SEK)	170,663	246,078
Receiver gate fee (SEK)	10,607,428	3,351,968
Total cost (SEK)	10,778,091	6,551,486

Hence, it can be seen that by sorting 90.22 % of the waste, the demolition contractor made a cost saving of 39.2 %, compared to the situation where there would be no sorting.

If all the truck loads were utilized to their maximum capacity for transporting the waste, the result would be a decrease in the number of loads to the recycling facility, from 531 to 429 loads in total. The optimum transportation cost of all the material fraction, if all the trucks were utilized to their maximum capacity, was = 171,798SEK. The difference between actual and optimum transportation cost was 31,800SEK. During demolition process contractor, could have planned transportation accordingly, so that each and every truck leaving to recycling facility would be utilized to full capacity. In that case demolition company, would have saved 31,800SEK within the transportation itself.

5.1.4 Case 4: Ekodukt

The duration for demolishing the Ekodukt at Sandsjöbacka was around 30 days. 2 extra workers, working for 8 hours a day were required for sorting waste. In this demolition project waste was sent to four different recycling facilities such as Skrotfragg, RGS 90, Stena Recycling and Renova. The table below summarizes the cost comparison between the present scenario (with on-site sorting) and the scenario where no sorting is done. (See appendix 4 for calculations)

Table 21. Cost comparison of sorting vs not sorting for case 4

Type of Cost	Without sorting	Present scenario (with sorting)
On-site sorting cost (SEK)	0	86,400
Transportation cost (SEK)	20,094	28,086
Receiver gate fee (SEK)	396,890	137,780
Total cost (SEK)	416,984	252,266

Hence, it can be seen that by sorting 91.7 % of the waste, the demolition contractor made a cost saving of 39.5 %, compared to the situation where there would be no sorting.

If all the truck loads were utilized to their maximum capacity for transporting the waste, the result would be a decrease in the number of loads to the recycling facility, from 51 to 41 loads in total. The optimum transportation cost of all the material fraction, if all the trucks were utilized to their maximum capacity, was = 19,544SEK. The difference between actual and optimum transportation cost was 4,462SEK.

5.1.5 Case 5: Construction Project Galleria

The Mölndals galleria was an ongoing project which is expected to be completed in 2018. The total cost calculation is performed by considering data from 2015 week 32 to 2016 week 47. In this project 3 extra workers, working for 8 hours a day were required for sorting the construction waste. In this construction project waste was sent to only NCC recycling facility. The table below summarizes the cost comparison between the present scenario (with on-site sorting) and the scenario where no sorting is done. (See appendix 4 for calculations)

Table 22. Cost comparison of sorting vs not sorting for case 5

Type of Cost	Without sorting	Present scenario (with sorting)
On-site sorting cost (SEK)	0	1,736,640
Transportation cost (SEK)	29,344	34,584
Receiver gate fee (SEK)	97,666,105	18,760,038
Total cost (SEK)	97,695,449	20,531,262

Hence, it can be seen that by sorting 99.7 % of the waste, the construction contractor made a cost saving of 78.98 %, compared to the situation where there would be no sorting.

5.1.6 Results from economic analysis

1) The cost calculations from the above cases confirm the findings from literature that the cost for the waste generator is lower when the material is sorted, compared to when the material is not sorted.
2) The calculations also show that the trucks used for transport of waste are not utilized optimally, since many a times, the transportation capacity is underutilized.
3) The comparison of the different cases according to their sorting rate and percentage savings achieved (compared to a situation with no-sorting) is shown in table.23 and Fig.13.

Table 23. List of the cases according to their sorting rate and percentage savings achieved

Case no.	% Sorting	% Savings
Case 1	59.9	16.87
Case 4	70.0	39.50
Case 3	90.2	39.20
Case 2	91.7	56.26
Case 5	99.7	78.98

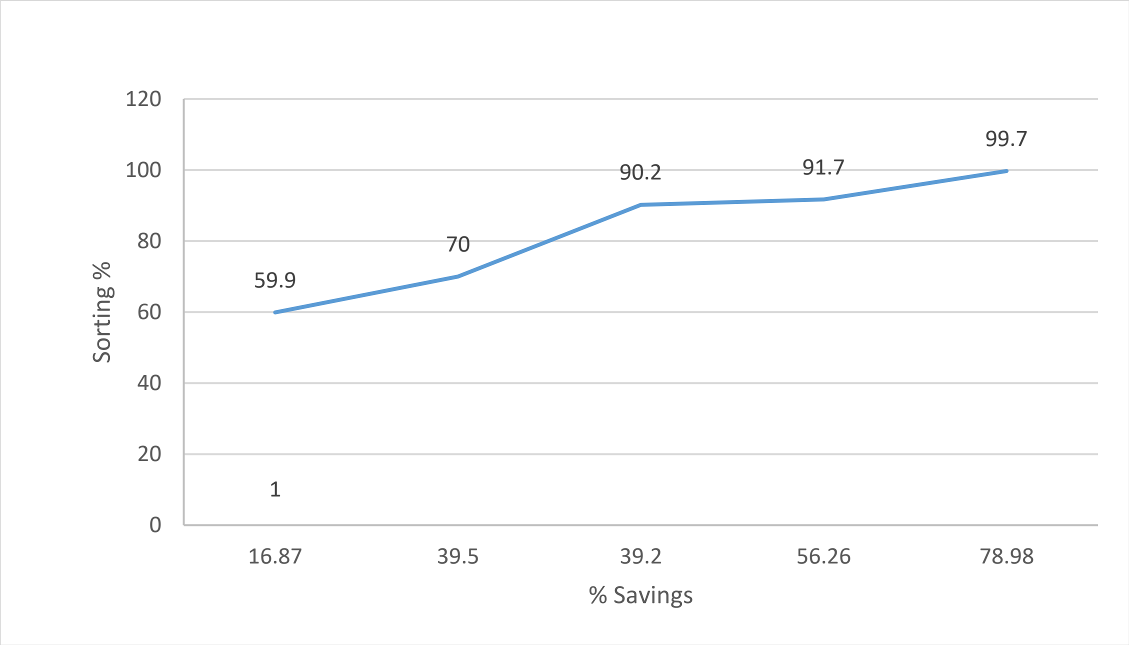

Figure 13. Comparison of the cases according to their sorting rate and percentage savings achieved

This figure shows that there is a certain trend observed between the sorting rate and percentage cost savings i.e. as the sorting rate increases, the percentage cost savings also increases. However, it should be noted that this result corresponds to the cases that were studied, but may not be a general rule for all kinds of cases.

5.2 Results for RQ1

What are the current practices of waste identification, sorting, collection and logistics used by in the construction and demolition companies for the management of CDW?

5.2.1 Identification

Fig 14. shows the CDW flow and management currently practiced in Sweden, based on the cases studied and the interviews conducted. In Sweden, for any project to start, a permit must be issued by the municipality. The municipality has two codes which need to be followed – the planning code and the environmental code, in order to issue the planning permit and environmental permit respectively. Following this, the permit to start a project can be issued. The general procedure is as follows.

The customer usually hires a consultant to get the permit from the municipality. The consultant prepares a pre-demolition audit, which contains a list of all the hazardous materials, along with their volumes and locations on the site. The consultant then applies to a department of the municipality, called Stadsbyggnadskontoret (SBK), for getting planning clearance. SBK checks if all information is given according to the planning code. They check for things like location of the project, historical importance off the structure, any cultural values attached to the building etc. If such things are within the acceptance limits, then SBK gives planning clearance. SBK also checks whether there are hazardous substances involved in the project. If no hazardous substances are involved, then SBK gives the permit to start the project. If hazardous substances are involved, then they forward the application to the environmental department of the municipality called Miljöförvaltningen. An environmental inspector at the Miljöinspektör checks the pre-demolition audit, whether inventory of hazardous waste has been in an appropriate manner i.e. along with quantities, locations and if possible, photographs of the potential hazardous waste. If everything is in accordance with the environmental code, Miljöförvaltningen give the environmental clearance. The application is then sent back to SBK and SBK gives the permit to start the project.

The construction/demolition contractor simultaneously prepares the waste management plan. The plan only includes an estimation of the types of wastes that will be generated, the quantity of waste and where it will be sent. However, a waste management is not required by legislation. But, it could be demanded by the customer or it could be required for some certification. Currently, the main purpose of the waste management plan only seems to be the identification of potential wastes and only for the use of the construction/demolition contractor. Moreover, most of the construction/demolition companies do not have a standardized format for the waste management plan.

5.2.2 Sorting and collection

The methods chosen to demolish can vary from selective demolition to total demolition. The decisions regarding the degree of sorting are mainly taken based on the customer requirements and the most cost effective option i.e. the option where the sum of on-site sorting cost, transportation cost and gate fees is the least. In the demolition cases studied, the bins and containers were not marked differently for different waste fractions, generally because of the shorter project duration compared to a construction project. The contractor claimed that the people working on site knew where to put the different material and that no additional markings or cognitive help was required. On the other hand, in the construction case, the site manager said that communication is generally a problem due to the large number of people working there. She had developed signs and marking to provide visual aid to the workers, to avoid any mistakes in the waste sorting and collection. This has led to very good sorting and collection on the construction site.

It is also worth noting that all the cases studied, sorting has not been done according to the basic levels as recommended in the Resource and Waste Guidelines (2015). For example, plastics have been sorted out in only case 5. In spite of this, the recycling rates calculated for all the cases are generally high i.e. all except one have above 70% recycling rate. This shows a drawback of the present method of calculation of the recycling rate in Sweden i.e. the calculation is done based on quantity (weight) of the CDW, but does not differentiate between the different types of waste fractions.

5.2.3 Logistics

The EU CDW Management Protocol (2016) suggest that optimal transport routes to each destination company should be mapped at the start of the project and mentioned in the waste management plan. Most of the waste management plans do not contain the identification of the optimum transport route to the recycling company or identification of optimum transport loads depending on the vehicle capacity. Only around half of the construction/demolition contractors that were surveyed consult the transportation/logistics companies during the preparation of the waste management plan. This is because transportation of waste is usually the responsibility of the waste receiver. Since the legislation does not require a waste management plan to be made, the construction/demolition contractor only includes the information that is required by him/her, unless stated otherwise by the customer. Most of the times, the transport rates are fixed per trip, irrespective of the weight and distances.

In addition, as stated by one of the recycling companies, the responsibility of reporting the waste statistics falls on the recyclers currently and not on the waste generators i.e. the construction/demolition contractors. The construction/demolition contractors only report to the customers, if the customers demand it. The waste generators must also have the responsibility of reporting the waste statistics to the authorities since this will make them more aware of their waste generation and make them more accountable and responsible.

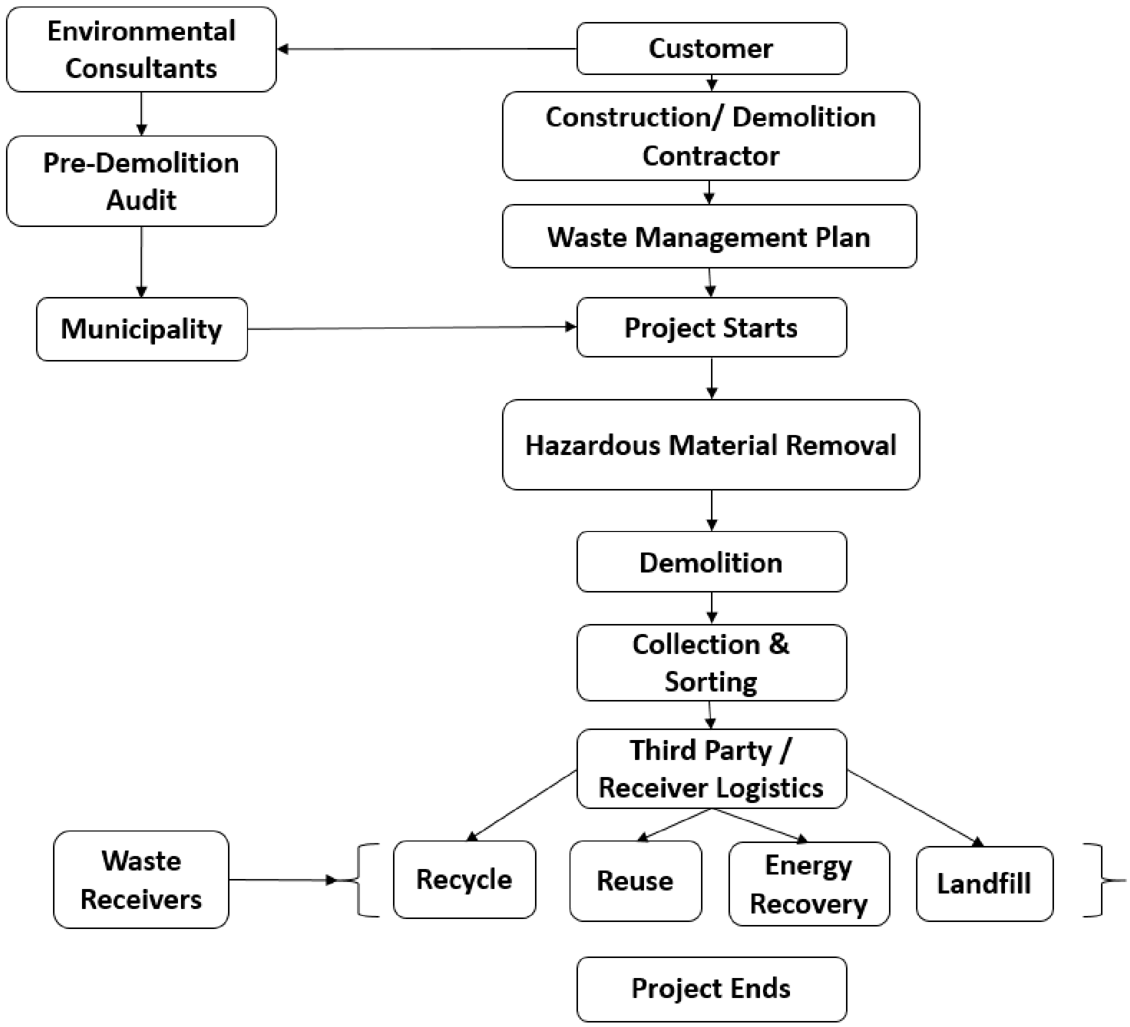

Figure 14. Current state of operations

5.3 Results for RQ2

What are the main factors that affect the waste identification, sorting, collection and logistics of CDW?

Identification

The best practices followed in Netherland, Belgium, Luxemburg and Denmark revealed that a preparing and following a good waste management plan can aid significantly in the identification of wastes that will be generated. Some of the interviewees said that identification of waste can however become tricky in demolition projects, when old buildings are involved. Especially for materials like plastics, where there are many different grades available, it becomes difficult to identify them. However, the interviews with the material experts and recycling companies revealed that even sorting according to just the basic levels of sorting would be a very good practice. Taking an example of plastics, this means that even if all the plastic is sorted and collected as one fraction, good recycling rates could be obtained. The on-site sorting need not be done in very detailed levels, distinguishing between the different grades of plastic.

Sorting and collection

As mentioned before, in the demolition cases studied, the bins and containers were not marked differently for different waste fractions generally. The reasons for this were cited by the contractor as shorter project duration compared to a construction project and knowledge of the on-site workers about where to put different material. However, as seen in one of the cases, some demolition projects can also last for several months. In such cases, the bins and containers should be labelled and marked for different waste fractions, since not doing so could lead to mistakes and mixing of different waste fractions. This is also in accordance with the recommendations made in the EU Construction & Demolition Waste Management Protocol, to improve waste collection and logistics.

The environmental manager at NCC mentioned that there were generally 200 people working on the site at any given time. They are employed by different sub-contractors present on the construction site. These people speak different languages, and not all of them understand Swedish. In these cases, it becomes difficult to instruct and inform all the people about the waste identification and sorting procedures.

The survey results showed that cost to the waste generator (i.e. the sum of on-site sorting cost, transportation cost and gate fees) was the main factor that decided the degree of sorting for a certain project. This was affirmed with the interviews that were conducted with the construction/demolition contractors. The economic calculations on the cases studied also showed that as the percentage of on-site sorting is increases, the cost to the waste generator is found to decrease. The next most important factor is the site space, according to the surveys. Again, this result corroborated with the answers to the interviews. When there is not enough space available on the site, then big containers for storing the sorted waste cannot be kept on the site. The third most important factor is the environmental factor, according to the surveys. It is good to observe that most of the construction/demolition and recycling companies within Sweden are aware of their environmental responsibility.

Logistics

The EU Construction & Demolition Waste Management Protocol suggests that recycling facilities should be chosen to minimize the distance travelled by the CDW. The road networks should be utilized in the optimum manner so that transport distances are minimized. Traceability of the waste should also be ensured by maintaining records of dispatch and receipt of CDW. As mentioned before, the general practice is for the construction/demolition contractor to call the transportation when a threshold quantity of waste is generated and collected. Most of the times, the transport rates are fixed per trip, irrespective of the weight and distances.

To summarize, the following are the main factors that affect the identification, sorting, collection and logistics of CDW:

1) Waste management plan
2) Communication with people working on the construction/demolition site
3) Cost of waste management for the waste generator
4) Optimum transport networks and capacity utilization
5) Site space

6 Discussion

The first part of this chapter contains a discussion of the problems observed from the results obtained in the previous chapter. In the second part of this chapter, suggestions are provided which could help to increase the recycling rates in Sweden, which is the purpose of the project.

6.1 Discussion of the results

- **Problems observed: Municipality does not refer to waste management plan**
  At the start of a demolition project, a pre-demolition audit is generally conducted by a third-party consultant, which contains a list of the hazardous wastes, their location and volumes. The municipality refers only to the pre-demolition audit when a permit is to be given for a demolition project to start. Since the pre-demolition audit consists of information only about the hazardous waste, there is no communication to the municipality about the handling of the non-hazardous wastes and how they will be treated.

  Potential for improvement: The municipality could also demand and approve of the waste management plan before the permission for starting the construction/demolition project is given. This would ensure that proper measures are planned for handling all the wastes that would be generated during the project, not only the hazardous waste.

- **Problems observed: All the stakeholders are not always involved during the creation of waste management plan**
  The construction/demolition contractor constructs a waste management plan, which contains a list of the different waste fractions, hazardous and non-hazardous, their volumes and where they will be sent to. Sometimes the other stakeholders like waste receivers and logistics companies are consulted while creating the waste management plan and on some occasions, no other stakeholder is consulted.

  Potential for improvement: The construction/demolition contractors could involve the waste receivers and the logistics while preparing the waste management plan.

- **Problems observed: Waste management plan is not used throughout the project**
  After the project starts, the waste management plan is no longer used, except for keeping records of where the waste has been sent by the construction/demolition contractor. This shows that the waste management plan, which is potentially a very useful document to manage and track the whole project, is not used optimally.

Potential for improvement: The waste management plan could be used throughout the chain, from the start of the project, till the end of the project. As the practices followed in Netherlands showed, plans used during the start of the project, during the execution of the project and during final reporting, can help in increasing the recycling rates of CDW.

- **Problem observed: Lack of standardization of waste management plan**
  Currently in Sweden, the waste management plan is mostly being used as a document for identification of the hazardous wastes. In Sweden, most construction/demolition companies create a waste management plan before the start of the project. However, many of these companies do not have a standardized format that they can follow. This lack of a standardized format can cause many problems. For example, increasing the duplication of work for each project, lack of accountability for waste management, lack of any improvement etc. Standardization is vital to ensure that correct practices are followed repeatedly. Standardization is also needed to make any sort of improvements in the system (Liker and Meier, 2013). Lack of standardization results in ad hoc practices being followed. Another problem includes not following the Resource and Waste Guidelines suggested by the Swedish Construction federation.

  Potential for improvement: A standardized format of the waste management plan could be created and followed for all projects.

- **Problem observed: The format of waste management plan as suggested by the Swedish Construction Federation is not extensive enough**
  The current format as suggested by the Resource and waste guidelines during construction and demolition (2015) (see appendix 1) starts with a description of the status of the project and some administrative information. This is followed by identifcation of the hazardous waste, the way it will be handled, the quantity, the transporter, receiver along with verifications. Details about decontamination, storage and risks are also specified here. This is followed by identifcation of all the other non-hazarous wastes, the way it will be handled, the quantity, the transporter, receiver along with verifications. However, here there is no mention about the optimum transport routes, the type or capacity of trucks that would be used and the optimum transport loads based on the capacity. There is no information about the types of containers that will be used for storage and collection. There is no information about the equipment that will be required for performing the sorting. There is also no information about the type of demolition procedure to be adopted.

  Potential for improvement: The waste management plan could be improved to make it a more comprehensive document for planning the project. The improved waste management plan can be then used as a standardized document.

- **Problem observed: Transportation capacity is not being utilized in an optimum manner:** As observed in case studies, the trucks were not being utilized in the most efficient manner. Many of the truckloads were not utilized to full capacity. This will eventually lead to increase in costs (discussed in section 5.4), which as seen above, is the most important factor when deciding the degree of sorting of CDW. 14% of the construction/demolition companies do not make a waste management plan for all projects. This is a concern, because without a waste management plan, there is no possibility to check how the CDW has been handled. This leads to lack of accountability and could also lead to improper waste handling practices. This also can cause a lack of traceability of the CDW material, which could decrease the trust in the CDW management process.

  Potential for improvement: The overall cost of the project must be minimized. Although transportation cost is not the most significant of all the costs (the other two costs being on-site sorting cost and receiver gate fee), there is potential for improvement in planning the transportation activities, so that the transportation capacities are utilized optimally. Planning the different aspects during the phase of preparation of the waste management will result in better logistics. It will also make cost calculations easier. More information could also be added like for example, the type of storage bins or containers to be used for the particular waste fraction.

- **Problem observed: On-site communication between the personnel needs improvement**
  Communication to the workers on-site regarding identification, sorting and collection instructions, is a challenge on larger construction/demolition sites. Project durations can vary from a few weeks to several years. As observed in case 5, there can even be more than 200 workers working simultaneously on a construction site. These workers come from different backgrounds, speak different languages and have different skills. There is a need to train, instruct and communicate with these workers regularly to ensure good on-site sorting practices.

  Potential for improvement: There can be some extra provisions for such large projects which could help in the communication, like waste administrators as used in case 5.

Based on the above identified potentials for improvement, three suggestions for improvement have been formulated. As mentioned before, the suggestions provided are related to improving the waste identification, sorting, collection and transportation. These suggestions are just few of the possible improvements that could be made, based on the observations made during this thesis, using the surveys, interviews and case studies. They are not an exhaustive list of all the possible methods of improvements.

6.2 Suggestions for improvement

Based on the discussion in section 6.1, the following are the suggestions for improvement:

1) Using the waste management plan throughout the chain
2) Improving the waste management plan
3) Using additional waste administrator on-site

6.2.1 Using the waste management plan throughout the chain

There are many benefits that could be obtained by using the waste management plan throughout the chain of operations. The waste management plan could be used as a simple document that could be used throughout the construction/demolition project. The advantages of using the waste management plan throughout the chain are:

1) ***Easy to give Permit***

   The city municipality currently gives the permit based on the pre-demolition audit conducted by either the demolition contractor or the environmental consultants. A discussion with the environmental department of the municipality revealed that giving these permits could sometimes become a risk. If, however, the waste management plan is also made obligatory to be submitted, before the start of a project, the municipality can have more of an assurance that the appropriate plans to treat the CDW that will be generated have been made.

2) ***Easy to follow the operations according to the waste management plan***

   As mentioned before, currently, the waste management plan is only referred to at the start of the project. However, there is potential to use this document throughout the entire process of waste identification, sorting, collection and logistics, in a more horizontal manner.

3) ***Easy to track the flow of waste materials to the different receivers***

   The waste management plan has provisions for the waste receivers to confirm the acceptance of each batch of waste that they receive. This would improve the traceability of the CDW materials and increase the trust in the CDW management process.

4) ***Easy to provide a final report to the customer/municipality***

   Since the waste management plan would contain the initial plan of how the waste was to be handled and also how the waste was actually handled during the entire project, it would become very easy to check whether the guidelines had been followed. It would become easy to give appropriate ratings to the project, in case of any certification to be awarded.

Fig.15 shows the proposed future state of operations. The customer would give the contract to the construction/demolition contractor and separately to an environmental consultant, who would perform the pre-demolition audit for potential hazardous waste. After this, the construction/demolition contractor would create the waste management plan, in consultation with the recycling companies and the third party logistic companies while also referring to the pre-demolition audit. The municipality would have to approve both, the pre-demolition audit as well as the waste management plan to give the permission to start the project. This means that most activities would be planned and approved before even the start of the project. Next, the project would begin, hazardous waste would be removed, demolition would start, waste would be generated, which would be sorted, collected and then transported to the different waste receivers. However, in each of these steps of hazardous waste removal, demolition, waste sorting, collection and logistics, the waste management plan would be referred to and followed. The receipt of the waste would be confirmed by the waste receivers, along with information about what they plan to do with the waste. The responsibility of the maintenance of the waste management plan should be with the waste generator i.e. the construction/demolition contractor. At the end of the project, the waste management plan would be sent as a final report for the customer to check how the waste has been handled throughout the project.

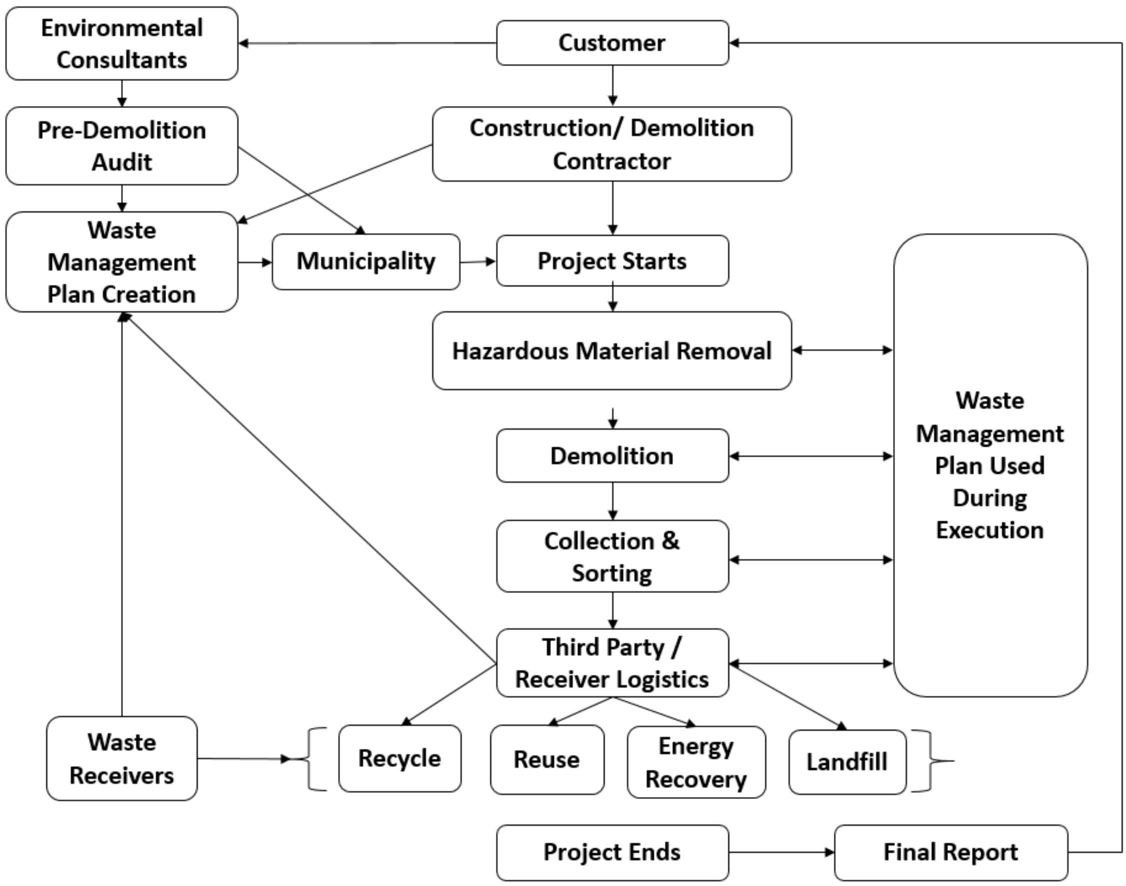

Figure 15. Proposed future state of operations

6.2.2 Improving the waste management plan

Following are some suggestions for additions to the EU waste management plan guideline:

1) A brief description about the type of demolition procedure to be adopted. Such a brief description would inform the customer, municipality and all the other stakeholders to be aware of the plan of operations.
2) Information about the optimum transport routes to the waste receiver.
3) Information about the optimal transport loads based on the type of waste and the type of vehicle used for transportation. As seen from the cases, the transport capacity is not optimally utilized. If the optimal transport loads are calculated and mentioned on the waste management plan, it would become easier to avoid underloading of the trucks.
4) Information about the equipment and if possible, the number of workers required for sorting. As seen from the cases, sometimes problems regarding manpower and equipment can occur due to improper planning. If it is possible to estimate the manpower and equipment required beforehand, they could be mentioned in the waste management plan to avoid any such shortages.
5) Information about the type of storage bins or containers to be used for each waste fraction.
6) Information about the re-use of any waste that is done on-site itself. In case 3, some of the demolished concrete was used on-site itself, as a filling material. This is a good example of waste re-use, which unfortunately does not get reported anywhere. Such things could be mentioned in the waste management plan.

6.2.3 Additional waste administrator on-site

The NCC case was one of the best practice cases, achieving very good sorting and hence a very good recycling rate. One of the main reasons for the success of this case was the use of two waste administrators on site. Their sole job was to co-ordinate effective identification, sorting, collection and logistics of waste that was generated. The waste administrator also has the responsibility of communicating the sorting and collection instructions with all the workers on the site. This particular project was on a comparatively larger scale than the other projects. In smaller projects, having one waste administrators might also be sufficient. However, employing one or more waste administrators would also add to the cost of the project, which should be taken into account. Along with NCC recycling, other recycling companies such as Ragn Sells also provide such services, where one or more consultant from the company will assist and drive the efficient management of CDW.

6.3 Limitations of the study and recommendations for future studies

In this section, the limitations of the thesis are listed down and future studies are proposed which could overcome these limitations.

1) The sample surveyed was less than 10% of the total population. This means that

there is a possibility that the opinions of the entire population are not reflected in the results of the surveys. A more extensive survey study could be conducted in the future to provide a more accurate picture, representing the entire population.

2) The cases selected were all from the Gothenburg area. The results could be very different for construction/demolition projects in other areas, like rural areas. Differences could include the number of recycling companies in the vicinity, good transportation infrastructure of the area, market for recycled materials in the area, manpower availability in the area, among many others. Additionally, the 5 cases were obtained from two companies. The operations of these companies may not truly reflect the current practices followed within Sweden. A far larger sample of cases, from different companies and in different regions of Sweden would be required, to truly gauge the current practices followed in Sweden.
3) Out of the five cases studied, four cases were already completed. Hence, direct observation of the practices on the site could not be made. Only the construction case was an on-going project which allowed for direct observation on the construction site. In the future, more on-going projects could be studied to understand the waste management practices by direct observation.
4) Case 1 (Volvo PVD Torslanda), which was considered to be the bad practice case had a recycling rate of 59.9%. This figure reflects the average CDW recycling rate in Sweden, so it is not truly a bad practice from the perspective of Sweden as a whole. However, this was a bad case from the perspective of RIVAB AB and hence this case was chosen. In the future, cases with much lower recycling rates could be studied to give a true impression of the bad practices followed.
5) If the true purpose is to improve the environmental aspects of CDW management, then preventing the waste should be the ideal target. If waste is generated, then re-use of the waste should be the main target. However, this thesis does not study these two important aspects of waste prevention and re-use. A future study could be conducted where waste prevention and re-use are also studied in detail.
6) While calculating the costs for the waste generator, the gate fees for disposing the waste at the recycling facilities were obtained from Table 1. Table 1 was constructed using standard rates of gate fees, from different sources. But the interviews revealed that these gate fees were negotiable at times, depending on the quantity of the waste and relations with the construction/demolition contractor. In the future, the terms of these negotiations could also be studied, so that the costs for the waste generator can be minimized even more, which will encourage better sorting and ultimately, better recycling.
7) While calculating the costs to the waste generator, the cost of bins and containers was not considered. This is because in all the cases that were studied during this thesis, the construction and demolition contractors owned the containers and bins that were used by them. However, in other cases, companies rent out the containers and bins, which would add costs to the waste generators. There could be a difference in the container costs for on-site sorting and no on-site sorting conditions. Hence, it could be beneficial to study cases in the future, where the containers are rented by the construction/demolition contractors.

7 Conclusion

This chapter summarizes the results of the thesis and the important results are highlighted.

The problem of CDW recycling and the EU target of 70% recycling rate was first explained. The actual method of calculating the recycling rate of CDW in Sweden was found out and described in the form of a mathematical formula. It was found out that the main factors affecting the on-site sorting are – cost to the waste generator, site space available and environmental considerations. It was proved from the cases that the cost for the waste generator is generally lesser when on-site sorting is done, compared to when no on-site sorting is done. Hence, the purpose of the thesis was relevant and could drive better recycling rates. It was observed that the transportation capacities were not utilized optimally in the cases studies.

The following suggestions were provided for improvement of CDW management in Sweden:

1) Using the waste management plan throughout the chain
2) Improving the waste management plan
3) Using additional waste administrator on-site

It was found that the waste management plan was not used according to the guidelines suggested by the Swedish Construction federation. These guidelines provide a good standardized format for the waste management plan, which if used well throughout the CDW flow and management, would make it easy to give permit, easy to follow the operations according to the waste management plan, easy to track the flow of waste materials to the different receivers and easy to provide a final report to the customer. Improvements were also suggested in the waste management plan, with provisions for additional information to be added into the waste management plan, which would make it a comprehensive document helpful to many stakeholders. It could help in better operations of CDW flow and management and help in optimizing processes, like transportation for example. It could also help in traceability of the waste received, which would result in better recycling and also increase the trustworthiness to make use of these recycled materials in new constructions. The third suggestion of using a waste administrator on-site, would help in solving the problem of communication, which usually occurs on construction and demolition sites. However, employing one or more waste administrators would also add to the cost of the project, which should be taken into account. This thesis fulfilled its purpose by providing some suggestions to contribute to the improvement of CDW management in Sweden.

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Appendix 1. Waste Management Plan

Instructions are reported in this manner. Can be deleted when the plan is filled in.

Status	Date	Revised date
☐ **Material inventory report**		
☐ **Appendix to inspection plan for demolition**		
☐ **Final waste management report**		

Information which should be submitted in the inspection plan for demolition is marked in this way with a light grey background.

Administrative information			
Property designation		Address	
Property developer		Address	
Project Supervisor's contact person		Address, telephone, mobile telephone, email	
Inspection manager		Address, telephone, mobile telephone, email	
Material inventory			
Material inventory carried out, date		See appendices	
Material inventory carried out by		Address, telephone, mobile telephone, email	
Planning permission/demolition permit, notification			
Permission sought, date	Permission granted, date	Notification, date	

Building and activities				
Construction type (e.g. apartment block, industry, offices)	Year of construction	Year of refurbishment	Floorspace	Number of storeys
Primary construction material (e.g. wood, concrete)	Foundation	Frame	Roof	See appendix
Current use/activities (may be several)	From year	Previous use/activities (may be several)		From year
Scope of demolition				
Describe the scope of the demolition, e.g. the entire building, part of the building (which part?), water and drainage, ventilation etc. or describe the scope of the rebuilding.				
Floorspace affected by the demolition.				
Ground				
Risk of ground contamination ☐ Oil tanks	☐ Oil separator	☐ Other:	☐ No risk of ground contamination	
Inventory of ground contamination ☐ Carried out, date	Appendix	☐ Will be done	☐ Will not be done	
Contract (Completed when contract has been ordered)				
Contractor	Site manager	Tel., email		
Address	Waste management manager	Tel., email		
Short description of the scope of the contract				
Contract work form	Start date	Completion date		

Hazardous waste
and other waste requiring special attention

Appendix 5 to the Resource and Waste Guidelines (Search list – Materials and products from demolition/exchange) can be used as an aid during inventory.
The handling of hazardous waste and other residual products is described in general in Appendix 1 to the Resource and Waste Guidelines (List of hazardous waste).
The table below provides information for the contract.

Completed after material inventory				Completed by the contractor						
Waste class	Waste code Stated for each waste type	Building section/position/reference	Estimated quantity/scope [1]	Handling/ storage	Quantity removed	Transporter	Recipient	Received quantity	Verification	Comments

1 Quantities acting as a basis for the contractor's tender should be reported in a separate quantity list where the quantities of HW are reported.

Comments

1 Estimated quantities stated in this plan should not form the basis for the contractor's tender.

For those submitting information regarding inventory*: Also state waste type sought but not found during material inventory. Submit references to any sample analyses. Submit references to supplementary information on drawings or in other documents.*

For appendices to inspection plans for demolition which must be submitted before the contract is ordered: Provide information under this heading with the client's requirement for handling and final processing of each reported waste type.

For contractor*: State inspected authorisation for transporters and recipients. Verifications must be present during final reporting and be referred to from this list. Deviations should be commented.*

Spaces which could not be inventoried

Describe here and/or mark on drawing.

Decontamination

Describe decontamination if this should be carried out.
Observe that certain decontamination should be reported to the municipality's environmental council.

Occupational health and safety risks during dismantling/decontamination and disposal of waste

Describe occupational health and safety risks and protective measures required.
Refer to current occupational health and safety legislation and other sources for information.

Environmental risks during dismantling/decontamination and disposal of waste

Describe the environmental risks and protective measures required to protect the environment.
Refer to current legislation and other sources for information.

Other waste

The entered waste type is the basic level according to the Resource and Waste Guidelines. Landfill and Mixed waste are alternative fractions. Fractions in addition to the basic level can be selected from Appendix 4 to the Resource and Waste Guidelines (Waste fractions – overall list).

Completed during environmental inventory and/or by the contractor		**Completed by the contractor**							
Waste type/fraction	**Waste code**	**Estimated quantity**	**Handling/storage**	**Quantity removed**	**Transporter**	**Recipient**	**Received quantity**	**Verification**	**Comments**
Material/products to be reused									
Wood									
Combustible materials									
Plastic for recycling									
Scrap metal									
Aggregates									
Landfill (sorted)									
Mixed waste - for post-sorting									

Comments

For appendices to inspection plans for demolition which must be submitted before the contract is ordered: Provide information under this heading with the client's requirement for handling and final processing of each reported waste type.

Appendix 2. Surveys

Bygg och rivningsavfall – Bygg och rivningsföretagens perspektiv

Enligt EU avfallsdirektivet ska alla länder inom EU uppnå en 70 procentig återvinningsgrad av bygg och rivningsavfall. Trots att byggsektorn efter gruvnäringen står för Sveriges största avfallsmängder är det endast 50-60% av bygg och rivningsavfall som återvinns. Constructivate är ett forskningsprojekt finansierat av Mistra (stiftelsen för miljöstrategisk forskning) med syfte att se över hur man kan uppnå en mer resurseffektiv återvinning av bygg och rivningsavfall. I projektet tar vi ett helhetsgrepp och betraktar hela flödet från projektering till rivning och studerar lagstiftning, återvinningstekniker, sortering, logistik,
affärsmodeller, certifieringar och materialsammansättningar. Denna enkät är en del av kartläggningsarbetet med fokus på logistikdelarna ur ett byggföretag/rivningsföretags perspektiv.

1) Görs en avfallshanteringsplan för den byggnad som ska byggas/rivas?

- Ja
- Nej
- Ibland

2) Om ja, finns det ett standardiserat format för den avfallshanteringsplan som du följer?

- Ja
- Nej

3) När en avfallshanteringsplan skapas, konsulteras följande aktörer:

	Ja	Nej
Återvinningsföretag		
Logistik-transportföretag		
Uppdragsgivare		

Om det finns några andra aktörer som konsulteras, vänligen ange denna:

4) Vilka av följande delar innehåller avfallsplanen?

	Ja	Nej
En uppskattning av volymen för olika avfallsslag		
En bedömning av potentiell återanvändningsgrad/återvinningsgrad för olika avfallsslag		
Specificering av det återvinningsföretag som respektive avfallsfraktion ska transporteras till		
Specificering kring hur godset ska transporteras (rutter, drivmedel etc.)		
Specificering kring hur godset ska lastas (lastbärare, fyllnadsgrad etc.)		
Kostnadsanalys för att jämföra olika alternativ kring hur avfallet ska hanteras (återvinning, återanvändning, deponi)		

Finns det några andra delar som avfallsplanen innehåller så ange gärna dessa här:

5) Sorterar du avfallet som uppstår på byggplatsen/rivningsplatsen

- Alltid
- Ofta
- Sällan
- Aldrig

6) Värdera hur viktiga följande faktorer är för att sortering av avfallet (1: inte alls viktig och 5: väldigt viktig)

	1	2	3	4	5
Att projekttiden tillåter tid för att sortera					
Att övriga aktiviteter inte påverkas allt för mycket					
Att det finns tillräckligt med personal					
Att det finns en marknad/avsättning för det återvunna materialet					
Att det är förhållandevis enkelt att sortera materialet					
Miljöhänsyn					
Styrning och management					
Utrymme					
Att utrustning för sortering finns tillgänglig					
Kundkrav					
Lagkrav					
Kostnader för att skicka materialet osorterat i jämförelse med att skicka material sorterat (personalkostnad, transport, återvinning)					

9. **Finns det några andra faktorer som är viktiga**
så ange gärna dessa här:

7) Kostanden för avfallshantering kan delas upp i 3 delar: 1) Kostnad för att sortera avfallet (personalkostnad, utrymme, utrustning etc.). 2) Kostnad för att transportera avfallet. 3) Kostnad för att lämna in avfallet till återvinningsföretag (för en del fraktioner kan det handla om intäkt). Ange nedan hur många procent av den totala kostanden som respektive del står

för. a. Kostnad för att sortera avfallet 5%

10%

15%

20%

25%

30%

35%

40%

45%

50%

55%

60%

65%

70%

75%

80%

85%

90%

95%

100%

b. Kostnad för att transportera avfallet

- 5%
- 10%
- 15%
- 20%
- 25%
- 30%
- 35%
- 40%
- 45%
- 50%
- 55%
- 60%
- 65%
- 70%
- 75%
- 80%
- 85%
- 90%
- 95%
- 100%

c. Kostnad för att lämna in avfallet till återvinningsföretag

- 5%
- 10%
- 15%
- 20%
- 25%
- 30%
- 35%
- 40%
- 45%
- 50%
- 55%
- 60%
- 65%
- 70%
- 75%
- 80%
- 85%
- 90%
- 95%
- 100%

8) Hur transporteras avfall från era anläggningar

- Egna transportörer
- Transportör anlitas av oss (typ tredjepartlogistiker)
- Återvinningsföretaget ordnar med transporten

Om ni gör på något annat sätt så skriv gärna det här:

9) Om ni anlitar en transportör hur prissätts transporterna

- Per vikt
- Per avstånd
- Vikt och avstånd
- Fast pris per resa

Om ni gör på något annat sätt så skriv gärna det här:

10) Hur bestäms det när avfallet ska lämna bygg/rivningsplatsen?

- Avfallet skickas efter en i förväg bestämd tidsplan (exempelvis på tisdagar och torsdagar)
- Avfall skickas vid behov (när container eller liknande är full)

Om ni gör på något annat sätt så skriv gärna det här:

11) Rapporterar ni till någon (exempelvis statlig myndighet, återvinningsföretag, beställare etc.) gällande volymer och fraktioner?

- Ja
- Nej

Om ja till vem rapporterar ni och vad rapporterat ni

12) Informerar återvinningsföretagen om vad som hänt med det avfall ni lämnat in?

- Ja
- Nej
- Ibland

13) Ange gärna dina synpunkter kring hur återvinningsgraden av bygg och rivningsavfall skulle kunna öka.

Bygg och rivningsavfall – Återvinning

Enligt EU avfallsdirektivet ska alla länder inom EU uppnå en 70 procentig återvinningsgrad av bygg- och rivningsavfall. Trots att byggsektorn efter gruvnäringen står för Sveriges största avfallsmängder är det endast 50-60% av bygg och rivningsavfall som återvinns. Constructivate är ett forskningsprojekt finansierat av Mistra (stiftelsen för miljöstrategisk forskning) med syfte att

se över hur man kan uppnå en mer resurseffektiv återvinning av bygg och rivningsavfall. I projektet tar vi ett helhetsgrepp och betraktar hela flödet från projektering till rivning och studerar lagstiftning, återvinningstekniker, sortering, logistik,
affärsmodeller, certifieringar och materialsammansättningar. Denna enkät är en del av kartläggningsarbetet med fokus på återvinning.

1) Vilka av följande avfallsslag tar ni emot:

	Ja	Nej
Betong		
Plast		
Trä		
Papper		
Gips		
Jord		
Elavfall		
Farligt avfall		
Brännbart		
Mixat material		

2) Förutom typ av avfallsslag beror prissättningen på andra faktorer såsom kvalitet av materialet etc.?

Ja
Nej

Om ja vilka faktorer ingår i prissättningen

3) Gällande materialfraktionerna betong och plast vilken av följande scanarios förenklar mest för återvinningen?

Avfall som kommer från bygg och rivningsplatsen har sorterats mycket noggrant (exempelvis har man sorterat betong i olika kvaliteter såsom armerad betong, krossad betong etc.)

Avfall som kommer från bygg och rivningsplatsen har sorterats i plast och betong men inte i olika kvaliteter

Avfall som kommer från bygg och rivningsplats är osorterat. Vi har bättre möjligheter hos oss att sortera materialet på det sätt vi vill ha det.

Övriga kommentarer:

4) Hur transporteras avfall till era lokaler?

- Egna transporter
- Vi anlitar transportör/logistikföretag
- Transporter ordnas av byggfirma/rivningsfirma
- Other:

5) Om ni köper in transporttjänsten utifrån hur prissätts

dessa transporter?

- Baserat på vikt
- Baserat på avstånd
- Vikt och avstånd
- Fast pris

Övrigt:

6) Vem bestämmer när avfall ska skickas/hämtas till era anläggningar?

- Byggföretag/Rivningsföretag
- Vi (återvinningsföretag)
- Transportör (tredjepartslogistikern)

Övrigt:

7) Hur ofta mottar ni avfall från bygg och rivningsföretag?

- Dagligen
- Varannan dag
- Varje vecka
- Oreglebundet

8) Rapporterar ni om vilka avfallsslag ni tar emot till någon statlig myndighet och vad ni gör med detta material?

- Ja
- Nej

Om ja, vem rapporterat ni till och vad rapporterat ni (volym, avfallstyp, vikt, återvinningsgrad, återanvändningsgrad etc.)

9) Rapporterar ni till byggherre/rivningsentreprenör vad som gjorts med avfallet?

- Ja
- Nej
- Om de ber om detta

Om ja eller om de ber om detta, exakt vad rapporterar ni om (volym, avfallstyp, vikt, återvinningsgrad, återanvändningsgrad etc.)

10) Är det enkelt att spåra varifrån avfallet kommer?\

- Ja
- Nej
- Ibland

Om ja eller ibland, hur kan ni spåra avfallet

11) Hur viktiga uppfattar du att följande faktorer är för att lyckas öka återvinningsgraden av bygg och rivningsavfall i Sverige? (1: inte alls viktig och 5: väldigt viktig)

	1	2	3	4	5
Kostnader					
Miljöpåverkan					
Lagstiftning					
Kundkrav					

19. 12) Ange gärna dina synpunkter kring hur återvinningsgraden av bygg och rivningsavfall skulle kunna öka.

Bygg och rivningsavfall – Deponering

Enligt EU avfallsdirektivet ska alla länder inom EU uppnå en 70 procentig återvinningsgrad av bygg och rivningsavfall. Trots att byggsektorn efter gruvnäringen står för Sveriges största avfallsmängder är det endast 50-60% av bygg och rivningsavfall som återvinns. Constructivate är ett forskningsprojekt finansierat av Mistra (stiftelsen för miljöstrategisk forskning) med syfte att se över hur man kan uppnå en mer resurseffektiv återvinning av bygg och rivningsavfall. I projektet tar vi ett helhetsgrepp och betraktar hela flödet från projektering till rivning och studerar lagstiftning, återvinningstekniker, sortering, logistik,
affärsmodeller, certifieringar och materialsammansättningar. Denna enkät är en del av

kartläggningsarbetet med fokus på deponering av avfall.

Är din deponi fortfarande aktiv?

- Ja
- Nej

Tar du emot avfall från bygg och rivningsbranschen? Mark only one oval.

- Ja
- Nej

1) Har du märkt av någon trend gällande deponering av bygg och rivningsavfall de senaste åren?

- Det har skett en ökning av bygg och rivningsavfall
- Det har skett en minskning av bygg och rivningsavfall
- Ingen trend

2) Har ni tillräckligt med plats för att ta emot avfall till er deponi

- Nej, vi kommer snart att få platsbrist
- Ja, vi har möjlighet att ta emot avfall för flera år framöver

3) Har ni olika kostnader för att ta emot olika typer av avfallsfraktioner?

- Ja
- Nej

Om ja, vad kostar det att lämna ifrån sig plast till er deponi

Om ja, vad kostar det att lämna ifrån betong till er deponi

Om ja, vad kostar det att lämna ifrån sig blandat avfall

4) Finns det andra faktorer (såsom kvalitet på material) som styr kostnadsbilden för att lämna ifrån sig avfall för deponering?

Ja
Nej

Om ja, vilka är dessa faktorer?

5) Rapporterar ni till någon (statslig myndighet etc.) vilka fraktioner och kvantiteter ni tar emot?

Ja
Nej

Om ja, till vem rapporterar ni och vad rapporterar ni (exempelvis vikt, volym, typ av avfallsslag etc).

6) Hur ofta tar ni emot avfallsvolymer

Dagligen
Varannan, var tredje dag.
Varje vecka
Oregelbundet
Är det enkelt att spåra från vart avfallet kommit?

Ja
Nej
Ibland

8) Hur viktiga uppfattar du att följande faktorer är för att lyckas öka återvinningsgraden av bygg och rivningsavfall i Sverige? (1: inte alls viktig och 5: väldigt viktig):

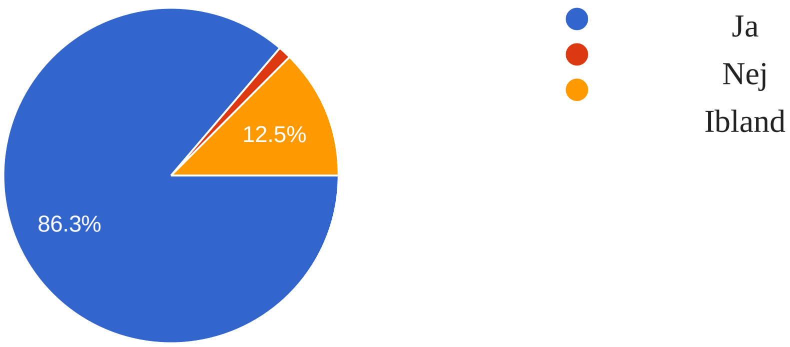
	1	2	3	4	5
Kostnader					
Miljöpåverkan					
Lagstiftning					
Kundkrav					

9) Ange gärna dina synpunkter kring hur återvinningsgraden av bygg och rivningsavfall skulle kunna öka.

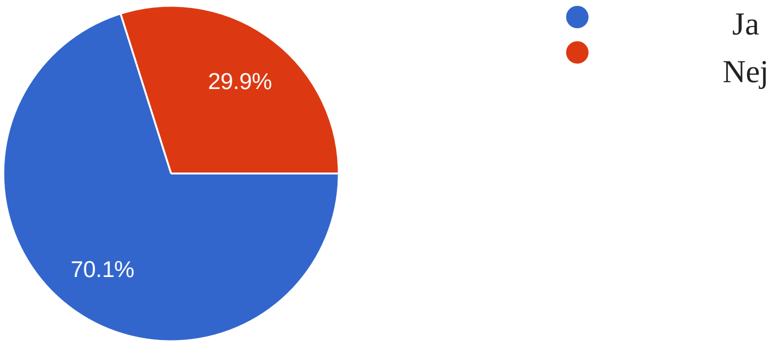
Appendix 3. Survey Results

a) Bygg och rivningsföretagens perspektiv

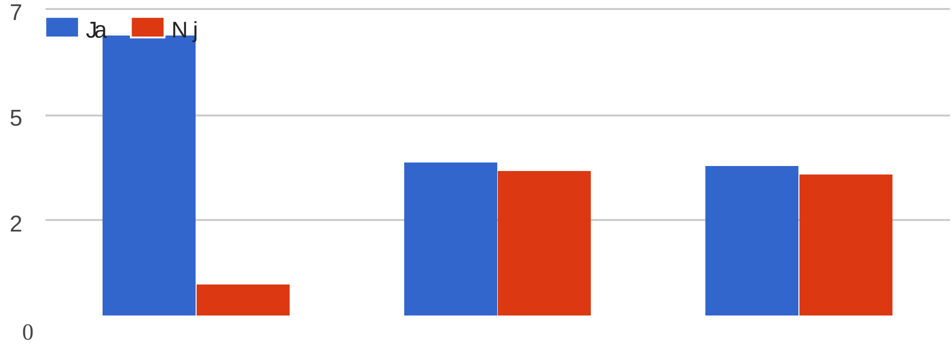
1) Görs en avfallshanteringsplan för den byggnad som ska byggas/rivas?
80 responses



2) Om ja, nns det ett standardiserat format för den avfallshanteringsplan som du följer?
77 responses



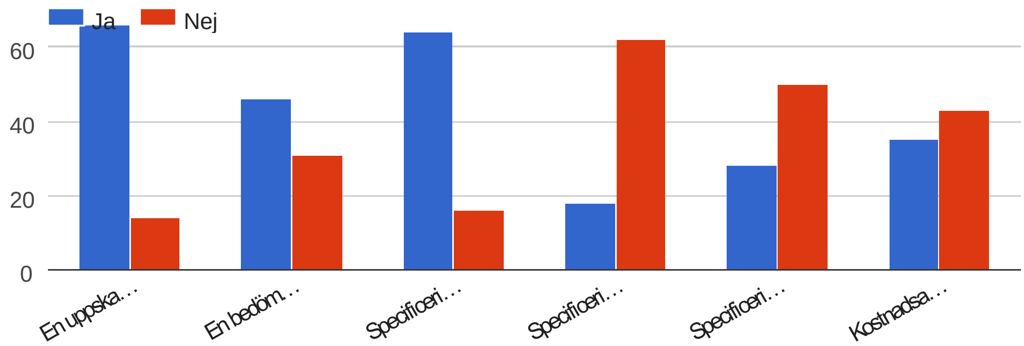
3) När en avfallshanteringsplan skapas, konsulteras följande aktörer:



Om det nns några andra aktörer som konsulteras, vänligen ange denna:
8 responses

- NCC Recykling
- Konsulter
- Vid rivning är det oftast rivningsföretaget som tar fram avfallsplanen.
- Rivningsentreprenör i rivininingsskede / Rivningsplan tas å fram.
- Vi handlar oftas upp rivning på entreprenad / underentreprenör.
- Miljösakkunnig
- Rivningsentreprenör, miljösamordnare.
- Ev.UE som t.ex Rör ,El ,Vent

4) Vilka av följande delar innehåller avfallsplanen?

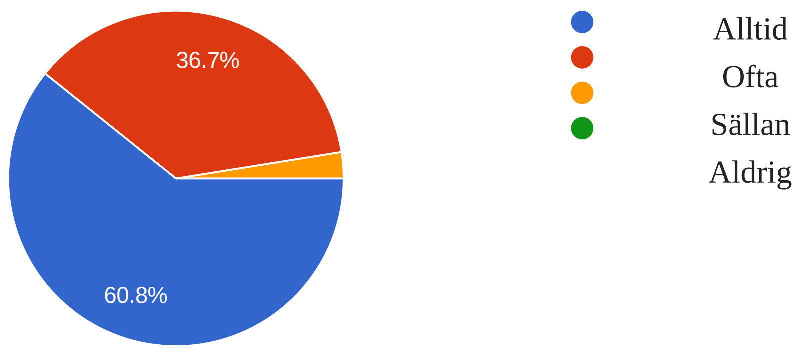


Finns det några andra delar som avfallsplanen innehåller så ange gärna dessa här:
6 responses

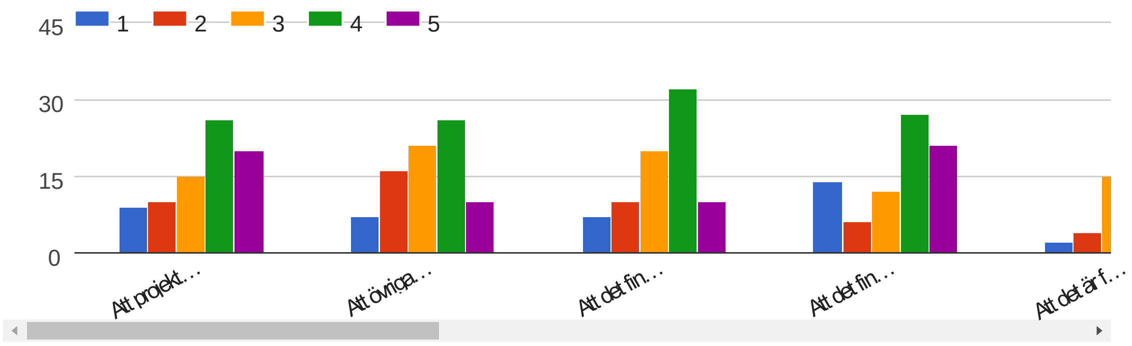
- Avfallsplanen är mer övergripande och beskriver olika fraktioner samt hämtningsfrrkvens
- Speci kation och utförande samt deponi för miljöfarligt avfall

- Miljöfarligt avfall
- Farligt avfall
- Vilka fraktionser som skall sorteras för sig.
- Givetvis hanteras "Farligt avfall" enligt lagar och förordningar

5) Sorterar du avfallet som uppstår på byggplatsen/rivningsplatsen
79 responses



6) Värdera hur viktiga följande faktorer är för att sortering av avfallet (1: inte alls viktig och 5: väldigt viktig):

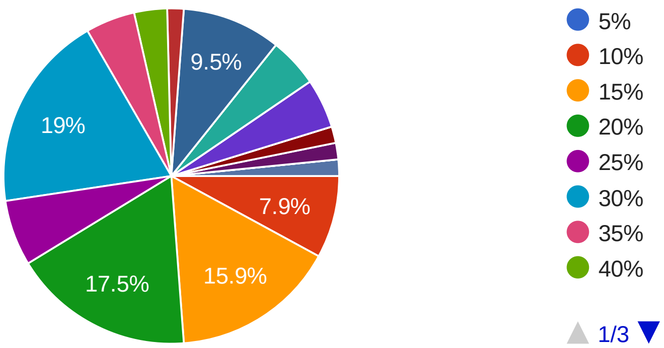


Finns det några andra faktorer som är viktiga så ange gärna dessa här:
4 responses

- Ordentlig sopstation = bättre sortering = renare bygge = Bättre arbetsmiljö
- Volymen. Så det är tillräckligt mycket.
- Engagemang och intresse bland personalen och UE
- Vi sorterar alltid upp allt material oavsett det är ett krav från oss.

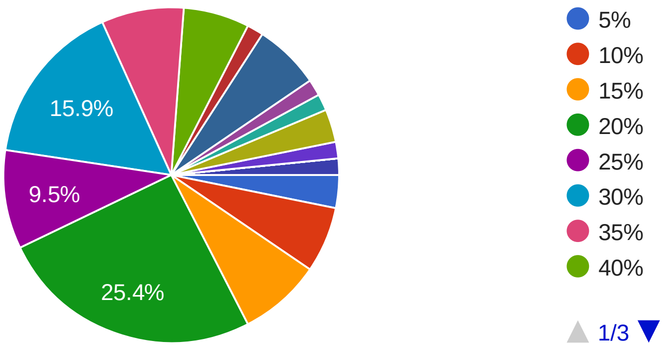
7) Kostanden för avfallshantering kan delas upp i 3 delar: 1) Kostnad för att sortera avfallet (personalkostnad, utrymme, utrustning etc.). 2) Kostnad för att transportera avfallet. 3) Kostnad för att lämna in avfallet till återvinningsföretag (för en del fraktioner kan det handla om intäkt). Ange nedan hur många procent av den totala kostanden som respektive del står för. a. Kostnad för att sortera avfallet

63 responses



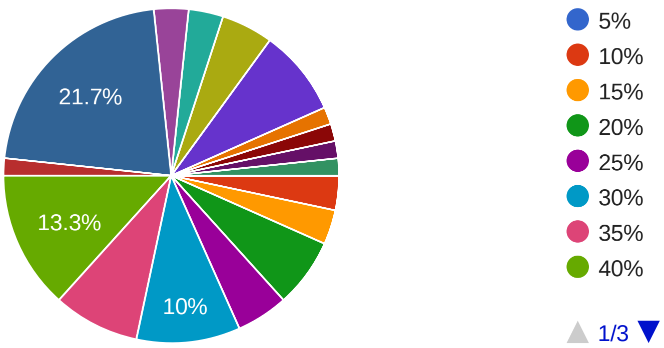
b. Kostnad för att transportera avfallet

63 responses



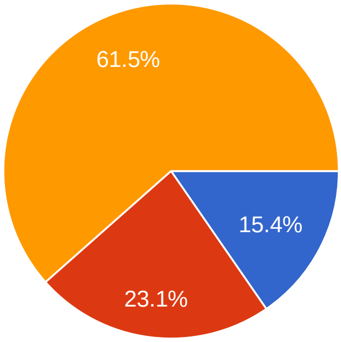
c. Kostnad för att lämna in avfallet till återvinningsföretag

60 responses



8) Hur transporteras avfall från era anläggningar

78 responses



Egna

transportörer

Transportör anlitas av oss (typ tredjepartlogistiker)

Återvinningsföretaget ordnar med transporten

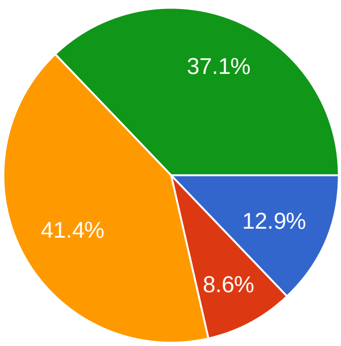
Om ni gör på något annat sätt så skriv gärna det här:

2 responses

- konad på post 7
- Annan entreprenör utför arbetet aldrig PEAB

9) Om ni anlitar en transportör hur prissätts transporterna

70 responses



Per vikt

Per avstånd

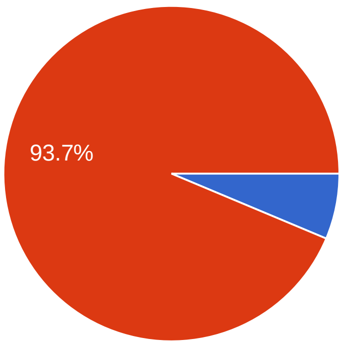
Vikt och avstånd Fast pris per resa

Om ni gör på något annat sätt så skriv gärna det här:
5 responses

fast pris per resa eller enhet samt viktpris

- Fast pris gäller ak + balja. För mindre kärl är det timpris som gäller.
- Per timme
- Timpris
- Även vanligt med fast pris per resa

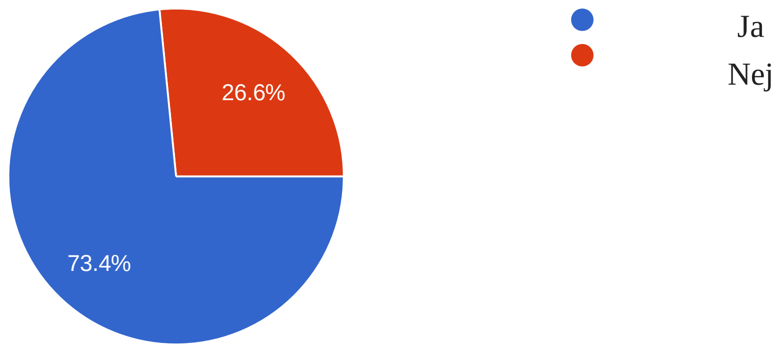
10) Hur bestäms det när avfallet ska lämna bygg/rivningsplatsen?
79 responses



Om ni gör på något annat sätt så skriv gärna det här:
1 response

Båda beroende på storlek /behov

11) Rapporterar ni till någon (exempelvis statlig myndighet, återvinningsföretag, beställare etc.) gällande volymer och fraktioner?
79 responses

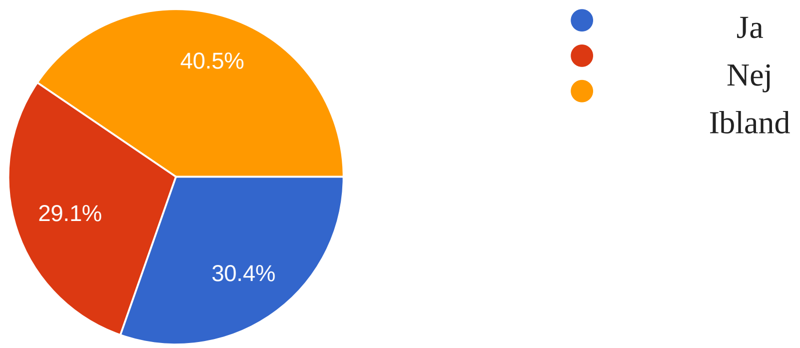


Om ja till vem rapporterar ni och vad rapporterat ni
45 responses

- Beställare (3)
- Kommunen (3)
- Beställaren (2)
- Kontrollansvarig enl PBL som rapporteras till Kommunen
- Beställare har ofta detta krav.
- Beställare, sammanställning av antal transporter, vikter och fraktioner
- Beställare
- En del beställare vill ha redovisning.
- Beställare + internt
- Miljöfarliga avfall
- Beställaren och internt
- Volymer, fraktioner till återvinningsföretaget
- Beställare och i fall av förorening eller farligt avfall till myndighet.
- Till den kommun vi utför rivningen i.
- Beställaren
- Internt varje Beställaren.
- Miljökontor et i kommun internt
- Miljö & hälsa
- Miljö och Hälsa
- Mängden avfall och fraktion till kommunen
- Beställare (vid intresse) eller projektspeci k rutin.
- Till kunden mängd avfall
- Till Beställaren samt miljöförvaltningen
- Internt
- Svanen, Beställare, Miljöbyggnad mm
- Tra kverket
- Myndighet
- Beställare, kommun

- Beställare mängd samt mottagare
- kommun
- Vikt för respektive fraktion rapporteras oftast till beställare (när det efterfrågas)
- Beställaren fraktionslistor
- Beställaren men bara ibland
- Sopstatistik till beställare i många fall
- Oftast är det beställaren, samt för eget miljöarbete vill vi veta vad vi hanterar
- Till beställare och myndighet mängd och typ.
- Beställare och internt inom företaget
- Efter genomfört projekt överlämnas en slutdokumentation

12) Informerar återvinningsföretagen om vad som hänt med det avfall ni lämnat in?
79 responses



13) Ange gärna dina synpunkter kring hur återvinningsgraden av bygg och rivningsavfall skulle kunna öka.
21 responses

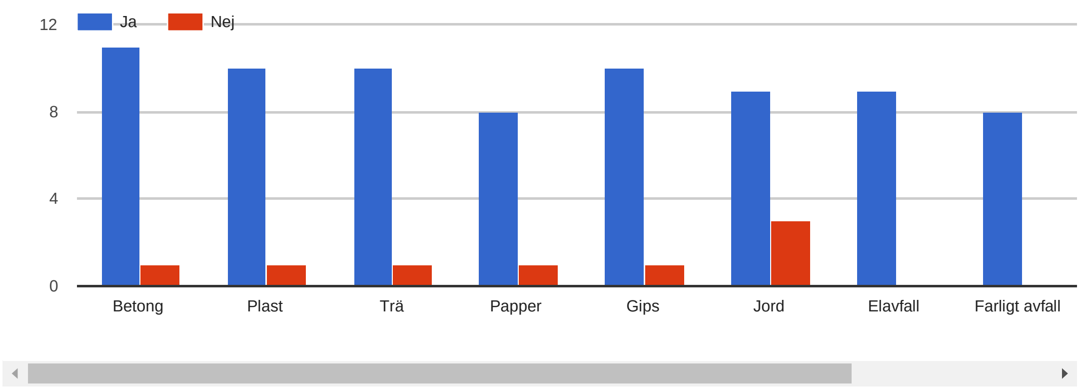
- Lägre avfallspriser på sorterat material.
- krav från beställare och vilja och intresse från platsledning.
- Bättre planering i genomförande, men även vid inköp av material och UE jag tror kraven borde ligga hos återvinningsföretagen eftersom byggarbetsplatser ofta är begränsade utav utrymmet.
- Bättre undersökning och utredning innan start av projektering. framförallt ett byggherreansvar.
- Bättre betalt för sorterat avfall samt att det verkligen återvinns och inte eldas upp
- Att mer privata aktörer sköter återvinningen. Blir troligtvis inte lika stelbent

som vid vissa t.e.x. kommunala anläggningar Det som har störst påverkan är hur stor yta det nns möjlighet att ha containrar på. Trångt bygge= svårare med sortering Enklare att göra avfallet till en produkt. Idag är det mycket svårt.

- Kostnad för inlämning
  betydligt reducerad.
  prissänkning för det som
  sorteras och ökning på
  det som inte
- Att tekniken ökar hos återvinningsföretaget så att man kan lämna osorterat dit
- Så som det är idag så måste kommuner se över hur man nekar betong kross som återfyllning mm sedan se till att lätta på brännbara fraktioner ej tillåta import av hushålls sopor mm
- Bättre planering.
- Mer tid vid rivningsarbeten
- Köpa tjänsten på plats av återvinningsföretagen
- Vet ej, det vi inte sorterar sorteras av mottagare. (dyrt i projekt) Kanske skall kontrolleras med mottagare?
- All egenkontroll och uppföljning skall vara dokumenterad
- En tydlig beskrivning av vad som händer med det inlämnade avfallet att kanalisera ut på bygget samt en kosekvensbeskrivning av vad ett felsorterat avfall innebär
- Att projektörerna tänker i dag vad vi ska riva i morgon, material, inf metoder mm.
- Beror på avfallstyp, inerta material torde dock kunna användas bättre

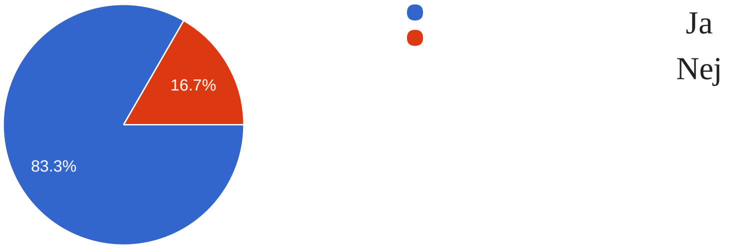
b) Survey - Återvinning perspektiv

1) Vilka av följande avfallsslag tar ni emot:



2) Förutom typ av avfallsslag beror prissättningen på andra faktorer såsomkvalitet av materialet etc.?

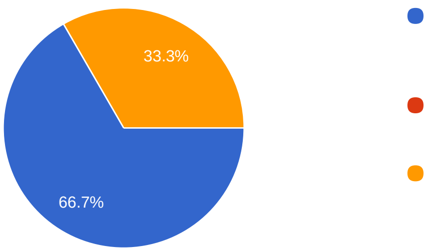
12 responses



Om ja vilka faktorer ingår i prissättningen
9 responses

- Renhet på material, gäller såväl inblandning av andra material som farlighet på materialet. Var geogra sk i Sv fallermaterialet, regionala prisskillnader. Stycke storlek på materialet.
- Renhet, solitäritet, innehåll av miljöbelastande organiska och icke organiska föroreningar, mängd, våra avsättningsmöjligheter inklusive transportavstånd till dessa.
- Acceptanskriterier, volymer
- Metallinnehåll och farlighetsgrad
- Ingående material, storlek, förekomst av oönskade material, sammansättning t ex gips på träreglar.
- Främst renhetsgraden, det är väldigt vanligt att det nns lite orenheter i materialen. Kvantité, enklare att hantera i stora mängder.
- Materialets renhet och sorteringsbarhet
- Storlek på materialet, volym, analyser på materialet.
- Logistik, omlastning , kvalite

3) Gällande materialfraktionerna betong och plast vilken av följande scanarios förenklar mest för återvinningen?
12 responses

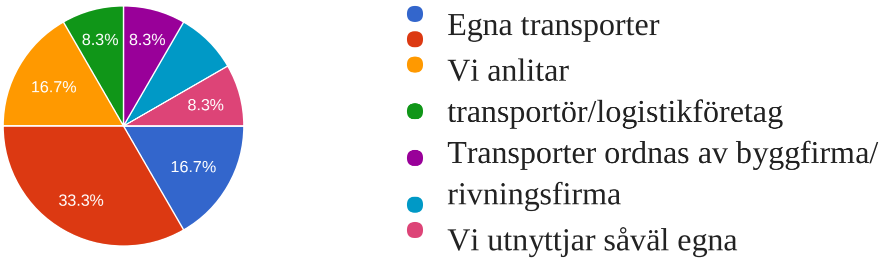


Avfall som kommer från bygg och rivningsplatsen har sorterats mycket noggrant (exempelvis har man sorterat betong i olika kvaliteter sås… Avfall som kommer från bygg och rivningsplatsen har sorterats i plast och betong men inte i olika kvaliteter Avfall som kommer från bygg och rivningsplats är osorterat. Vi har bättre möjligheter hos oss att sortera materialet på det sätt vi vill ha det.

Övriga kommentarer:
3 responses

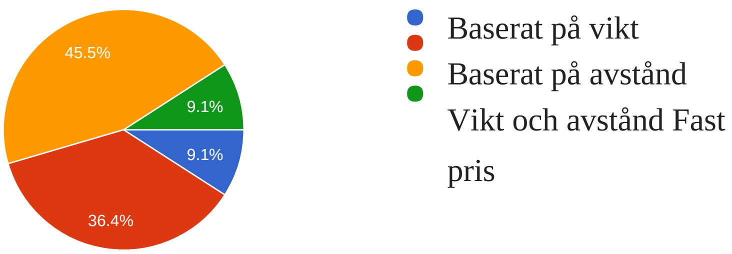
- Svaret ovan är inte representativt för alla kunder.
- Just kombinationen betong och plast är enkelt att sortera
- Återvinningsbolag har en uppbyggd infrastruktur för att effektivt sortera och återvinna material. Det torde vara samhällsekonomiskt fördelaktigt att inte lägga snickartimmar på detta arbete.

4) Hur transporteras avfall till era lokaler?
12 responses



transporter som logistikföretag
Oftast genom egenägd transportör, men varianter finns.
Både alt 1 och 3 förekommer
Blandning av eget åkeri och inlejda…

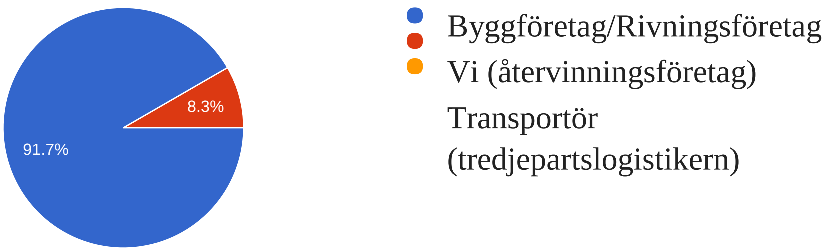
5) Om ni köper in transporttjänsten utifrån hur prissätts dessa transporter?
11 responses



Övrigt:
2 responses

Oftast vikt och avstånd men andra alternativ kan förekomma.
I regel ett fast pris inom en viss zon

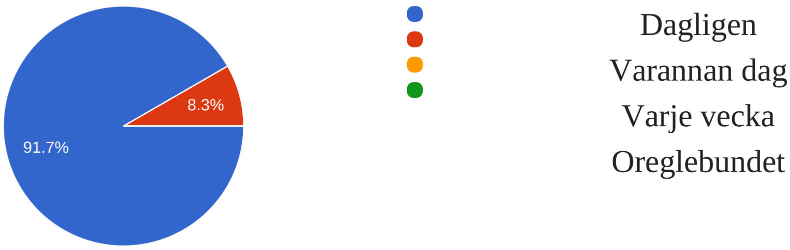
6) Vem bestämmer när avfall ska skickas/hämtas till era anläggningar?
12 responses



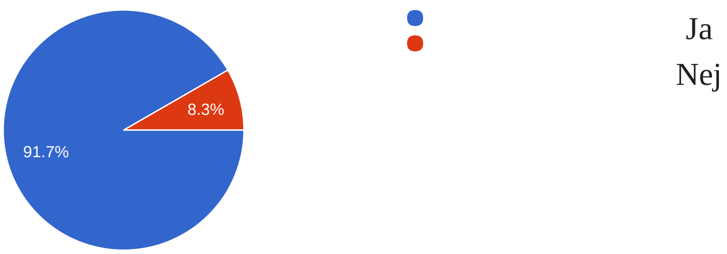
Övrigt:
1 response

Kunderna avropar till oss, när det behövs byte på lastbärare.

7) Hur ofta mottar ni avfall från bygg och rivningsföretag?
12 responses



8) Rapporterar ni om vilka avfallsslag ni tar emot till någon statlig myndighet och vad ni gör med detta material?
12 responses



Om ja, vem rapporterat ni till och vad rapporterat ni (volym, avfallstyp, vikt,

återvinningsgrad, återanvändningsgrad etc.)
10 responses

- Till Naturvårdsverket via SMP. Avfallstyp, vikt, återvinningsgrad, typ av behandling (återv, återanv, energiutv, deponi) Enligt nya bestämmelser om redovisning av bygg och rivningsmaterial enligt föreläggande.
- Länsstyrelsen,producent
- Naturvårdsverket, Länsstyrelsen och Kommunen
- Se miljörapporter från våra anläggningar
- Vi skickar in miljörapporter årligen
- Naturvårdsverket enligt gällande lagstiftning och NFS.
- Kommunen/Ton
- Via SMP till Naturvårsverket enligt A och B anläggnigsprincipen
- Tillsynsmyndigheten (kommunen) samt att vi skriver miljörapport

9) Rapporterar ni till byggherre/rivningsentreprenör vad som gjorts med avfallet?
12 responses

Om ja eller om de ber om detta, exakt vad rapporterar ni om (volym, avfallstyp, vikt, återvinningsgrad, återanvändningsgrad etc.)
10 responses

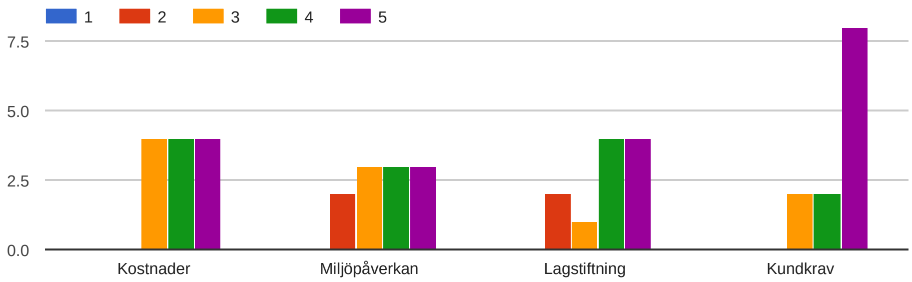
- Se ovan
- Allt ovanstående och i vissa fall slutdestination.
- Finns med statistik och faktura
- EWC-kod, Vikt, Avfallsklassi cering och vad som är nästa steg i kedjan.
- Enligt kundens önskemål
- Olika till olika kunder, i princip kan man få allt ex som i frågan.
- Avtalsberoende.
- Volym, avfallstyp, vikt, återvinningsgrad mm. Det dom efterfrågar.
- Volym, materialslag, återvinningsgrad, källsorteringsgrad samt kostnader förknippade med aktuell avfallshantering
- Vikt (och även slutdeponi vid förorenad jord, betong och asfalt)

10) Är det enkelt att spåra varifrån avfallet kommer?
12 responses

Om ja eller ibland, hur kan ni spåra avfallet
8 responses

- Om det levereras till vår anläggning frågar vi leverantören
- Kan vi inte om det inte är en direktkund
- Vi är samma företag som demonterar/river som förbehandlar/återvinner.
- Vi kör med egna transporter, då vet vi automatiskt varifrån allt kommer.
- Varje enskild transport har ett unikt nummer. Avfallet kan spåras fram till dess att det läggs för sortering (tömms ur behållare). Dessa tömningar övervakas för att upptäcka orenheter eller felaktiga fraktioner.
- Vi väger in och tar arbetsplatsnamn
- Med hjälp av segmentering i vårt affärssystem
- Nej gäller vid byggavfall som "osorterat, brännbart, isolering, gips m.m. Vid jord, asfalt och betong kräver vi alltid uppgift om var avfallet har uppkommit (adress; gata eller plats + kommun) innan det får transporteras till oss.

11) Hur viktiga uppfattar du att följande faktorer är för att lyckas ökaåtervinningsgraden av bygg och rivningsavfall i Sverige? (1: inte alls viktig och 5: väldigt viktig)



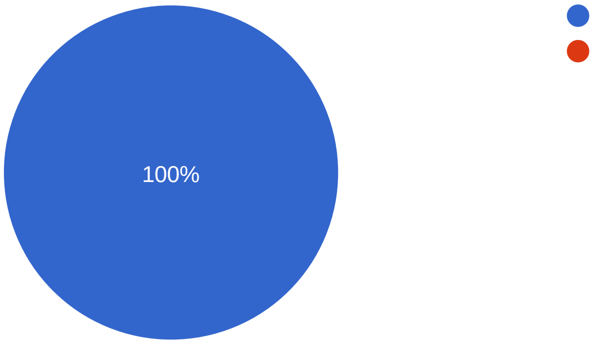
12) Ange gärna dina synpunkter kring hur återvinningsgraden av bygg ochrivningsavfall skulle kunna öka.

9 responses

- Stimulera användningen av återvunna material, avgörande är inte om vi kan sortera ut material utan att få någon som är villig att använda de utsorterade materialen. Blir efterfrågan tillräcklig (styrmedel) kommer också utsorteringen att öka.
- Öka kraven på sortering där avfallet uppstår. Låt den som genererar avfallet lämna statistik till myndigheten årligen. Det känns konstigt att mottagaren ska bära detta ansvar utan helhetsbild.
- Ökad information,sortering, miljöaspekter - mixa blanda, kortsiktig lönsamhet är inte framtiden
- Att myndigheterna ställer högre krav på spårbarhet och att inte "vemsomhelst" som kan får lova att riva/återvinna.
- Vi ligger på ca 99 % på vår anläggning, ni är välkomna att komma och besöka oss. Tar ni tåget kan vi hämta upp er på stationen i Malmö. MVH Carl Fredrik
- God tillsyn på anläggningar som bedriver miljöfarlig verksamhet, underlätta för återvinningsbranschen att skapa en god och effektiv ekonomi i processen och tillåt marknadskrafterna driva på utvecklingen.
- Logistik och plats/yta på byggarbetsplatserna för återvinning. Plats för uppställning av lastbärare/containrar av olika slag på byggarbetsplatserna.
- Dialog före, under tiden samt efter ett byggprojekt mellan Byggföretagsledning och SUEZ
- Det behövs tuffare lagstiftning med kontroll och uppföljning. Tyvärr måste man nog även styra det ekonomiskt men då både med piskor och morötter, alltså inte bara med höjda avgifter som är brukligt i Sverige utan något slags bonusmalus-system. Höjda deponiskatter och dyrare transporter behövs.

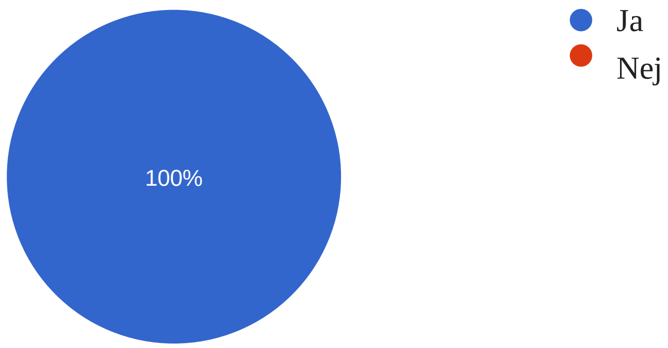
c) Survey - Deponi perspektiv

Är din deponi fortfarande aktiv?
15 responses

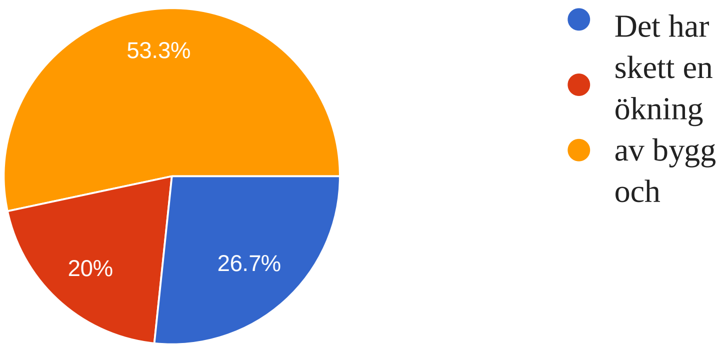


Ja Nej

Tar du emot avfall från bygg och rivningsbranschen?
15 responses



1) Har du märkt av någon trend gällande deponering av bygg och rivningsavfall de senaste åren?
15 responses

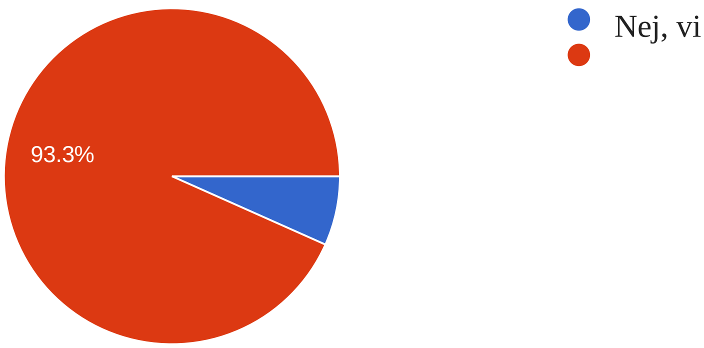


rivningsavfall

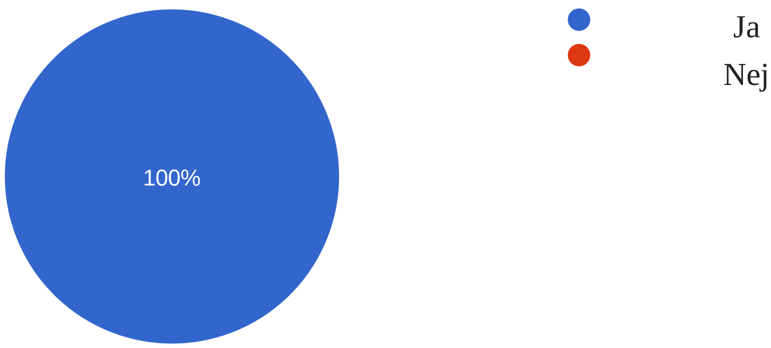
Det har skett en minskning av bygg och rivningsavfall

Ingen trend

2) Har ni tillräckligt med plats för att ta emot avfall till er deponi
15 responses



3) Har ni olika kostnader för att ta emot olika typer av avfallsfraktioner?
15 responses

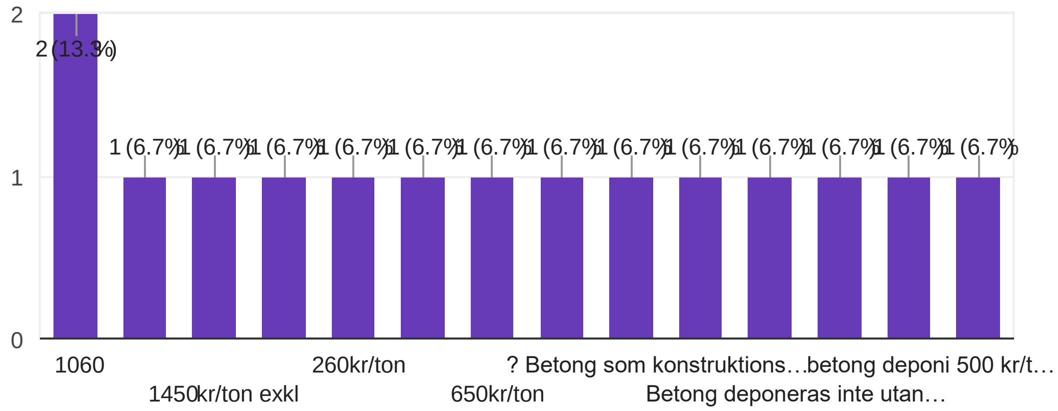


Om ja, vad kostar det att lämna ifrån sig plast till er deponi
15 responses

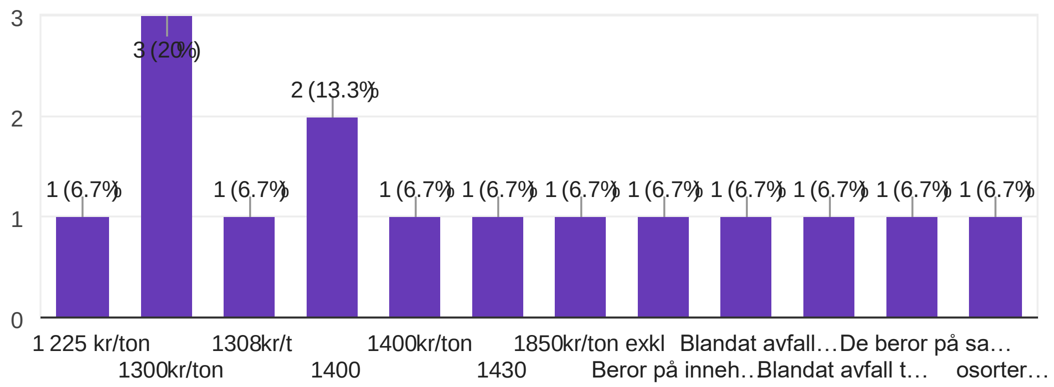
- Vi deponerar inte plast
- Ren plast hänvisas till annan aktör
- Inget brännbart på deponin
- Deponeras inte
- 750 kr/ton

- 800 kr/ton
- 1280 kr ton exkl men vi får inte deponera detta.
- 0
- ??? Vi tar inte emot rena plastfraktioner på deponi
- Plast är ett material som inte får deponeras enligt det förbud mot deponering av brännbart avfall som infördes år 2002. Plast till förbränning kostar 820 kr/ton. När det gäller plast till materialåtervinning ges priser individuellt beroende på kund - vilken typ av plats, kvantitet mm
- 1000
- brännbart avfall från verksamheter 1300 kr/ton exkl moms
- Går inte till deponi. Till förbränning 1 364 kr/ton.
- VI deponerar ingen plast
- Det är deponiförbud för plast. Kostnad till förbränning 580 kr/ton grindpris.

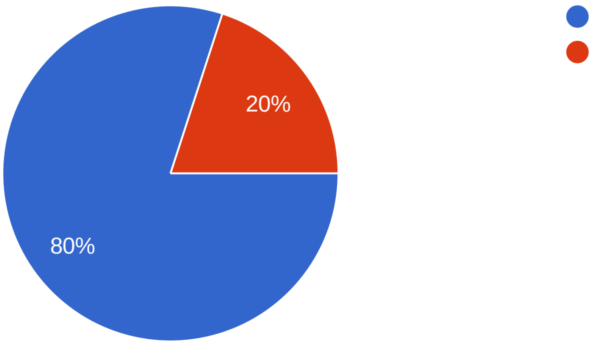
Om ja, vad kostar det att lämna ifrån betong till er deponi
15 responses



Om ja, vad kostar det att lämna ifrån sig blandat avfall
15 responses



4) Finns det andra faktorer (såsom kvalitet på material) som styr kostnadsbilden för att lämna ifrån sig avfall för deponering?
15 responses

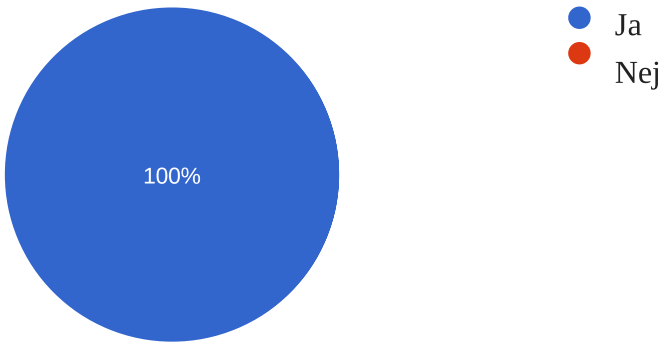


Ja Nej

Om ja, vilka är dessa faktorer?
12 responses

Deponiskatt
Renhetsgrad
Deponiskatt, användning som konstruktionsmaterial, sluttäckning Innehåll och föroreningar Det beror på föroreningsgraden hur ren fraktionen är.
Gips, Tryckimpregnerat trä, Metall
Vi tar inte emot material med mer än 10 procent brännbart avfall på deponi.
Avgörande är om avfallet klassas som farligt - eller icke-farligt avfall. Farligt avfall deponeras på särskild deponi anpassad för farligt avfall. I särskilda fall kan en prisdifferens nnas för avfall som deponeras på deponi för icke-farligt avfall. Exempel på ett sådant är Asbest och gips som måste hanteras särskilt.
t ex betong som kan användas som vägmaterial kostar 200 kr/ton exkl moms, Rena jordmassor som kan användas 0 kr/ton medan jordmassor som måste deponeras 1500 kr/ton exkl moms
Rena fraktioner är billigare än blandade.
Beroende på om det klassas som farligt avfall (tex asbest) eller om det går att använda som konstruktionsmaterial.

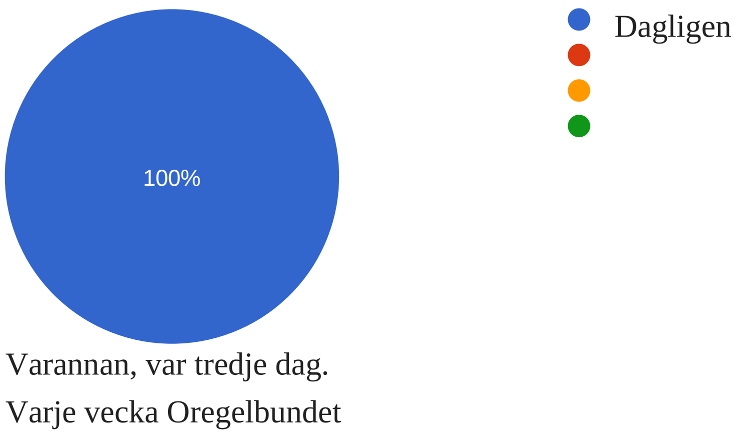
5) Rapporterar ni till någon (statslig myndighet etc.) vilka fraktioner och kvantiteter ni tar emot?
15 responses



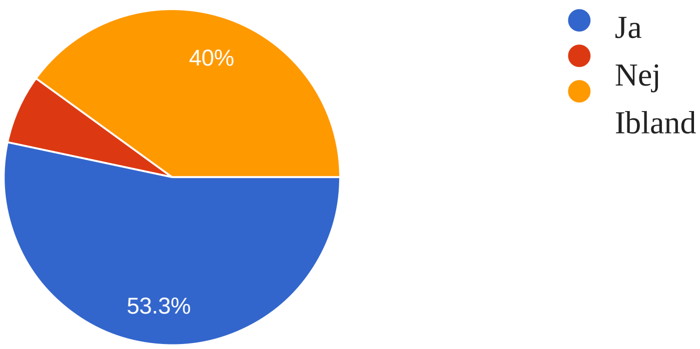
Om ja, till vem rapporterar ni och vad rapporterar ni (exempelvis vikt, volym, typ av avfallsslag etc).
14 responses

- Bygg och rivningsavfall rapporteras enligt lag
- Miljörapporten, statistik avfall webb
- Tillsynsmyndigheten, normalt Lst
- Avfall Sverige
- Vi rapporterar vikt på olika avfallsslag.
- Till vår tillsynsmyndighet som är länsstyrelsen. Vi rapporterar årligen och månatligen hur mycket avfall (i ton) som har behandlats med de olika behandlingsmetoder vi tillämpar. Även avfallsslag och mängd (i ton) rapporteras. Miljökontoret vikt totalt över året miljörapport SMP
- Naturvårdsverket.
- Miljökontoret
- Årliga miljörapporten.

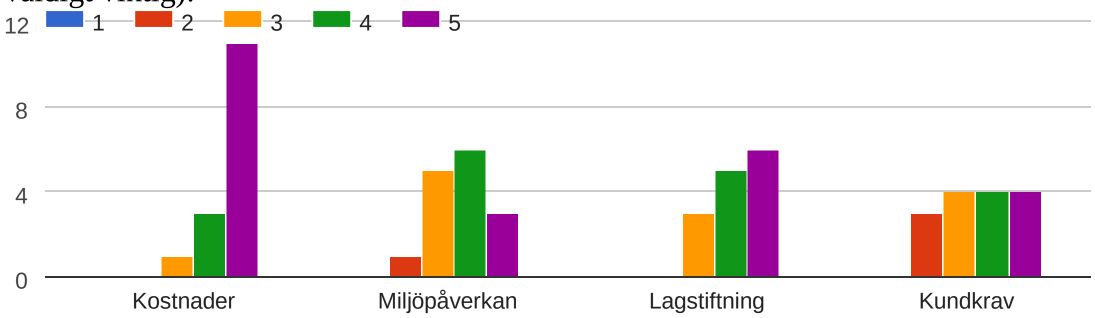
6) Hur ofta tar ni emot avfallsvolymer
15 responses



7) Är det enkelt att spåra från vart avfallet kommit?
15 responses



8) Hur viktiga uppfattar du att följande faktorer är för att lyckas ökaåtervinningsgraden av bygg och rivningsavfall i Sverige? (1: inte alls viktig och 5: väldigt viktig):



9) Ange gärna dina synpunkter kring hur återvinningsgraden av bygg ochrivningsavfall skulle kunna öka.
8 responses

- Återvinningsmöjlighet för isolering
- Jag ser inga problem med byggavfallet utan det sorteras i olika fraktioner. I princip bara isolering deponeras gå ut med mer info till byggarna.
- Sortering på plats där avfallet uppstår
- Krav på rena fraktioner, dvs. ta bort blandat avfall eller höj kostnader för blandat avfall. Ren gips t.ex. kommer in alldeles för sällan.
- Yteffektiva och rationella system för materialseparation på platsen där avfallet uppstår.
- Lägg större krav på byggherren att rapportera. Det ger en större förståelse i hela kedjan.
- Avfallslämnarna har det absolut största ansvaret eftersom sortering vid källan alltid är det bästa. Vi upplever att mycket plast och well som skulle kunna återvinnas går tillförbränning. Inför tydligare taxedifferentiering och överväg lagstiftning som stipulerar att återvinningsbara fraktioner sorteras ut och återvinns, i enlighet med avfallshierarkin.

Appendix 4. Economic Calculations

Case 2: Rosendal school:

Total Cost= On-site sorting cost + Transportation Cost + Receiver gate fee

On-site sorting cost = Number of man hours required for sorting x wages/hour

The duration for demolishing the school was around 3 months. 2 extra workers, working for 8 hours a day were required for sorting the waste.

On-site sorting cost = (Number of extra workers x Number of man hours x Wages/hour x total Duration of the project) = (2 x 8 x180 x 90) = 259,200SEK

Transportation cost = Driver cost + Fuel cost

The distance from the demolition site to recycling facility was calculated using Google Maps. In this demolition project waste was sent four different recycling facilities - RGS 90, Samgräv/Fläxhult, Stena Recycling and Renova.

Transportation cost = (No. of hours for transport x driver wages/hour) + (Distance from construction/demolition site to receiver x 2 (To and fro) x Fuel price/litre / Truck fuel efficiency)

Calculation example of the mixed waste fraction transported to RGS 90 Recycling facility from the demolition site = (1 x 180) + (16 x2 x 12/4) = 276 SEK/Truck load

Transportation cost of mixed waste fraction = (Number of loads mixed waste fraction x Transportation cost per load) = = 55 x 276 = 15,180SEK

The transportation cost of all different material fractions transported to different recycling facilities in total is = 49,955SEK

Now let us consider a scenario where the waste was not sorted i.e. the entire waste generated was sent to the receiver as mixed waste. In this case, the entire waste would be sent to RGS 90. The transportation cost of sending all the mixed waste to RGS would be46,092SEK. Which means that (49,995 – 46,092) =3,903SEK extra is required.

However, from the data regarding transportation activities, it was observed that maximum utilization of trucks was not achieved during transporting waste to the recycling companies. Some trucks would contain 8 tons of waste, while some would contain only 3 tons of waste. This means that the full capacity of the trucks was not utilized. Further investigating this factor an optimum transportation cost was calculated. If all the truck loads were utilized to their maximum capacity for transporting the waste, the result would be a decrease in the number of loads to the recycling facility, from 167 to 106 loads in total.

The example shown below is mixed waste fraction:

Optimum number of truck loads for mixed waste= (Waste generated by material fraction in tons / Truck capacity in tons) = (275.2 / 8) = 34 Loads. The actual number of truck loads used to transport mixed waste was 55 and optimum number of truckloads required was 34 loads. Further investigation was carried to find out optimum transportation cost and to compare actual transportation cost with optimum transportation cost.

Optimum transportation cost = (Optimum number of truck loads for mixed waste x Transportation cost per load) = (34 x 276) = 9,384SEK

The optimum transportation cost of all the material fraction was =31,360SEK. The difference between actual and optimum transportation cost was 18,596SEK. During demolition process contractor, would have planned transportation accordingly, so that each and every truck leaving to recycling facility should be utilized to full capacity. In that case demolition company, would have saved 18,596SEK within the transportation itself.

Hence, the money saved by utilizing the full transportation capacity could be used to employ one extra worker for sorting of waste. This extra worker could be used for sorting the mixed waste fraction on the demolition site itself. This would have promoted better recycling rates of demolition waste. In fact, the demolition company would save some money since the receiver gate fee for individual material fraction would be reduced.

Receiver Gate Fee:

Total Receiver gate fee = weight of waste fraction in tons x gate fee/ton for that fraction
In this case, Receiver gate fee is 1,444,255SEK.

If no on-site sorting would take place, the entire gate fee would have to be for mixed waste.
In this case, the gate fee would be 3,969,732SEK.

The table below gives a comparison of the different scenarios.

Table 24. Cost comparison of sorting vs not sorting for case 2

Type of Cost	Present scenario (with sorting)	Without sorting
On-site sorting cost	259,2000SEK	0
Transportation cost	49,955SEK	39,412SEK
Receiver gate fee	1,444,255SEK	3,969,732SEK
Total cost	1,753,410SEK	4,009,144SEK

Case 3: Volvo Penta

Total Cost= On-site sorting cost + Transportation Cost + Receiver gate fee

On-site sorting cost = Number of man hours required for sorting x wages/hour

The duration for demolishing the Volvo Penta building was around 293 days. 7 extra workers, working for 8 hours a day were required for sorting waste.

On-site sorting cost = (Number of workers x Number of man hours x Wages/hour x total Duration of the project) = (7 x8 x180 x 293) = 2,953,440SEK

Transportation cost = Driver cost + Fuel cost

The distance from the demolition site to recycling facility was calculated using Google maps. In this demolition project waste was sent four different recycling facilities such as Samgräv AB, RGS 90, Stena Recycling and Renova.

Transportation cost = (No. of hours for transport x driver wages/hour) + (Distance from construction/demolition site to receiver x 2 (To and fro) x Fuel price/litre / Truck fuel efficiency)

Calculation example of the pure concrete fraction transported to Samgräv AB Recycling facility from the demolition site = (2 x 180) + (24 x 2 x 12/4) = 504SEK/Truck load

Transportation cost of pure concrete fraction = (Number of loads pure concrete fraction x Transportation cost per load) = 265 x 504 = 133,560SEK. The transportation cost of all different material fractions transported to different recycling facilities in total is = 246,078SEK.

Now let us consider a scenario where the waste was not sorted i.e. the entire waste generated was sent to the receiver as mixed waste. In this case the entire waste would be sent to Renova. The transportation cost of sending all the mixed waste to Renova would be 213,143SEK. Which means that (246,078– 213,143) = 32,935SEK extra is required.

However, from the data regarding transportation activities, it was observed that maximum utilization of trucks was not achieved during transporting waste to the recycling companies. Some truck loads would contain 8 tons of waste, while some would contain only 3 tons of waste. This meant that the full capacity of the trucks was not utilized. Further investigating this factor an optimum transportation cost was calculated. If all the truck loads were utilized to their maximum capacity for transporting the waste, the result would be a decrease in the number of loads to the recycling facility, from 531 to 429 loads in total.

The example shown below is pure concrete fraction:

Optimum number of truck loads for pure concrete = (Waste generated by pure concrete in tons / Truck capacity tons) = (4965 / 20) = 248 Loads

The actual number of truck loads used to transport mixed waste was 265 loads and optimum number of truckloads required was 248. Further investigation was carried to find out optimum transportation cost and to compare actual transportation cost with optimum transportation cost.

Optimum transportation cost = (Optimum number of truck loads for pure concrete x Transportation cost per load) = ((248 x 504) = 124,992SEK.

The optimum transportation cost of all the material fraction was = 206,104SEK. The difference between actual and optimum transportation cost was 39,894SEK. During demolition process contractor, would have planned transportation accordingly, so that each and every truck leaving to recycling facility should be utilized to full capacity. In that case demolition company, would have saved 39,894SEK within the transportation itself.

Hence, the money saved by utilizing the full transportation capacity could be used to employ one extra worker for sorting of waste. This extra worker could be used for sorting the mixed waste fraction on the demolition site itself. This would have promoted better recycling rates of demolition waste. In fact, the demolition company would save some money since the receiver gate fee for individual material fraction would be reduced.

Receiver Gate Fee:

Total Receiver gate fee = weight of waste fraction in tons x gate fee/ton for that fraction
In this case, Receiver gate fee is 3,351,968SEK.

If no on-site sorting would take place, the entire gate fee would have to be for mixed waste.
In this case, the gate fee would be 10,607,428SEK.

The table below gives a comparison of the different scenarios.

Table 25. Cost comparison of sorting vs not sorting for case 3

Type of Cost	Present scenario (with sorting)	Without sorting
On-site sorting cost	2,953,440SEK	0
Transportation cost	246,078SEK	170,663SEK
Receiver gate fee	3,351,968SEK	10,607,428SEK
Total cost	6,551,486SEK	10,778,091SEK

Case 4: Ekodukt

Total Cost= On-site sorting cost + Transportation Cost + Receiver gate fee

On-site sorting cost = Number of man hours required for sorting x wages/hour

The duration for demolishing the Ekodukt at Sandsjöbacka was around 30 days. 2 extra workers, working for 8 hours a day were required for sorting waste.

On-site sorting cost = (Number of workers x Number of man hours x Wages/hour x total Duration of the project) = (2 x8 x180 x 30) = 86,400SEK

Transportation cost = Driver cost + Fuel cost

The distance from the demolition site to recycling facility was calculated using Google maps. In this demolition project waste was sent four different recycling facilities such as Skrotfragg, RGS 90, Stena Recycling and Renova.

Transportation Cost = (No. of hours for transport x driver wages/hour) + (Distance from construction/demolition site to receiver x 2 (To and fro) x Fuel price/litre / Truck fuel efficiency)

Calculation example of the scrap reinforcement fraction transported to Stena Recycling facility from the demolition site = (2 x 180) + (33 x 2 x 12/4) = 558SEK/Truck load

Transportation cost of scrap reinforcement fraction = (Number of loads scrap reinforcement fraction x Transportation cost per load) = = 21 x 558 = 11,718SEK. The transportation cost of all different material fractions transported to different recycling facilities in total is = 28,086SEK.

Now let us consider a scenario where the waste was not sorted i.e. the entire waste generated was sent to the receiver as mixed waste. In this case the entire waste would be sent to Skrotfragg recycling. The transportation cost of sending all the mixed waste to Skrotfragg recycling would be 24,174SEK. Which means that (28,086– 24,174) = 3,912SEK extra is required.

However, from the data regarding transportation activities, it was observed that maximum utilization of trucks was not achieved during transporting waste to the recycling companies. Some truck loads would contain 8 tons of waste, while some would contain only 3 tons of waste. This meant that the full capacity of the trucks was not utilized. Further investigating this factor an optimum transportation cost was calculated. If all the truck loads were utilized to their maximum capacity for transporting the waste, the result would be a decrease in the number of loads to the recycling facility, from 51 to 41 loads in total.

The example shown below is scrap reinforcement fraction:

Optimum number of truck loads for scrap reinforcement = (Waste generated by pure concrete in tons / Truck capacity tons) = (145 / 9) = 16 Loads

The actual number of truck loads used to transport mixed waste was 21 loads and optimum number of truckloads required was 16. Further investigation was carried to find out optimum transportation cost and to compare actual transportation cost with optimum transportation cost.

Optimum transportation cost = (Optimum number of truck loads for scrap reinforcement x Transportation cost per load) = (16 x 558) = 8,928SEK

The optimum transportation cost of all the material fraction was = 22,825SEK. The difference between actual and optimum transportation cost was 5,261SEK. During demolition process contractor, would have planned transportation accordingly, so that each and every truck leaving to recycling facility should be utilized to full capacity. In that case demolition company, would have saved 5,261SEK within the transportation itself.

Receiver Gate Fee:

Total Receiver gate fee = weight of waste fraction in tons x gate fee/ton for that fraction
In this case, Receiver gate fee is 137,780SEK.

If no on-site sorting would take place, the entire gate fee would have to be for mixed waste.
In this case, the gate fee would be 396,890SEK.

The table below gives a comparison of the different scenarios.

Table 26. Cost comparison of sorting vs not sorting for case 4

Type of Cost	Present scenario (with sorting)	Without sorting
On-site sorting cost	86,400SEK	0
Transportation cost	28,086SEK	20,094SEK
Receiver gate fee	137,780SEK	396,890SEK
Total cost	252,266SEK	416,984SEK

Case 5: Construction Project Galleria

Total Cost= On-site sorting cost + Transportation Cost + Receiver gate fee

On-site sorting cost = Number of man hours required for sorting x wages/hour

The Mölndals galleria was an ongoing project which is expected to be completed in 2018. The total cost calculation is performed by considering data from 2015 week 32 to 2016 week 47. In this project 3 extra workers, working for 8 hours a day were required for sorting the construction waste.

On-site sorting cost = (Number of workers x Number of man hours x Wages/hour x total Duration of the project) = (3 x8 x180 x 402) = 1,536,640SEK

Transportation cost = Driver cost + Fuel cost

The distance from the construction site to NCC recycling facility was calculated using Google maps. In this construction project waste was sent to only NCC recycling facility.

Transportation cost = (No. of hours for transport x driver wages/hour) + (Distance from construction/demolition site to receiver x 2 (To and fro) x Fuel price/litre / Truck fuel efficiency)

Calculation example of the combustible waste fraction transported to NCC Recycling facility from the construction site = (1 x 180) + (14 x 2 x 12/4) = 264SEK/Truck load

Transportation cost of combustible waste fraction = (Number of loads scrap reinforcement fraction x Transportation cost per load) = 30 x 264 = 7,920SEK. The transportation cost of all different material fractions transported to NCC recycling facility in total is = 34,584SEK.

Receiver Gate Fee:

Total Receiver gate fee = weight of waste fraction in tons x gate fee/ton for that fraction
In this case, Receiver gate fee is 18,760,038SEK.

If no on-site sorting would take place, the entire gate fee would have to be for mixed waste.
In this case, the gate fee would be 97,666,105SEK.

The table below gives a comparison of the different scenarios.

Table 27. Cost comparison of sorting vs not sorting for case 5

Type of Cost	Present scenario (with sorting)	Without sorting
On-site sorting cost	1,736,640SEK	0
Transportation cost	34,584SEK	29,344SEK
Receiver gate fee	18,760,038SEK	97,666,105SEK
Total cost	20,531,262SEK	97,695,449SEK