Assessment of ICT Tools for Construction Material Management in the Stockholm Region

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ROYAL INSTITUTE OF TECHNOLOGY

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Assessment of ICT Tools for Construction Material Management in the Stockholm Region

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Abstract

The aim of the master's thesis is to assess potential for implementing ICT tools to support smarter regional management of secondary construction materials. It is estimated that about 4.8-15.4 million tons of secondary construction material is generated in Stockholm every year. However the management of the material is not optimal. The methods chosen to complete the aim were based on systems analysis tools for an overview of the environmental effects from the system and a method focusing on interviews of salient stakeholders.

Two new management scenarios were proposed and studied. Both scenarios included an ICT tool, where buyers and sellers can exchange secondary material via a website, call center or application. One scenario also included a medium term storage solution to store material before being allocated. The results from the systems' analysis were mostly positive, showing a significant potential reduction in GHG emissions. Also a high potential economic profit was estimated. Most stakeholders responded positively to the proposed scenarios. However, the stakeholders also pointed out some challenges with the system. Such as the unwillingness of companies to corporate together and that planning is very sensitive to changes. Due to the major potential gain, it is recommended to continue the development of such a project with a key client as owner and large contractors as strategic business partners.

Acknowledgements

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I want to show my gratitude to my family and friends, who have supported me in pursuing my dreams abroad. And lastly, I want to thank my partner for sparring with me and inspiring me to do better every day.

Contents

List of Abbreviation

C&DW	Construction and Demolition Waste
EFTA	European Free Trade Association
ERP	Enterprise Resource Planning
EU27	European Union’s 27 member states
GIS	Geographic Information System
GHG	Green House Gases
GPS	Global Positioning System
ICT	Information and Communication Technology
LCA	Life Cycle Assessment
MFA	Material Flow Analysis
RFID	Radio Frequency Identification
RRR	Required Rate of Return
SGU	Svenska Geologiska Undersökning – Geological Survey of Sweden
SME	Small and Medium Enterprises
SMS	Short Message Service
ZWS	Zero Waste Scotland

Definitions

Aggregates	Aggregates are a category of granular material which can be used in construction and will most commonly be sand, gravel, crushed stone and rock.(UEPG, 2014b)
Backfilling	According to the European Commission there is no clear definition of backfilling. However, backfilling is recovery operation where appropriate waste is applied for reclamation purposes either in excavated areas or for engineering purposes in landscaping and places where the waste can substitute non-waste materials. (Eurostat, 2011)
Business as Usual	Refers to the state of where no changes has occurred in relation to management (business)
Construction and Demolition Waste	Includes several different waste streams all arising from activities such as construction or demolition of building and infrastructure, road planning and maintenance. (European Commision, 2014a)
Information and Communication Technology	Technologies that support activities where information is involved. These activities could gathering, processing, storing and presenting data and will also involve collaboration and communication.(Gokhe, n.d.)
Secondary /recycled Construction Material (aggregates)	Can be defined in three ways. Aggregates can be a) obtained as a by-product from quarrying and mining operations b) obtained from other industrial processes e.g. incinerator ash and b) obtained from demolition and constructions of buildings, structures and civil engineering works. (British Geological Survery, 2013)
Virgin Material (Manufactured aggregates)	Are manufactured from mineral deposit which occurs naturally and specifically extracted for use as aggregates. (British Geological Survery, 2013)
Waste	*"Waste" means according to the Environmental Code any object, matter or substance belonging to a specific waste category which the holder disposes of or intends or is required to dispose of. (Ministry of Environment, p. 32)*

1 Introduction

This master thesis is a project within the SIMM-Center (Baltic Center for Sustainable Innovative Material Management). The center works in different projects to establish a long-term platform and business development for SME's within technology for a smarter management of soil- and rock material in Sweden and the Baltic Sea Region. This master thesis will look into adaptation of Information and Communication Technology (ICT) tools, specifically ICT tools for material management.

1.1 General Problem

The population of Stockholm is expected to increase with about 25 % by 2030 (Erman, 2013), hence the expected demand for aggregates will also increase and it is expected to increase by 1% per year (Arell, 2005). At the same time Sweden has, along with the European Commission, a target, that preparation for re-use, recycling and other material recovery of non-hazardous Construction and Demolition Waste (C&D waste), also including backfilling purposes, should reach a level of 70% before 2020 (Naturvårdsverket, 2012). Nevertheless, current trends show a recycling rate between 10% and 50% and therefore it must be increased (Naturvårdsverket, 2012). However, information about C&D waste flow is limited in Sweden and therefore the figures could be inaccurate

1.2 Specific Problem

To meet the various demands, goals and statistics for the construction industry, a list of Swedish and foreign organizations' ICT solutions has been compiled. Most of the solutions have a website as a base from where materials are exchanged, but also real time stock databases, GIS and telephone services have been introduced. However, due to unknown reasons, the success of these solutions has in many cases been limited and therefore a deeper investigation of the problem is needed.

1.3 Hypothesis

Development and implementation of specific ICT solutions will have a positive impact. The ICT solution will change the material management system in different parts of the construction industry. This will lead to improved management of material and increase the recycling rate of C&D waste, decrease level of transportation and thereby decrease the environmental impact of the defined system.

1.4 Aim

The aim of the master thesis is to evaluate the potential of ICT tools to support smarter regional management of recycled and reused heavy construction materials such as concrete, stone, soils, and asphalt.

1.5 Objectives

The main objectives of the master's thesis are as follows:

A. Quantify the amounts of secondary material available for upgrading (or for improved management/flows).
   A.2 Identify the stakeholders involved in the system and their respective roles

B. Identify current and potential ICT solutions

C. Create potential ICT solution for the stated problem

D. Present the identified technologies to stakeholders involved for feedback and priorities

E. Calculate, via scenarios, the potential effects of such ICT solutions (economic, environmental, and social) with systems' assessment tools

F. Create a SWOT-analysis based on the result from objective D and E

G. Examine the potential impact of legislative measures to promote the implementation of such management systems. (NVV, SCB)

1.6 System Boundaries

This master thesis includes only Swedish stakeholders, but cases from the rest of the world, mostly in northern European countries, which are known for having a high success rate for recycling of material, are included in the study. The time scope of the systems analysis goes to 2030. ICT in the construction industry is an area which has been studied for many years, where research has been performed as far back to as the 90's and has also covered a large geographical area. However, ICT is constantly changing and developing and the attitude towards ICT tools is also changing often to a more positive view as ICT is becoming a greater part of our everyday life. It is therefore important for this project that the literature is as up-to date as preferably from within the last 10 years.

1.7 Methods

Different methods have been used to gather information on the system of focus. Engagement methodologies such as workshops with actors, structured interviews, and informal interviews were used to support other methodologies such as scenario development and systems analysis. In

Figure 1, a flow of the different activities, objectives (parentheses) and methods [brackets] is shown. The figure shows which methods and activities were used in order to answer the objectives of this master thesis. Furthermore, the figure shows the order of the activities and it is possible to see in which part of the report each activity has been applied.

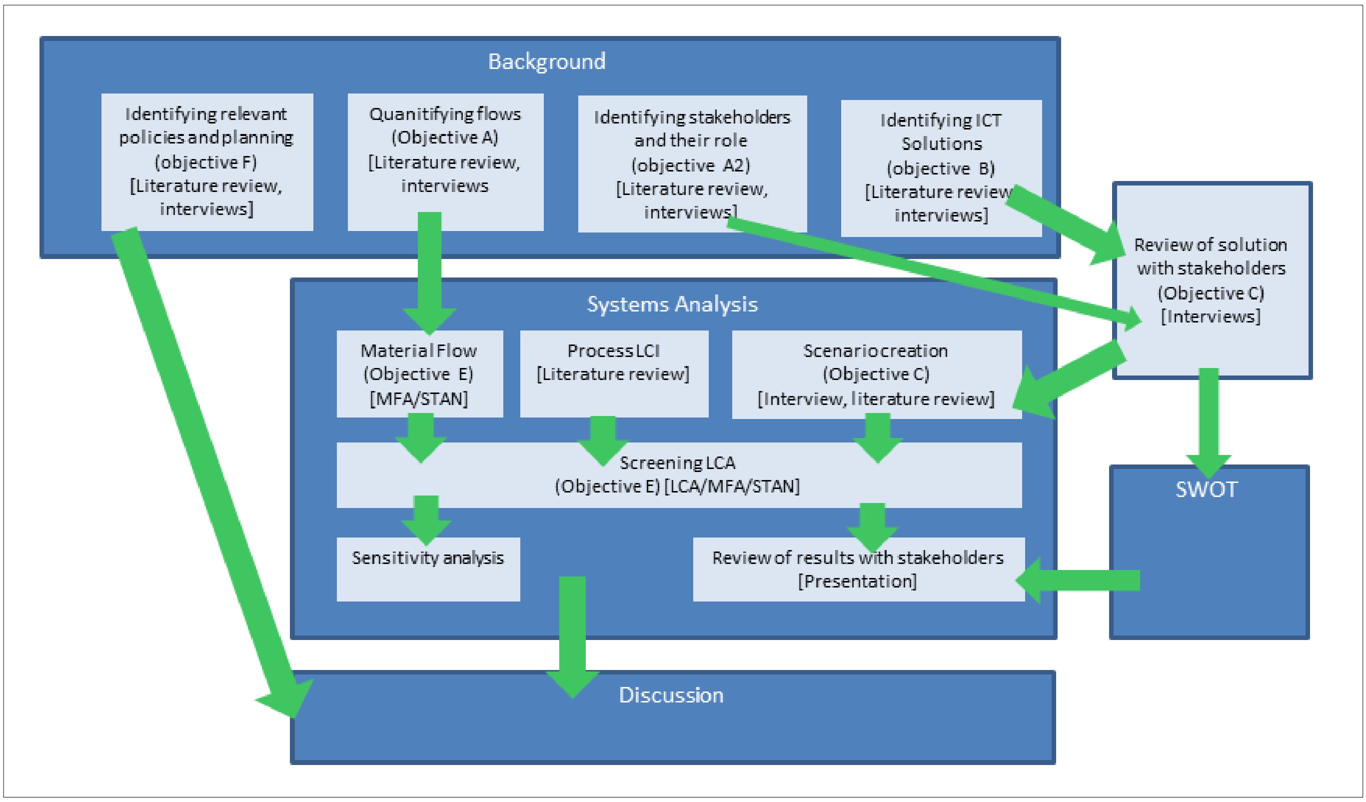


Figure 1 - Flow of the activities, objectives and methods

Scenario Development

Based on information found on existing ICT tools within construction and material management, scenarios were developed. This was done in order to illustrate a potential system for the future, both in order to have a tangible scenario to present to stakeholders, but also to get ideas for future systems and to be able to estimate the different benefits.

Stakeholder identification

The stakeholders for the project are identified through the course of different steps.

First, companies of all sizes working with heavy construction material in the right geographical proximity were identified. This study included, quarrying, production of aggregates, construction and recycling. Furthermore, one objective is to investigate the potential of legislative measures to promote the management system, therefore different governmental authorities were identified. In Table 1 an overview is presented of which sort of organizations have been participating.

Table 1 - Stakeholders represented in study

Authorities	Clients	Contractors	ICT deliverer
- The Ministry of environment - The Swedish EPA	- The Swedish Road Administration	- NCC roads - NCC Construction – Sweden - Peab	- Jordbörs

The second step is to identify the right person(s) within the different organizations. These persons are found either from the organization's websites or by contacting a company's contact person by either phone and/or e-mails.

When identifying the specific persons they were contacted by phone and/or e-mail to investigate the possibilities of having a personal meeting or phone conversation.

Stakeholder interviews
The stakeholders of the project have been targeted according to industry sectors. They were targeted in order to cover different viewpoints of the case. Therefore actors within recycling of aggregates and construction materials, transportation of goods, providers of aggregates and construction of buildings, roads etc. were chosen to be contacted. Furthermore, in order to have the opportunity to meet in person with stakeholders, actors within the county of Stockholm were chosen.

The contact with the actors had a dynamic structure where initial meetings and interviews were held and afterwards were followed up with questions.

<u>Questions</u>
The interviews were performed under a semi-structured interviewing method, meaning that questions were predefined (Eriksson, 2013), however the situation allowed other questions or subjects to be discussed.

The questions applied differed per stakeholder. Each company or organization has different maturity within technology and ICT and with that aspect in mind some stakeholders were asked questions based on either expectation or experience. However, the focus of the interviews was to establish the knowledge of the specific interviewee and thereby get relevant input on the scenarios presented. The interviewee was asked to evaluate scenarios from their own work perspective and knowledge of the field and to highlight their own perspective on current and future challenges with provision and recycling of aggregates and C&DW.

Calculation of potential impact

The benefits of implementing the different scenarios in the stakeholder companies were calculated based on estimations of reduction and/or increase of time, monetary cost and impact on environment. Impact on the environment can include emission of greenhouse gases, exploitation of natural resources and other impacts that were deemed relevant.

<u>Screening LCA</u>
The chosen method for calculating the environmental impact is a Screening LCA. The framework of LCA can be found in ISO 14040:2006 and the definition is according to ISO (2010): "*definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, the relationship between the LCA phases, and conditions for use of value choices and optional elements*". A screening LCA was chosen in order to limit the focus to

only one impact category and in order to quickly identify the problematic areas, but also to quickly change scenarios.

Material Flow Analysis (MFA)

MFA is an analytical method, which has been applied to quantify the flows of aggregates in the Stockholm region. An MFA is created by building up a system for a budget, which consists of system boundaries, processes flows and stock (Graedel & Allenby, 2010). In Figure 2 it is possible to see the conceptual system of the MFA created in this study.

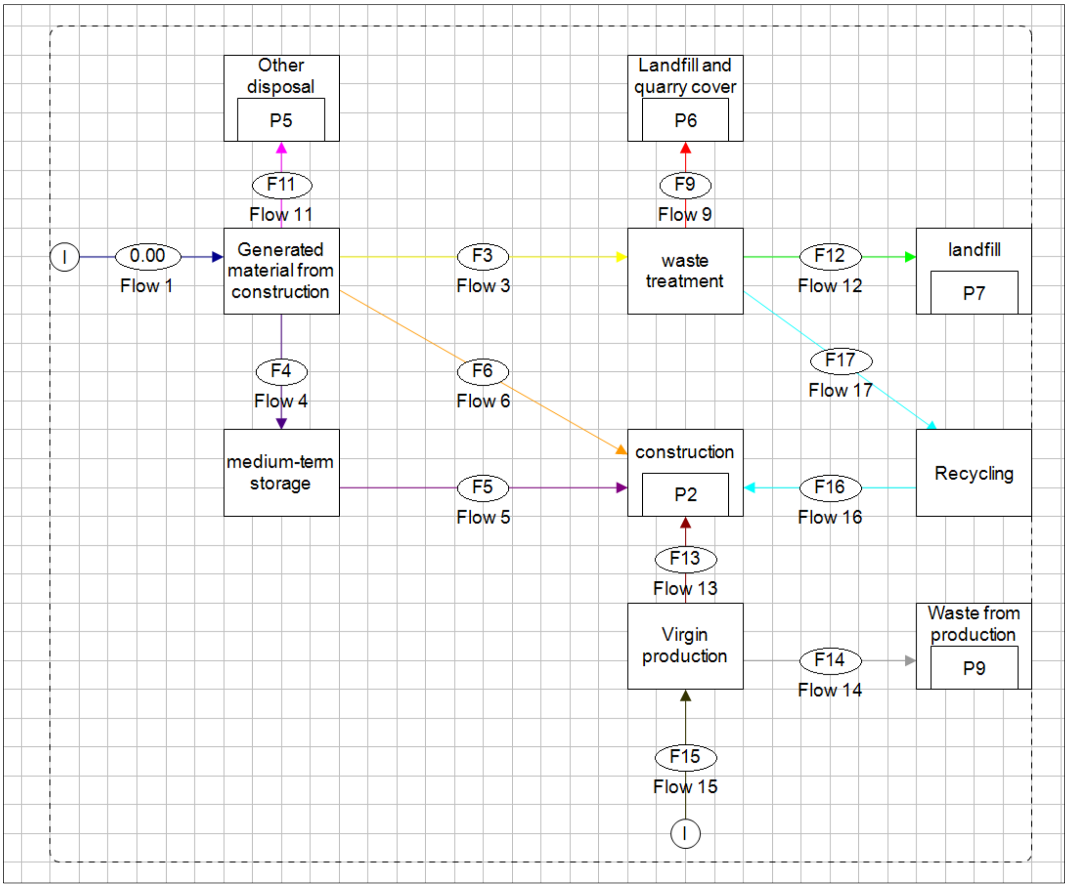


Figure 2 - Conceptual System of Material Flow in Stockholm Region

The conceptual system is the same as the one used for the Screening LCA, hence the two analytical methods are interrelated in this study. The base of the LCA study is the MFA, where each of the material flows has been assigned with an impact factor, where the environmental impact can be traced to each flow and process. Each of the boxes represents a process of the material life cycle and each of the lines represents flows of material. For each process or flow an impact is associated. The impact from the flows is caused by transportation of material.

Cost

To calculate the financial impact of the implementation of the suggested scenarios, NPV and Payback have been chosen. NPV shows the current value of the investments within a fixed project time and thereby it is possible to see if your investment is profitable. The payback time is a simple calculation

$$Payback\ time = \frac{Profit/year}{Total\ Investment}$$

Payback indicates when the capital investment will have been paid back.

SWOT

A Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis was carried out based on responses from stakeholders. Hence the name the SWOT analysis puts focus on strengths, weaknesses, opportunities and threats of implementing ICT in construction material management. By identifying these aspects and better understanding the broader context it allows us to work towards new strategies for material management on different levels.

2 Background

This chapter gives a background of aggregates and the aggregate life cycle including the use in the construction industry. Furthermore, this chapter looks at the material flow of aggregates and secondary material in the Stockholm Region and gives insight in C&DW together with the legislation, planning and management. Lastly the use of ICT in the Construction and Demolition industry will be approached and existing ICT tools are described.

2.1 Aggregates

In this section an overview of aggregates, aggregates' life cycle and purpose is given.

Aggregates are a category of granular material which can be used in construction and will most commonly be sand, gravel, crushed stone and rock. Aggregates can have many different purposes, but are often used as material under and for foundation and under roads and railroads. Aggregates are a natural product acquired and produced from quarries and pits, but can also occur as a by-product (secondary material) from industrial processes e.g. blasting of mountain material and other excavations. Another form of aggregates are recycled aggregates produced by reprocessing material which previously has been used in construction (UEPG, 2014b).

2.1.1 Aggregates in numbers

In the European Union's 27 member states and EU27 plus European Free Trade Association (EFTA) the total production of aggregates in 2012 was 2.7 billion tons and the industry has a turnover of more than 15 billion Euros. Statistics show a decline of production of 10% from 2011 to 2012 and it has been declining since 2007 due to the recession (UEPG, 2014b).

According to Sveriges Geologiska Undersökning (SGU) 78.7 million tons of aggregates were produced in 2012 in Sweden, which opposite to the total of Europe is an increase from the 77.2 million tons in 2011 (Sveriges Geologiska Undersökning, 2014). Of this 1 million tons were recycled material, which means only 1.2% of produced material came from recycled material. This number for the EU countries is 189 out of a total of million tons amounting to 6.6% meaning that Sweden's recycling rate is lower than the EU average. Belgium, Denmark, Germany and the Netherlands have the highest rate lying between 10 and 25% with the Netherlands in the top (UEPG, 2014a).

Moreover, it is estimated that Stockholm will soon experience a shortage of aggregates, especially of gravel, and therefore it is crucial to increase the rate of recycling and re-use of construction material to maintain the level of development (Länsstyrelsen I Stockholms Län, 2000).

2.1.2 Aggregates life cycle

The primary flow of aggregates can be seen in Figure 3. However the flows cover different types of material and therefore the raw material extraction will happen through different methods or different stages in the entire process.

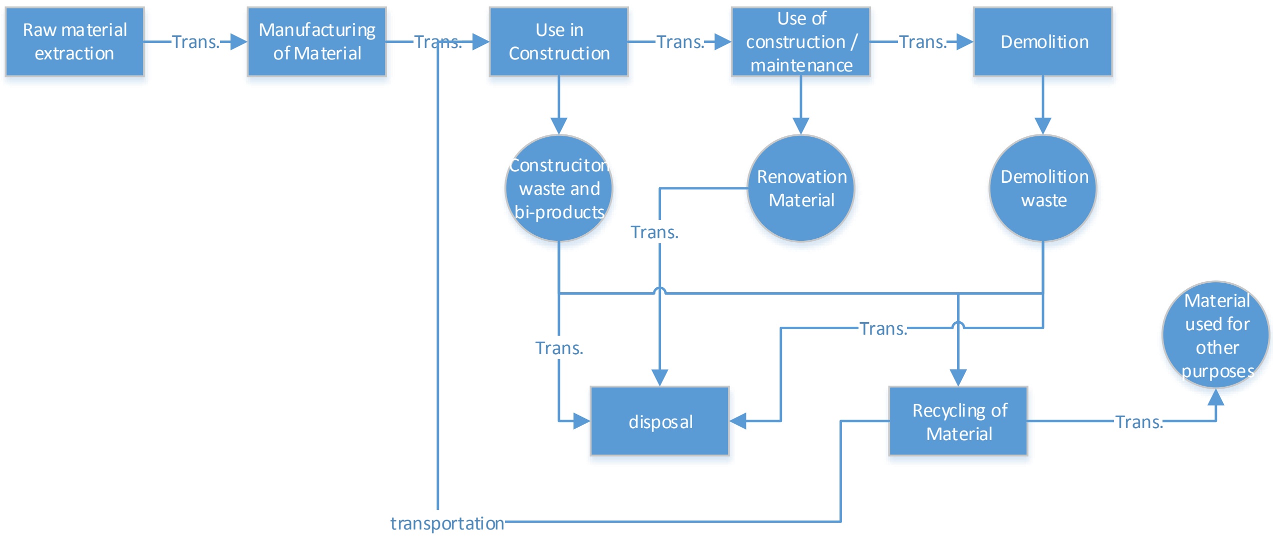


Figure 3 - Primary aggregate flow

2.1.2.1 Raw Material extraction and Manufacturing of aggregates

The manufacturing of virgin aggregates goes through different steps, which are illustrated in Figure 4

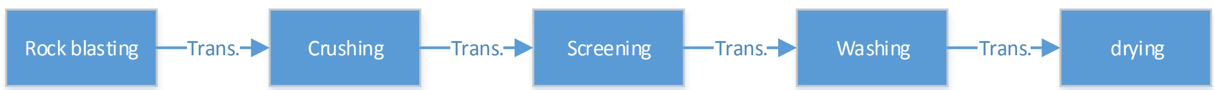


Figure 4 - Manufacturing of aggregates

The primary resources for aggregates are quarries. The materials one can extract/produce from different quarries are stone, rock, sand, gravel or slate and each goes through different processes. Of sand and gravel, 84% is produced in quarries and the rest from natural pits which corresponds to 5,9 million in all of Sweden (Sveriges Geologiska Undersökning, 2014). Before the material can be used it must be extracted the extraction process of the material is typically done by rock blasting and can be seen in Figure 5.

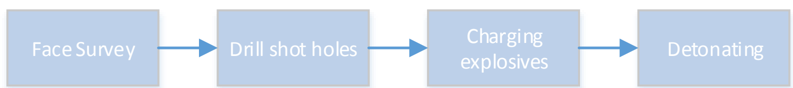


Figure 5 - Rock blasting process

The first part of the process is a face survey of the area wished to quarry. This is done in order to safely and efficiently design the blast. After this step it is now possible to drill shot holes positioned according to the blast design, thereafter checked and filled with explosives and detonated. A blast can fragment up to 60,000 tons of rock (Northstones Material, 2014). When the blasting is done one is left with a pile of crushed material with different sizes. This material will be transported to the next step typically by a wheel loader, truck or dump truck. In order for the material to get a more uniform size it goes through a crushing step (see Figure 6) which can be done in three to four stages.

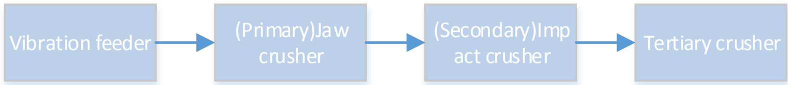


Figure 6 - Crushing process

The vibrating feeder will separate the smallest particles. The feeder will feed the crushers with the remaining pieces of rock which will be crushed into different sizes over separate stages. Hereafter the sizes are separated in a screening process and if necessary washed and dried and are then ready for use. This material will then typically be transported to the place of use or a place of storage.

2.1.2.2 Quality

As mentioned before the rocks have different particle sizes and have different designation according to the size (see Table 2)

Table 2 - Particle sizes

Particle name	Clay	Silt	Sand	Gravel	Crushed stone
Particle size	>0.004mm	0.004-0.063mm	0.063-2mm	2-256mm	<250mm

These are the common particles found in soil and the distribution may vary. Furthermore, clay and silt come from a different origin than a rock quarry and will not be processed the same way. The actual material from the rock quarries are screened into particle sizes from 0 to31.5mm and can be described in different categories such as 0/0.125, 0.125/0.25, 0.25/0.5, 1/2, 2/4, 4/8, 8/16, 16/32, 32/64 (Putzmeister, 2011).

2.1.2.3 Purpose of Aggregates

The rock material is often used as a component of composite material, such as concrete or asphalt, serving as reinforcement to the material. However it is also often seen that aggregates are used as a base under foundations, roads and railways and as ballast.

Two major purposes are considered road construction and construction of building. By-products are produced from these two processes (See Figure 7 and Figure 8)

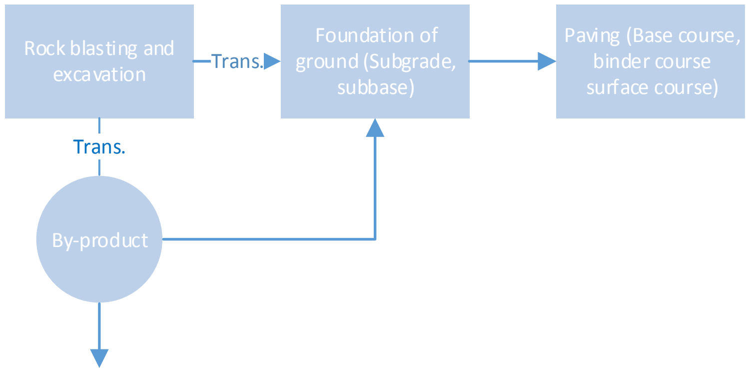


Figure 7 - Road construction process

The road construction is assumed to include rock blasting as it contains the same steps as if there was no rock formation on the way. The by-product produced will come from rock blasting of hill tops or excavation of tunnels and excavation of the ground. These products will be either re-used as a base for the roads, sent to a terminal after which they will be processed and preferably re-used or disposed in a landfill. The road will now be built up by several layers, the first layer (Subgrade) is a native layer, which can also be stabilized by different materials, the second layer can be unbound granular which could be the crushed rock from the blasting, if accessible, crushed slag or concrete. Hereafter the top layers will be applied, the base course serves to provide a stable foundation for the upper layers and the material will typically consist of gravel. The binder will now be applied and is course sand or fine gravel and lastly a surface course in the form of asphalt will be applied on the top layer. The different types of material can vary according to the type of road.

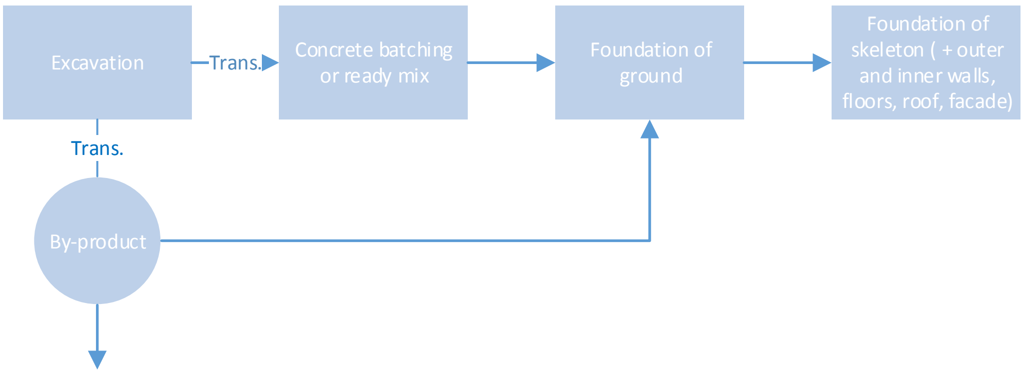


Figure 8 - Building construction process

The first step of the building process is excavation of the ground which leaves an excess of soil. The soil will have different compositions of material, but will typically have a mix of clay/silt, sand, gravel and stones. Some soil can be re-used in the same construction site, but some might be transported to other construction sites or to a terminal or quarry. The ground should now be ready for foundation which can also be done in various ways e.g. with a basement. The foundation is typically made with concrete which is a mix of water, sand and stones, and is often delivered as a ready mix with all ingredients except water or a central mix with water included; this material will come from a concrete plant. After the ground is founded and dry it is possible to install the skeleton and afterwards the outer and inner walls, floors, roof and façade. The walls of the frame will in many cases also consist of concrete.

2.1.2.4 Demolition/renovation

During a road's and building's life time it will be necessary to do renovations on both. However many of the processes will be similar to the processes of demolition of each of them and this section will therefore mainly focus on demolition (See Figure 9 and Figure 10)

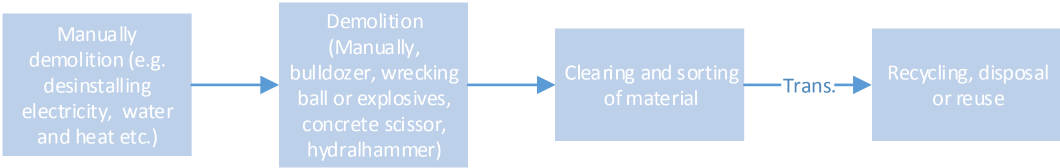


Figure 9 - Construction demolition process

When demolishing a building or doing major renovation work, the same processes will typically follow. First, it is necessary to manually remove or uninstall all electricity, water and heat in order to not cause accidents and to save possible valuable material. The next process is the demolishing itself which can be done by several methods. It can be necessary to demolish manually, because of either valuable façade materials or the geographical location of the building, e.g. in densely populated areas. However, it can also be done by bulldozers, wrecking balls or explosives, which requires a large open area. Finally, the demolished material will be cleared from the area and brought to recycling, disposal or reuse.

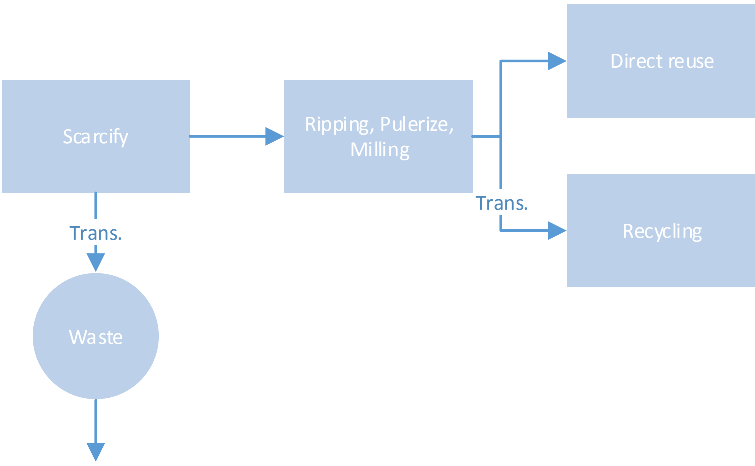


Figure 10 - Road demolition process

The demolition process of a road starts by the removal of the road lines marked to separate directions and indicate barriers. This is done in order to separate the line material from the asphalt, which will give the asphalt a lower quality when recycled. This process is typically done by scarifying. After this step the removal of pavement can begin. This can be done with various methods; ripping (with a mechanical digger), milling (machine with rotating drum) or pulverizing, which is mainly used for rehabilitation as the pulverized material will stay on the surface and mixed

with a stabilizer.
In many cases the roads are not intended to be removed, but to be repaved due to damage or expansion of road. Therefore the process is considered the same for both demolition and renovation. The pavement is possible to recycle 100%, however of the 23 million tons of asphalt the Nordic countries are producing each year, only 4-5 million tons are reclaimed (NVF, 2012).

In both cases the material might not be processed directly after demolition and will therefore be transported to a terminal or quarry to be stored.

2.1.2.5 Recycling/Reuse

As described in the previous section several types of material will be necessary to recycle, reuse or dispose after construction of building and roads. This section will not go into details of which methods can be used, but merely give and overview of what needs to be handled and which purposes they can be used for.

Asphalt

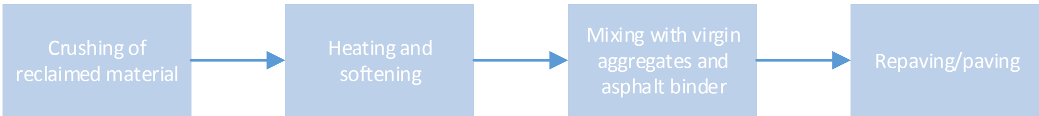


Figure 11 - Asphalt recycling process

Concrete

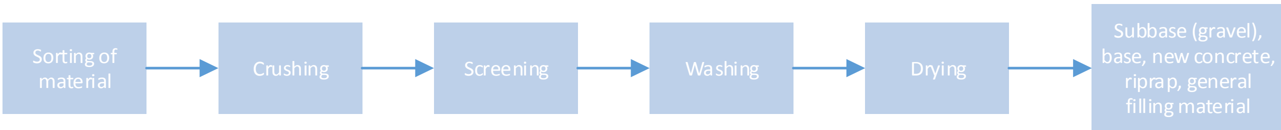


Figure 12 - Concrete recycling process

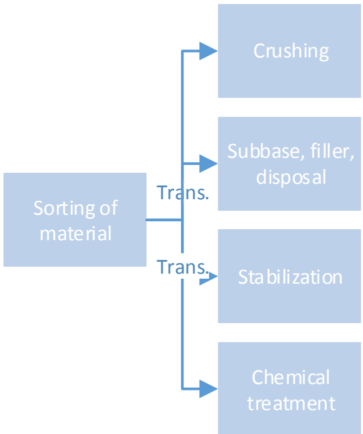


Figure 13 - Soil recycling process

Figure 14 - Uses of clay/silt

2.1.2.6 Disposal

If materials are not reused or recycled it will be disposed on a landfill in a controlled system. Statistics on the amount of Construction and Demolition waste that goes into landfill are scarce. The total amount of waste from the building sector is according the Swedish environmental protection agency 9,4 million tons (Naturvårdsverket, 2014b).

2.1.2.7 ICT's role in the life cycle

ICT has the potential of being implemented in many of the steps of the aggregate material life cycle. Basically there is a potential every time communication occurs or there is a movement or treatment of material.

As mentioned ICT can be applied every time there is a movement of material and this can both be internally at one actor, but also between two or more actors.

First the focus will lie on the first step of the life cycle, the aggregate material extraction. Tools that can be imagined to be used are internal signals telling when to stop drilling holes, when to detonate and when for trucks (or other suited mean of transportation) can collect exploded material and transport to manufacturing.

In the manufacturing process ICT can be used in between manufacturing step. Giving signal when one process is ready for more material in order to avoid bottlenecks looking at the material extraction process and manufacturing process which often takes place in same location. Therefore it would also be possible to connect to an ERP system. The ERP system can follow the quantities of specific materials (Items) through the different stages and monitor the quantities.

After manufacturing the material needs to be transported to various places, either to a storage or to place of use e.g. construction site. In order for this to happen a communication must be ongoing between supplier and receiver. The receiver will typically place an order with the supplier indicating a quality, volume and time of delivery. An order could be placed via different ICT tools such as telephone communication, e-mail or a specific ordering system with online communication. Furthermore, communication between either the receiver or supplier to the transportation company must take place. The means of communication will also be telephone communication, e-mail, or ordering system. At this stage there are a couple of issues that arise. First, it can be difficult for the supplier to predict the amount material to produce. At the same time it is difficult obtain the optimal load size for the trucks as the trucks in many cases will not even have a half full load(Sveriges officiella statistik, 2014). And lastly due to the location of quarries, prices are being pushed up. This is due to that transportation costs are expensive and prices are often fixed no matter the length transportation. Therefore actors are not buying from quarries close by.

As mentioned earlier, in the construction phase of both roads and construction creates waste or by-products. The by-product will often be directly reused, but if not the material needs to be either processed at a quarry or temporarily store. The receivers of the material must get the material specification and preferably in well time in advance in order to include in the planning process. Internally there will also be need for communication; this will include signals of when to start different processes, transportation between locations, ERP for registration of material.

In the demolition and renovation stage some of the same s can be applied as well. Furthermore communication is needed between demolition companies and recycling companies, because they need to communicate what type of material that will be delivered and in which quantities. However, there should also be communication from the recycling companies of how to best preserve a good quality of the material intended to be recycled. Last there must be communication between the recycling companies and the construction companies to inform about the availability of material together with volume and quality.

Beside the communication within the different stages of the material life cycle of aggregates, there are various ICT tools that can be applied that have an indirect effect on the material flow. Here can be mentioned; CAD, Spreadsheets, BIM (which has various functions), Intranet, VPN and Extranet. Moreover, it is of many stakeholders interest to know about the volumes of the material flow in all stages. A system would therefore benefit from each actor to inform on amount of material handled in their stage(s).

2.2 Material flow in Stockholm area

In this section an overview of production figures will be presented. This Includes both primary and secondary material. Furthermore, a projection for the future (2020) of the same figures will be made.

The current (2012) demand for aggregates, this including sand, gravel and stone, in the Stockholm region is 7.3 million Tons pr. year (Sveriges Geologiska Undersökning, 2014). This is understood as 7.3 million tons of virgin material is produced each year. As mentioned in the introduction, it is estimated that a large amount (4.8 – 15.4 million ton) (Lundberg & Frostell, 2012) of surplus material is generated in the Stockholm Region from infrastructure and construction projects. But the purpose of the material is not officially known. However, to achieve a fulfilling picture of the material flow a median number of 10 million ton pr. year in the Stockholm Region is assumed.

Future Demand (2020)

Stockholm City has estimated an increase in population from 2,091,000 people in 2012 to 2,500,000 people in 2030 (Erman, 2013). If the increase in population will be proportional it will result in an 8.7% decrease in population by 2020, therefore it is assumed that the increase in demand and excess material also will be 8.7%. The demand in 2020 is therefore an assumed to become 7.9 million ton and the excess material is assumed to become 1,087,000 ton.

2.3 Construction and Demolition waste in Stockholm, Sweden

C&DW is a big subject for discussion. Both official statistics and definition are argued over and no right way of managing the material has been found. This section will therefore try to clarify some of these issues and address the current challenges in management of C&DW.

As aggregates often are used in construction and infrastructure the aggregates as waste will often be defined as C&DW.C&DW is the largest waste stream in Europe (Cuperus, 2006). The management of the C&DW is regulated on a national level and will be different from country to country. (Cuperus, 2006) Officially in Sweden about 7.7 million tons of C&DW are reported every year (Naturvårdsverket, 2014a). However, suspicions are that the actual number is far larger (Lundberg & Frostell, 2012) as companies not always consider soil and stone masses as waste flows (Naturvårdsverket, 2014a). The total amount of C&DW of which the Stockholm Region is accounting for is not available. However, Stockholm Region is accounting for around 10% of virgin production of aggregates, which are used for construction projects.

2.3.1 Legislation and requirements

Companies must comply with a set of rules and requirement when handling C&DW. As mentioned management of C&DW is regulated on a national level and therefore a list rules exist. However, on EU level no specific legislation on C&DW exists. Nevertheless, some directives related to C&DW waste exist (Cuperus, 2006).

2.3.1.1 National legislation and Requirements

Environmental code

The environmental code is a legislative framework in Sweden from year 1999. The rules are related to management of land and water, nature conservation, the protection of plant and animal species, environmentally hazardous activities and health protection, water operations, genetic engineering, chemical products and waste. Since the environmental code is a framework law, the rules will not specify limit values for different operation or give a big level of detail when weighing the balance between different interests. It is of often being specified by central government agencies e.g. The EPA (The Ministry of Environment, 2014b). The legislation can be enforced by the different enforcement agencies e.g. County administrative boards or municipalities. Those will be given a list of enforcement tools and guidance by the governmental agencies.

Permits

When beginning a new construction or infrastructure project the responsible company must notify authorities on the upcoming project and have it approved. A list of documents must be presented to get permission e.g. construction plan (Sveriges Riksdag, 2011).

The rules applicable to this study, is regarding handling of C&D waste. Construction companies must obtain a permit in order to handled C&D waste. The company must comply rules regarding mixing of different types of waste. This means e.g. that is not allowed to mix the different types of waste, especially hazardous waste. This rule is enforced by the municipalities by sending out environmental inspectors who will audit the construction site. Furthermore, all companies must have a plan for handling of the waste, meaning companies must have a list of documents ready for the inspection.

Environmental quality goals
Sweden has 16 environmental quality goals. The goals are a description of what the Swedish environmental work should lead to (Naturvårdsverket, 2013). Within the quality goal ”good building environment” there are 10 clarifications (Naturvårdsverket, 2014c):

1. Sustainable urban structure
2. Sustainable planning
3. Infrastructure
4. Public transport, walking and cycling
5. Nature- and green areas
6. Cultural values in urban environment
7. Good daily environment
8. Health and security
9. Conservation of energy and natural resources
10. Sustainable waste management

2.3.1.2 EU legislation and Requirements

Waste Framework Directive
The directive is a list of concepts and definitions connected to management of waste e.g. definition of waste, recycling and recovery. It defines when waste stops being waste and become a secondary raw material and how to identify the difference between waste and by-products. Furthermore, it lays down some basic waste management principles. The principles require waste to be handled without causing danger to the environment or human health. Therefore EU Member states must prioritize the waste hierarchy, when forming legislation and policies. A target of the Directive include 70% preparing for re-use, recycling and other recovery of C&D waste (European Commision, 2014a).

Landfill Directive
The purpose of the Directive is to prevent or reduce the negative effects on the environment as good as possible, by presenting strict requirements for waste and landfills.
The Directive defines the different waste categories and landfills into different classes. Furthermore, the Directive defines unacceptable waste for landfilling. It sets up a system for permit for operating landfill sites and defines what a landfill permit application must include. Lastly, the directive gives the responsibility to the EU Member States that landfills must comply with the directive (European Commision, 2014b).

European standards

Briefly described, products produced from recycled material must fulfill the European standards which the European standardizing body CEN has elaborated, as well as national standards. The recycled aggregates are a subject to these standards that address technical (application issues) (Cuperus, 2006).

2.3.2 Responsibilities

In order to get a better idea of how construction project works and who responsible for the secondary is, a hierarchy of construction and infrastructure projects has been created.

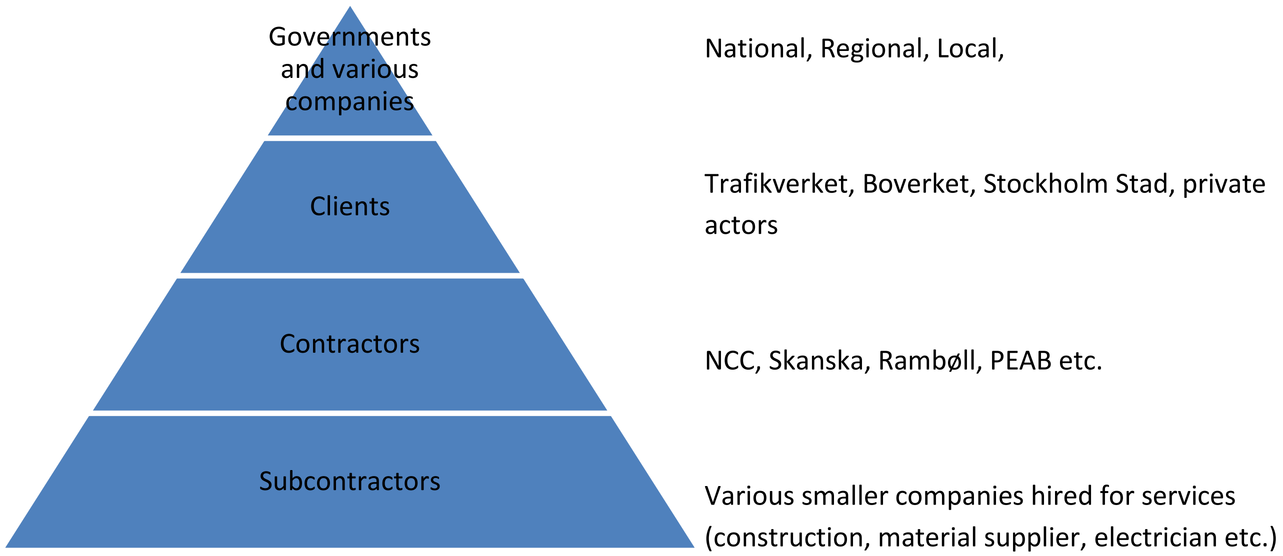


Figure 15 - Hierarchy of Construction and Infrastructure projects

Figure 15 represents the hierarchy of construction and infrastructure projects. (1) In the top of the pyramids the governments and various companies are placed. Companies in need of e.g. new office buildings, national governments decide they are e.g. in need of a new high way around a major city and local government needs building of a new public school. (2) Depending on whether the project is a construction project or an infrastructure project it would be ordered at either at what we call the "clients" which mainly in Sweden is or at contractors. If the project is an infrastructure project the client would mostly be *Trafikverket.* At *Trafikverket* they would take care of the overall planning of the project (see chapter 2.3.3). If e.g. a government wishes to invest in more social housing agencies/client such as The Swedish National Board of Housing, Building and Planning (Boverket) are contacted and will assist on planning. Also other organizations can act as client e.g. private actors and housing companies. (3) The client will distribute the different tasks/parts of the project to one or more contractors. Furthermore, the client would ensure that all rules and legislation is followed by the contractors. (4) As the client the contractors will also outsource different task e.g. Excavation of the ground to a subcontractor.

Outside the hierarchy there are also other actors contributing with different task during process. These include transportation companies which has the role of transporting the different masses from A to B and receivers of the surplus material. This can be either recycling companies, who recycles or deposits the masses or dumps (Swedish "tippar") who stores of deposits the masses. (Paulsson, Savola, & Dalaryd, 2010)

2.3.3 Planning

In order to understand the different actors' roles in the construction projects, an overview of the planning process is given in this section.

Figure 16 shows the process of planning for large construction project. This is a timely process, which can be many years from idea to action. Under the figure a description of each point can be found.

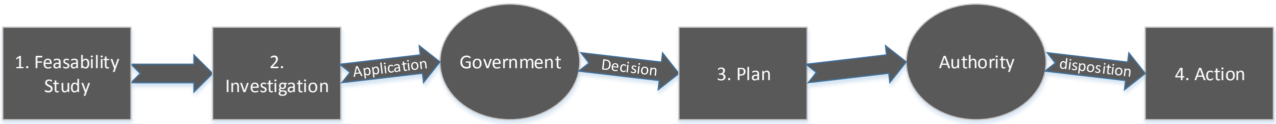


Figure 16 - Initial planning for large scale infrastructure project (Trafikverket, 2014)

1. Different stack solution and technical principles are developed. Where after a consultation is made with the society, organizations and authorities. The County Administrative will evaluate the environmental impact.
2. A few different location and design is developed and an alternative is selected in a second consultation. An environmental impact assessment must then be approved by the county administrative board.

Government: Reviews the admissibility and announces decision.

3. The chosen alternative is clarified regarding design and construction methods and an environmental impact assessment must be approved by the County administrative board. The plan is made together with the environmental court who reviews the relevant point under the environmental code.

Authorities: Gives disposition over area.

4. A base will have been build up for construction procurement and construction. Furthermore permit such as building permit and waste permits can be applied for.

These steps will apply for larger infrastructure projects and from the point of view of the client. However, contractors who have the operation responsibility of the projects will have different planning processes e.g. according to size and purpose of project. But, the work process will have some similar overall steps (Hendrickson, 2008).

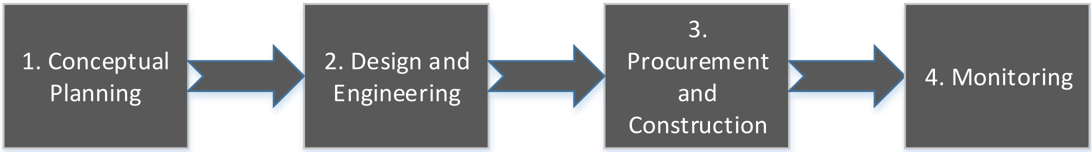


Figure 17 - Planning process for construction projects

In these steps (Figure 17), the planning will change over time. Maybe the design or timeframe will change as the planning proceeds. In the process it is not only contractors who have a role, authorities and supervisors work together with contractors in order to ensure all legislation is complied with (Paulsson et al., 2010). The actors' actions regarding handling of masses in a project are:

1. Authorities and Supervisors: Approval of Plan and Building law/Control Plan/Environmental Impact Assessment
2. Contractors: Creation of Mass balance
   Authorities and Supervisors: allocation of Building and Ground Permit
3. Contractors: Mass owner determination. Quarrying, determination of pollution and quality, reuse, recycling and disposal and procurement of masses with transport.
   Authorities and Supervisors: Approval of Public Procurement law. Notification about transport and handling of masses. Penalties for infringement.
4. Contractors: Following up if the masses are handled as planned.

2.3.4 Management of Surplus Aggregates

Management of aggregate is handled in different ways according which company is handling the material. In normal cases the client will give the right/the responsibility of managing and handling the excess material from infrastructure and construction project. This means that the contractors are the owners of the material they are in charge of. Different levels/types of technologies/tools are typical used for the management of aggregates. Some companies even have their own internal network or database for exchange of material between the different project the company's working on. A system like this obviously works best for a company working on several projects at the time. However, is not necessarily a given success and using the telephone network to place and acquire needed material is still a common method both internally in companies and between companies. Communicating via E-mail is also a common mean.

2.3.5 Definition of construction and demolition waste

A general concern expressed by the different public interviewees, is the definition of waste. There is an official definition for waste: *"Waste" means according to the Environmental Code any object, matter or substance belonging to a specific waste category which the holder disposes of or intends or is required to dispose of. (Ministry of Environment, p. 32)*

Which is also the definition of the Waste Framework Directive and in the in the European waste catalogue divided into different waste categories, where C&DW one of them.

Even though the definition is clearly stated some problems arise. As soon as a material is defined as waste it is required by law to have documentation for getting a permit to handle the waste (See section 2.3.1.2).The is a timely and resourceful process. This fact is a source for discussion between the private and public sector. Companies to a great extent are not interested in calling unused material waste. This will and is causing problems with waste statistics for Sweden. Because companies are avoiding calling material flows waste, it is very difficult to get the full picture of the material flow, and mapping the environmental impact from the construction and infrastructure sector. However, it has also been argued that some definitions in the Waste Framework Directive are not sufficient to identify a given waste stream as C&DW. But, the streams not easily identifiable represents a relative small amount compared to the actual amount (Bio Intelligent Service, 2011)

2.3.6 Waste Statistics

As mentioned in the previous chapter it is a challenge to obtain a precise picture of the waste flows in Sweden and in Stockholm particular.

E.g. it is estimated that in just Stockholm between 4.8 – 15.4 million ton soil and excavated material is generated (Lundberg & Frostell, 2012). However, official statistics from the Swedish EPA reports that the total amount of C&D waste is 7.7 million for the entire Sweden. This number also includes among other materials, soil and excavated material. By comparing these numbers it is obvious there is a miss-match between official and private numbers and according to the Swedish EPA. The picture of the different flows would most likely look very different if companies where cooperating better.

Furthermore, due to this gap the Swedish EPA is currently working on new methods for reporting statistics. Currently the Swedish EPA is receiving their statistics from third party. Their data is based on waste statistics from waste treatment plants, since the rate of waste treatment plants are much less than C&D companies. However, the suspicion is that much material is not passing waste treatment plants. Another problem that would occur if choosing to get data directly from companies (e.g. Form environmental reports) is that companies are divided in to three types of companies; A, B and C, where C-companies, the smaller companies are not required to have an environmental report. Therefore a large number of companies will be excluded from the statistics. The same applies if choosing a third option to interview large companies and base statistics and annual revenue. In Figure 18 it is possible to see the latest data from the Swedish EPA. Material that is not aggregates are excluded and the total C&D waste is therefore 7.06 million ton.

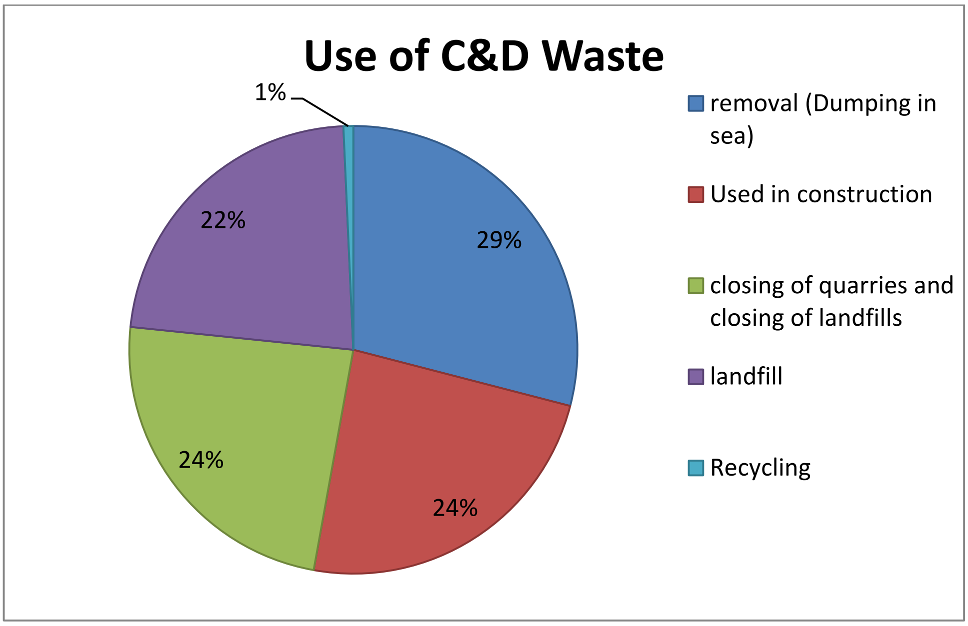


Figure 18 - Use of C&D waste in Stockholm Region (Naturvårdsverket, 2014a)

2.3.7 Challenges

Because of the problem, The Swedish EPA is currently trying to investigate other methods for generating statistics. To find new methods, but also to improve the recycling rate in Sweden. It is planned to study other countries which has a sound statistical foundation and has achieved good results in recycling. This study will not only hopefully give new inputs on how to change methods, but should also give an insight of the reason behind Sweden is performing worse than countries who reaches their goals.

2.4 ICT in the Construction and Demolition Sector

2.4.1 Existing ICT tools

A number of tools for management and exchange of surplus building material does exist. Examples of tools have been found in various countries and with various success rates. In Table 3, it is possible to an overview and characteristics of the identified tools. A more detailed description can be found in the sections below the table.

Table 3 - Identified ICT tools

Identified Tool	ICT Approach	Activity	Origin	Type of Material	Organization
EIS – Tocycle	Homepage, Tablet and Smartphone	Implemented in 2005, active in 2007. Currently not possible to check activity	Korea	Surplus material (Soil and rock)	Government owned
Byggmötet	Homepage	No activity since 2010	Sweden	Not Defined (all building material)	Private
Jordbörs*	Homepage	Currently no activity	Sweden	Soil and excavated material	Private
Maaporssi*	Homepage	Daily activity	Finland	Soil and excavated material	Private
Massabyte	Homepage, Tablet and Smartphone	Limited activity, most activity in Gothenburg area.	Sweden	Excavated material	Private
Resource Efficient Scotland – Construction Material Exchange	Homepage	No to limited activity	Scotland	Various types of material such as Aggregates, wood, paint etc.	Government owner
RMMS	Homepage, Tablet and Smartphone	Pilot	Finland	Not defined	Ramböll
NCC - Construction	E-mail	No activity	Sweden	Not defined	NCC
Schaktbanken	Homepage	No activity	Sweden	Not defined	Private
Massbalans	Homepage	Terminated after short test period (2010)	Sweden	All type of masses	"Vägverket" in corporation with Västra Götalands län

* Respectively Swedish and Finish edition of same homepage

Earth Information System, EIS - Tocycle

Tocycle is a concept which has been developed by Korea Institute of Human Settlements on the request of Ministry of Construction and Transportation in Korea after a wish to reduce waste resources by reusing of surplus soil and rocks and eventually provide an opportunity for reducing project costs (Tocycle, 2007). The Tocycle concept is based on a web-based Earth Information System, EIS. Hyuak Moon et al. Evaluates in a paper (Moon, Lee, Lee, & Kim, 2007) the effectiveness of EIS. The concept is realized on the website http://www.tocycle.com/en/index.html

EIS can transfer the surplus material and needs of construction site into a shared information system. The EIS operations are designed around three subsystems and other functions to give a better user-friendliness. Input, Search and statistical report are the three subsystems (Moon et al., 2007). In the input system the owner of a project can enter information related to earth and rock; this includes e.g. location, schedule, type of earth and rock, quantity of excavated backfill and specific information about the company. This information will then be available to search for in the search system by entering geographical proximity. The system gives input to an earth information statistics system that provides real-time statistics of the excavation or backfill.

The EIS system can be included in all steps of a construction project. Meaning that the management of resources can already begin in the design phase and will predict the future demand and surplus material.
In the EIS there is a GIS function. This function is used for entering location information by pointing at a map and sending an SMS. After the owner has registered the project, different participants of the project can now also enter surplus resources or search for needed information.

Because the government is owners of the EIS, it is required to make the regulations needed to make it work successfully, and monitor the volume of the shared resources.

By studying the website, it has been observed that now the service also offers an application for smartphones.

Byggmötet
Byggmötet, in English "construction meet" is a tool for contractors and property developers, which aims towards reducing material cost and contributing to a better ecosystem. The concept of Byggmötet is that you can get rid of you surplus resource from your project cost-free, by making your "colleague" pick of the resources and thereby avoid the transport and disposal cost. Byggmötet also includes trade with construction machines. Byggmötet consists of a web-based database www.byggmotet.se. Anybody can upload an advertisement for their surplus resources after creating a profile on the website and then everybody can search for the resources. (Byggmötet, 2014)

The website's search function is built up in simple way, by being able to search for a search word, a category where you can choose whether you want to sell, buy or hire and which type service/product, a specific product and the region of Sweden.

At the time writing the website does not seem to have any activity.

Jordbörs
Jordbörs, in English "Soil market" is a Swedish counterpart to the Finish website www.maaporssi.fi and can be found under www.jordbors.se. At Jordbörs you can create advertisement and search free for soil and you can leave contact information if you search for aggregates. The websites also includes other functions such as: offer and search for transport of the masses, offer and search for machine services. The website also has a general function of the possibility to offer general products and services. The website works the way, that when you have found the product you wish for, you can contact the website owner and receive contact information on the advertisement in exchange for a payment (Jordbörs Ab, 2014)

The website is open for use, but has never reach a success in Sweden and does currently not have any advertisement, but is a much bigger success in Finland, where the owner has a great profit on the business and the market potential is even bigger as the market is not saturated.

Massabyte
Massabyte, in English “mass exchange” is a new service in Sweden (www.massabyta.se). The service can be accessed on the computer, a smartphone or a tablet. It is possible to advertise in advance before beginning a project, in order to either allocate or acquire excavated material in advance. You will be able to know when and where there is excavated material there need to be transported. Therefore if you are a transportation company you can potentially find new customers and you will also be able to see on a map where you can deliver excavated material after use

Massabyte focuses a lot on advertisement in advance, as it will make it easier for companies to plan e.g. a material such as used asphalt is quite popular, but is often difficult to locate, because sometimes road projects are only ongoing for a short while maybe a day. Furthermore, Massabyte can by advertisement tell you where to dispose or deliver your unwanted excavated material (Massebyte, 2014).

Massbalans
A project initiated by the Swedish Trafikverket. A website was developed for the purpose of exchanging masses. The website consisted of mass ads with information about quantity, location and a short description of quality and contact information. The website was tested on a small group of actors in Västra Götalands län, but has never been publicly launched. The idea was not well received by head office of Trafikverket and the project was terminated before further measures were taken. (Paulsson et al., 2010)

Resource Efficient Scotland – Construction Material Exchange and Zero Waste Scotland – Business Resource Centre
Resource Efficient Scotland is a part Zero Waste Scotland (ZWS), which is a program managed by Waste & Resources Action Program on behalf of the Scottish Government. ZWS has an overall goal to reduce all waste. To reach this goal they provide different support programs, campaign and different interventions.

Construction Material Exchanged is a website available for everybody on http://cme.resourceefficientscotland.com/. On the website you can either search for advertise for surplus material. You will mark either “I am looking for…” or “I have extra of…”, next you choose material from list amongst these are also aggregate, concrete and soil and last you enter a city and you should now get search results where you will be able to find more information. If you use the function “I have extra of…” you will be directed to a page where you have to create a profile and fill in relevant information. If you do not have any hits with the function “I have extra of…” you will be referred to the website: http://www.zerowastescotland.org.uk/BusinessResourceCentre. The Business Resource Centre can refer you to companies that accept the searched material.

RMSS – Rambøll
RMSS stands for Regional Material Service System. RMSS is created by Ramböll and has been tested in the pilot project Absoils. RMSS is a system which is accessed via web and can therefore be activated by all computer, tablet and smartphone. The input/output of the system is definition of material in regards to volume, quality, location and schedule. The input will begin early in a project

and thereby it is possible to follow the schedule and get information about real-time. Furthermore it is connected to a map service which can show placement of material and thereby it is easy to get a picture of a large geographical area. (Koskela, 2012)

2.4.2 Study of ICT

Various of ICT tools are adapted within construction engineering and construction management. However, it is seen that the industry is not taking enough advantage of the functions ICT has to offer and is merely used as improvement tools rather than an agent for transforming and revolutionize the construction process (Ahmad & Sein, 2008). ICT has the potential of improving the communication practices and increasing the quality of documents, the speed of work, resulting in better economic control and will potentially also decrease errors in documentation (Nitithamyong & Skibniewski, 2004).

Several studies show that ICT in construction project can be difficult to implement and adopt. The construction industry in general has embraced ICT, but is not taking full advance of what is offered. It is mainly using as improvement tool and not as an aid to transform the process of construction (Ahmad & Sein, 2008). A paper (Adriaanse, Voordijk, & Dewulf, 2010) with two case studies indicates several reasons behind these adaption problems. The foremost problem is the complexity and resource requirements of implementing the tools itself. The choice of investing a lot of resources is difficult to reach, managers and other with top position need to see clear figures or have great arguments that will show that the idea will benefit the organization.

When a tool or solution is already implemented it is typical a challenge to integrate it in the workplace. This due to several issues; people use the new solution to other things than intended. Employees are not well enough trained in using the tools and the technical support is too limited, therefore the companies are unable to solve technical problems by themselves. And a major issue with the adaptation is that the outcome of the tool is not the wanted. Not all these factors are present in all companies and organization intending to implement ICT tools in their projects; however each of them can be great obstacle in achieving the objectives and it is crucial not make too many mistakes in the process of implementing the tools. This is due to the employees’ impression of the tool will stay, even if you get another change to improve.(Sørensen, Christiansson, & Svidt, 2009)

Furthermore, study conducted in South Africa by (Ahmad & Sein, 2008) investigated two aspects that might influence the use of ICT in the construction industry. (1) The teaching of ICT in leading Educational institution around the world and (2) the state of ICT as an important research field. Results from the study showed that both teaching and reaching are neglecting ICT.

ICT is often shown to be more challenging to implement in the construction industry. (Ahuja, Yang, & Shankar, 2009) A study from 2008 in India has identified several issues in respect to adaptation of ICT in SME’s building projects. The results is based on a questionnaire is conducted in the Indian construction industry. It was targeted towards project managers or employees with authority to manage project and in the survey sample three sorts of organization Contractors, Consultancies and Architects. This target group is a bit different from this thesis project as it focusing on material provision and reduction of impact on the environmental. However, it is maybe possible to draw parallels between the two studies as it can be some the same challenges the two group stand in front of.

In a paper of Sørensen et al. (2009), discussing ICT tools for construction project management, with focus on virtual models and RFID, has mentioned some challenges that must be approached, for a successful implementation of a system development, this is that is needs to "*Integrate interorganizational and conflicting working processes, There is lack of interoperability and de facto standards, need for better integration of the traditional paper document/drawing based working practices into modern virtual model based working paradigms* and *need for new competences at the middle management level or a project information officer service function who would be responsible for implementing the technology at the construction site* (Sørensen et al., 2009)*"*

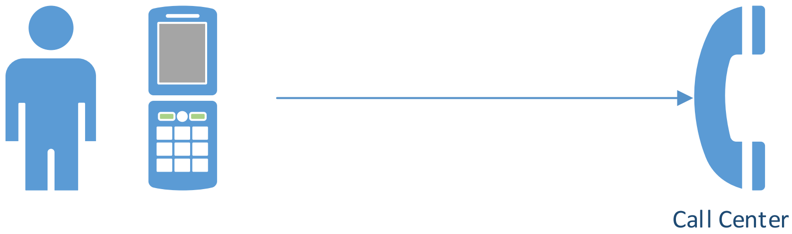
3 Results

3.1 ICT Approaches

Different ICT approaches will be presented in this chapter. These approaches will be based on different technologies and conditions e.g. including some of the technologies mentioned in chapter 2.1.2.7. Some scenarios will not be able to stand alone or it will be more desirable to combine different scenarios. The scenarios are created in order to evaluate in regards to implementing the solution in real life. The scenarios have been limited to include just solution that will apply to the stated problem area.

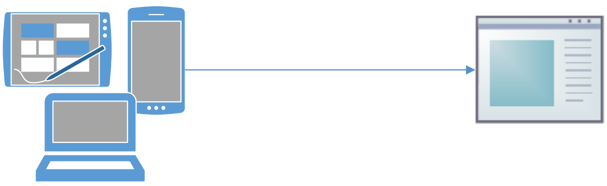
Approach 1 – Call Center based (CC)

A call center based system would work as the link between different actors within the construction industry. A company would call the CC, with a request of either acquiring masses or sell masses of excavated material or C&DW. The CC would be responsible of asking necessary questions and also to enter the given information in a database or find information in the database. The CC will identify either a buyer or a seller of the relevant material and mediate the deal between the two actors. The call center will require low level of training for the user as all the user needs to do is have information ready. The entire information flow of the call center scenario can be seen in Figure 21



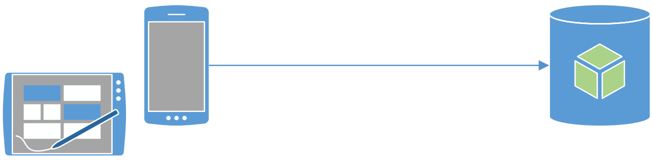
Approach 2 – Web-based Communication (Web)

Based on an online platform which can be accessed from any device with internet, the user will enter a website, where it is possible to log in with a user. The Website can be used for various purposes. To acquirer and sell surplus masses from construction work, but also to find statistics and material flows. The benefit with a website based system is that it allows the user to surf around in the system and extract information wanted. The entire information flow of the web scenario can be seen in Figure 22



Approach 3 – Application (App)

The application can be accessed with smartphones and tablets. It is the same principle as the web based approach. The advantage of such system is simplicity in the interface, there will be less functions to relate to, but can still be accessed any time. The entire information flow of the application scenario can be seen in Figure 22.



Sub-Approach 1 – Medium-Term Storage (MTS)

The principal of media-term storage is for the different actors to have a common area where material can be placed for storage before or after use. This could e.g. help construction sites not to have excessive material, but at the same time be able to order fair time in advance or help to store material for recycling until a waste treatment plant can accept it or another actor can use it in their project. A MTS must be placed in several location of the city and be of a short distance to the construction site, meaning maximum 10 km. The MTS should not only serve as storage, but should also facilitate functions, which often is handled at waste treatment plant in order to reduce transport. This means that it should be possible at the MTS to sort the C&DW and possibly also offer the possibility to do crushing and screening process.

Sub-Approach 2 – National Environmental Database (NED)

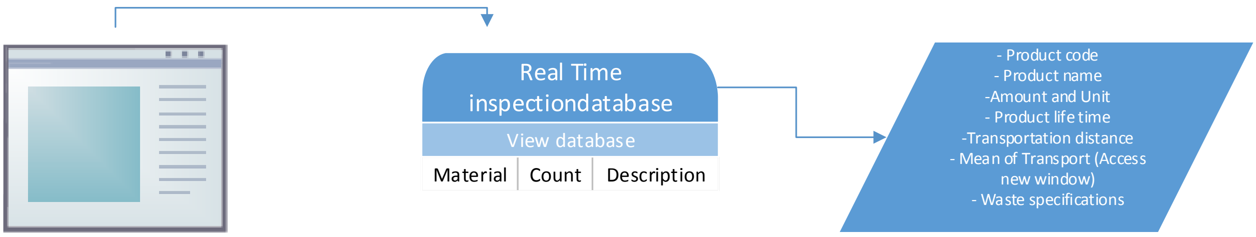


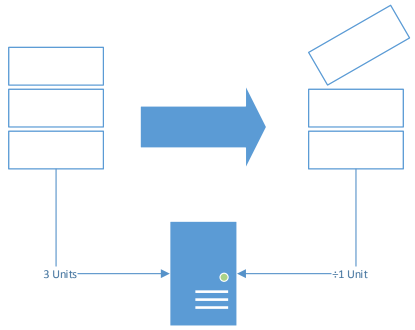
Figure 19 - National Environmental Database

This scenario is based on the flow seen in Figure 19 it is a web-based platform where companies can enter detailed information material flow, production, transportation and disposal. A database would be available for everyone to see and would create an output with statistics on different subjects.

Sub-Approach 3 – Global Positioning System, GPS

A GPS would be connected to the truck. The truck driver would need is to turn on the GPS at time of departure. The GPS would register the route of the truck and thereby give a picture of the material flow.

Sub-Approach 4– Enterprise Resource Planning, ERP
The materials are followed throughout the entire flow, scanning materials when moved or stock has changed and leading it into a server. The process can start already from the acquiring stage.



Sub-Approach 5 – Online map/GIS
In order to locate nearby materials, it is possible for the constructor to use a database with map integration. Based on location the system will identify different suppliers, where by it will be possible to see different product specification or specific types of companies/services. All companies will have access and add different statistics and data to their specific location. Figure 20 illustrates in a simplified way the principle of GIS.

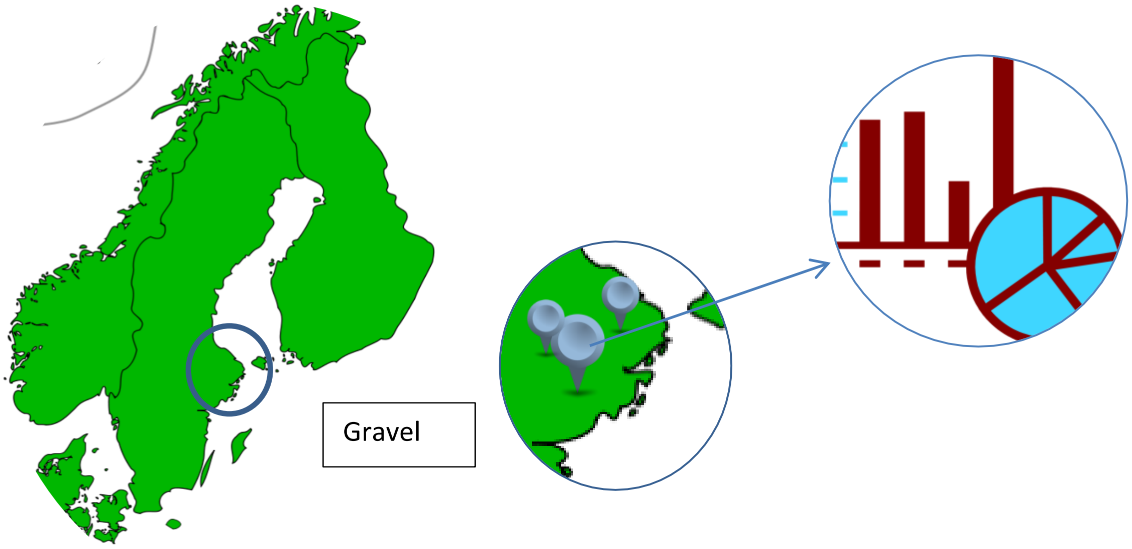


Figure 20 - Illustration of geographical proximity in potential ICT tool

3.1.1 Descriptions

Based on the stated problem, different approaches have been chosen. Three main scenarios, which can be combined if wanted, with other sub-approached. The combinations, requirements, amount of functions, benefit and level of cost is described in Table 4. As seen the requirements or the base is different in the different approaches, CC needs staff in the call center to handle the information flow, where the two other approaches Web and App only need an online platform. Furthermore, the information flow of the three approaches can be seen in Figure 21 and Figure 22. The information flow describes the principal of the approach and shows the different action that should be taken from the different actors.

Table 4 - Chosen approaches and their properties

Approach	Requirements	Possible combinations	Functions	Benefits	Cost
Call Center	Phone with head set, call center (staff), maintenance of platform	MTS, GPS	Few	Personal contact which avoids extra work and confusion	≈ 500.000 SEK + annual wages See section 3.2.3
Web	Computer, Smart phone, tablet, maintenance of platform	MTS, ERP, GIS, NED, GPS	Many	Simple functions, user friendly	≈ 500.000 See section 3.2.3
App	Smart phone, tablet, maintenance of platform	MTS, ERP, GIS, (NED), GPS	Medium	Many functions, covering all company's needs	≈ 500.000 See section 3.2.3

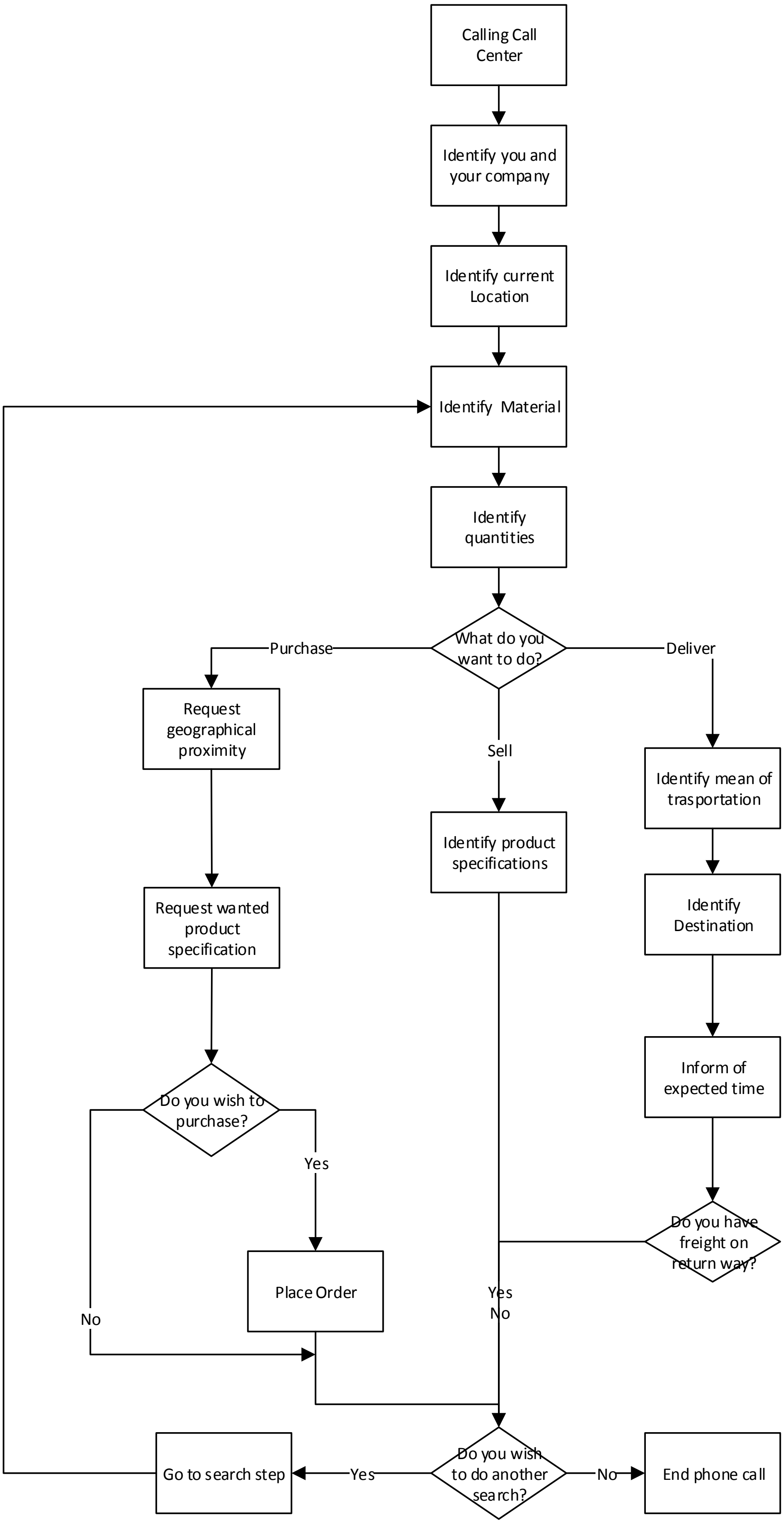


Figure 21 - Information flow for call center scenarios

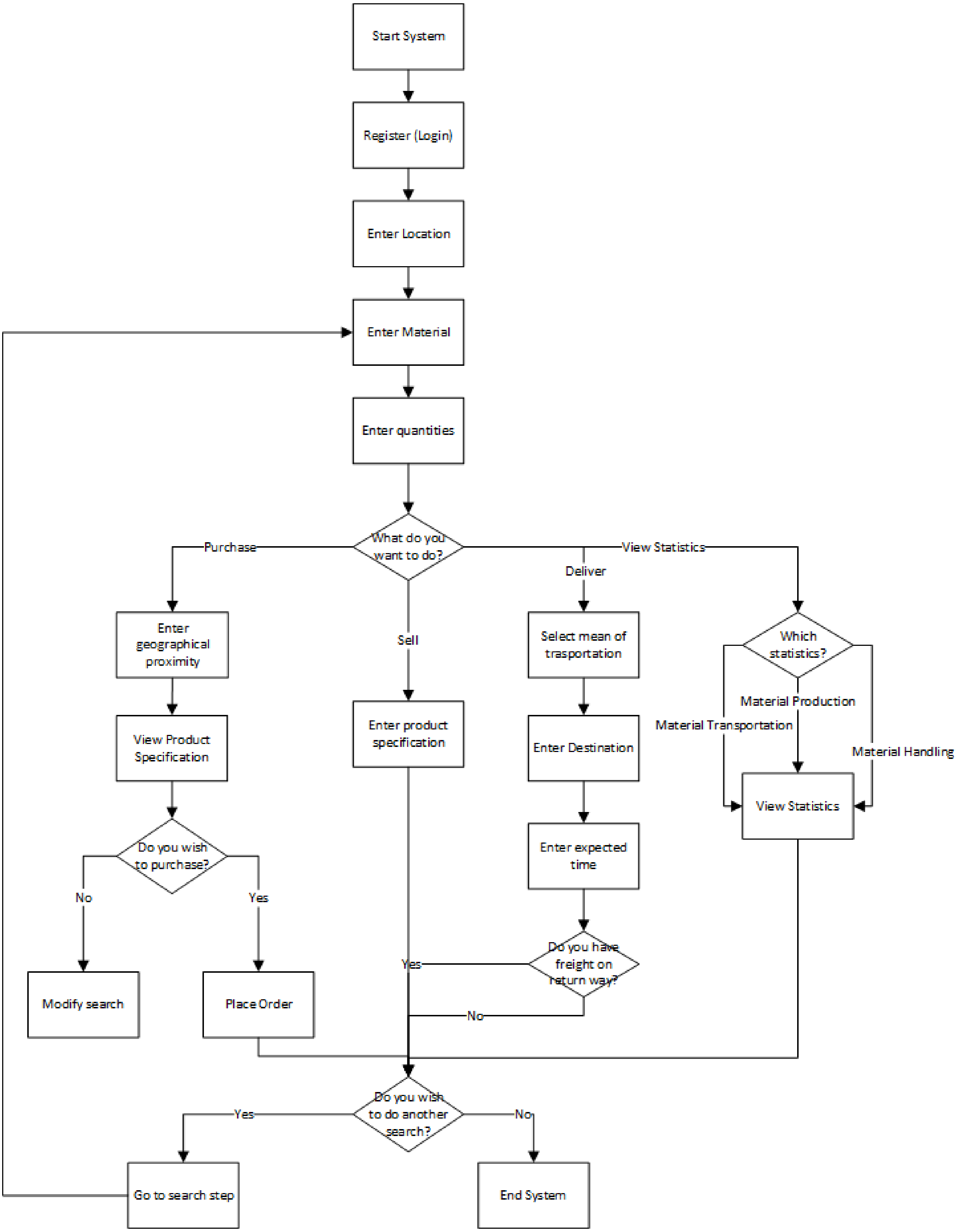


Figure 22 - Information flow for web- and app based scenario

3.1.2 Limitation of approaches

One purpose of creating three approaches using different technologies was to compare and choose one scenario, the “best” scenario. However, after starting industry interview, it quickly became clear that all scenarios would be necessary. This is because a company cannot afford for the system to break, meaning if e.g. the internet breaks down a phone line would be an excellent back-up. Moreover, it was made clear that for the possible users of the system all approaches were possible as most companies are technologically mature enough to handle the system. Meaning the most employees is supplied with a device having internet connection and a phone. Due to the limitation, two different alternatives will be used for calculation in the next chapters of the report:

1. Implementation of ICT (CC, Web and App)
2. Implementation of ICT + Medium Term Storage

In both approaches a GIS is incorporated in the ICT solution

3.2 Systems Analysis of current and alternative management of secondary material in the Stockholm Region

3.2.1 Material Flow Analysis (MFA)

A diagram has been developed to be able to follow the material flow through the different stages of the aggregates life cycle. As mentioned in the previous section two different alternatives have been proposed. These two alternatives will be illustrated in this section together with the current flow.

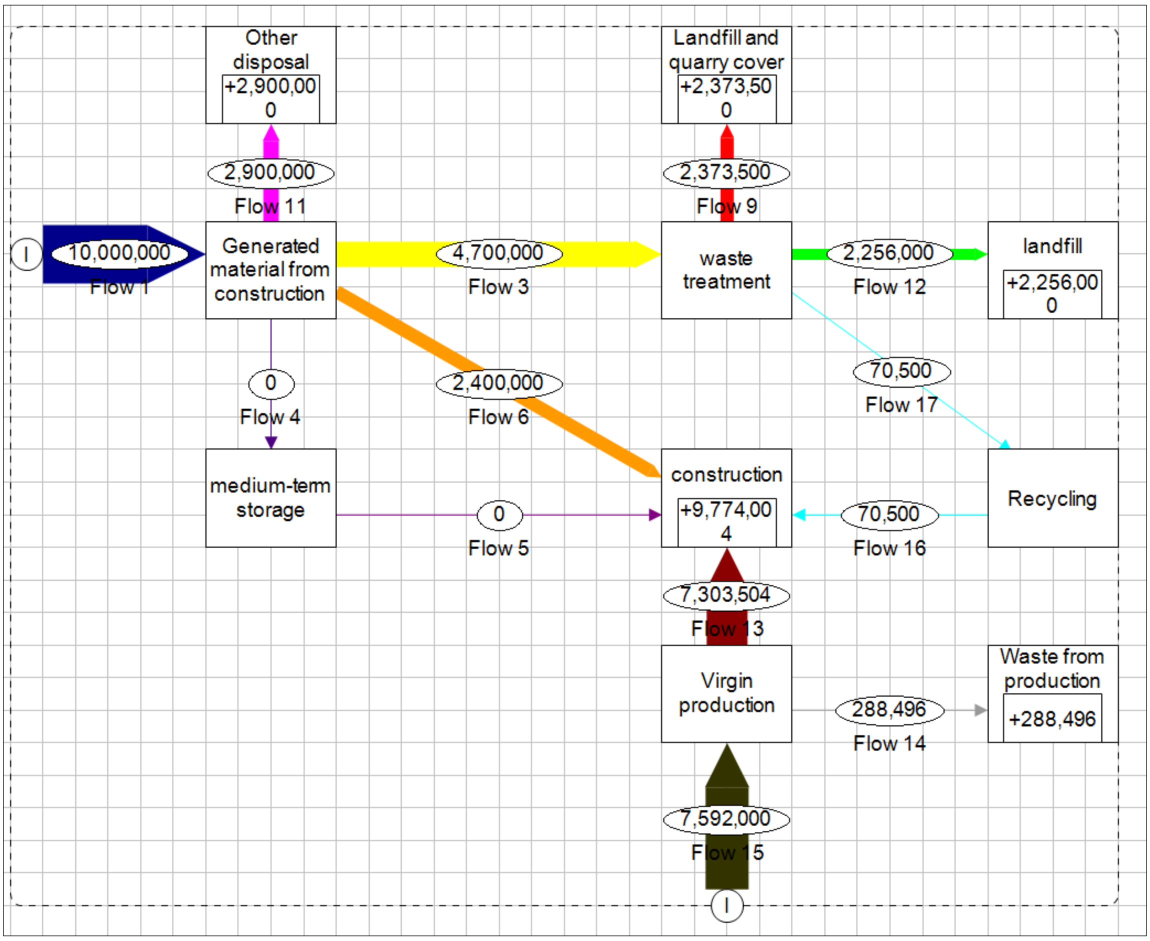


Figure 23 shows the estimation of the current flow. The flow is based on the same numbers used in the screening LCA and behind each of the flows there is also a transport. The MFA's shows where the major flows of material occur. And from comparing the different MFA's it will be possible to identify the different allocations and differences in size (quantity) of the flows.

Quantities

The current production of virgin material can be seen in Table 5

Table 5 - Virgin production of aggregates in Stockholm and Sweden (Sveriges Geologiska Undersökning, 2014)

	Production (Sweden)	Production (Stockholm)
Aggregates	78.7 million tons	7.3 million tons

Furthermore as mentioned in the introduction a generation between 4.8-15.4 million tons of secondary material is estimated in for the Stockholm Region. This gives a mean around 10 million tons

These two inputs and the official waste statistics from the Swedish EPA (2.3.6) can be applied in the conceptual system (1.7) and a MFA for the current situation is created (

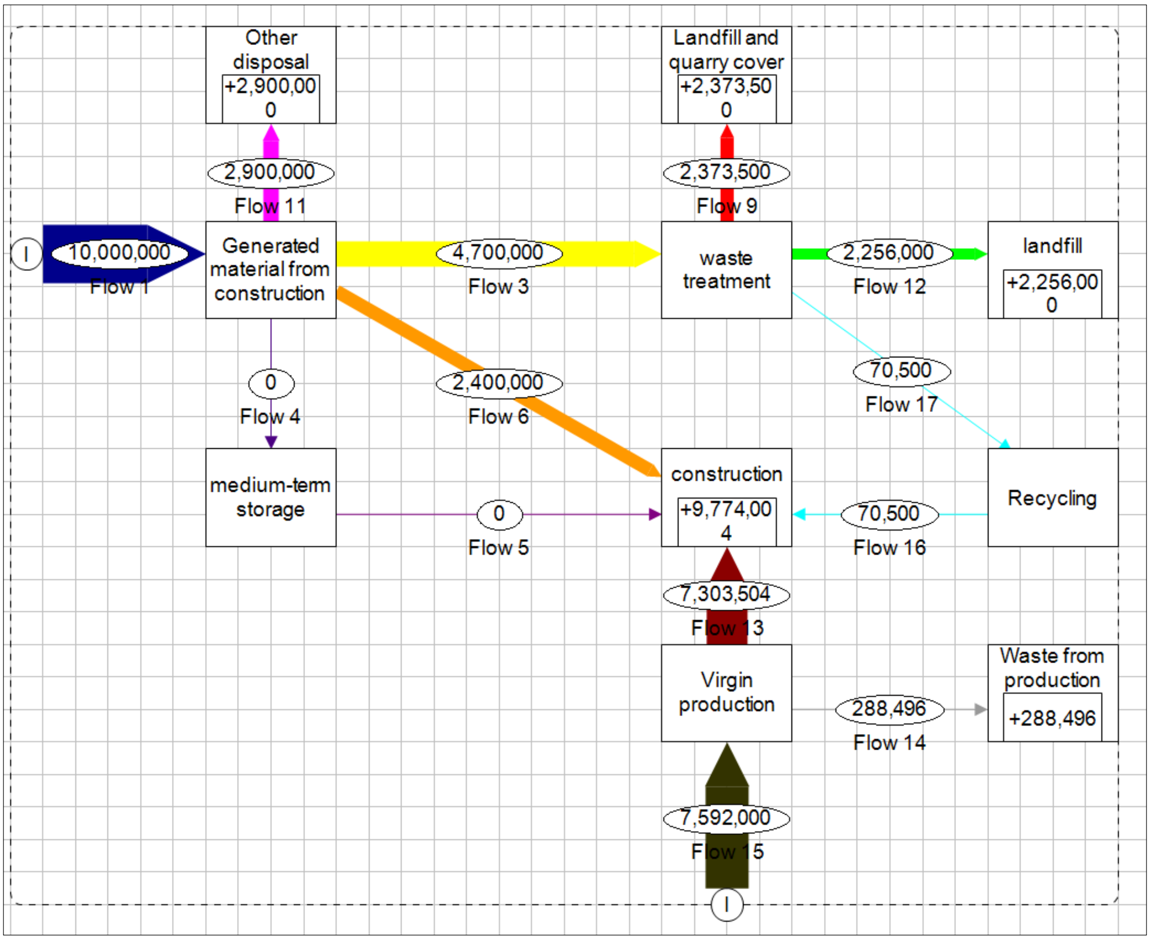


Figure 23).

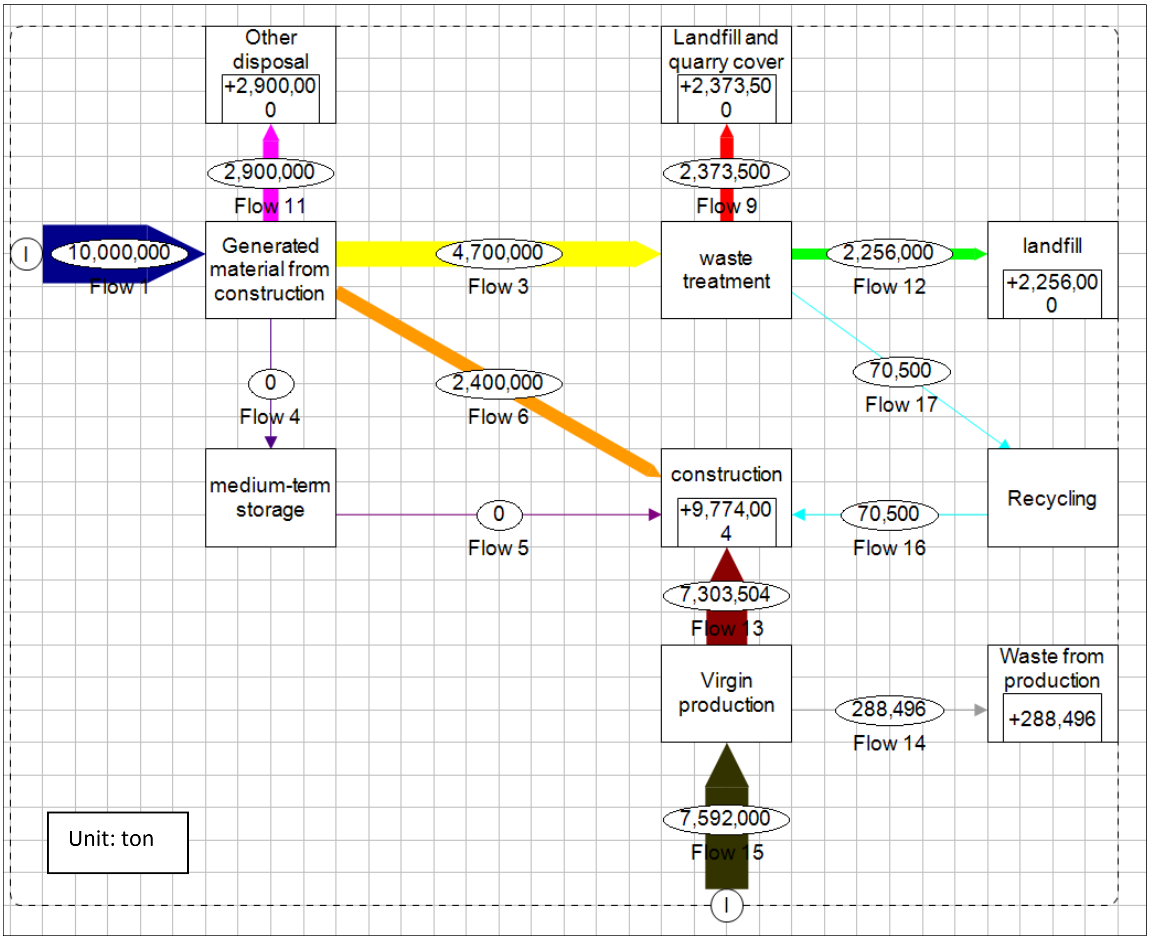


Figure 23 - MFA for Stockholm, 2012

ICT Scenario

Based and the current flow, a new flow have been developed showing the impact from implementing the suggested solution. The ICT Scenario is based on a different recycling rate and optimized transportation. Meaning the recycling rate is assumed to increase from 25% to 40 %, the truck load is assumed to increase by 25% and the distances decrease by 5%.

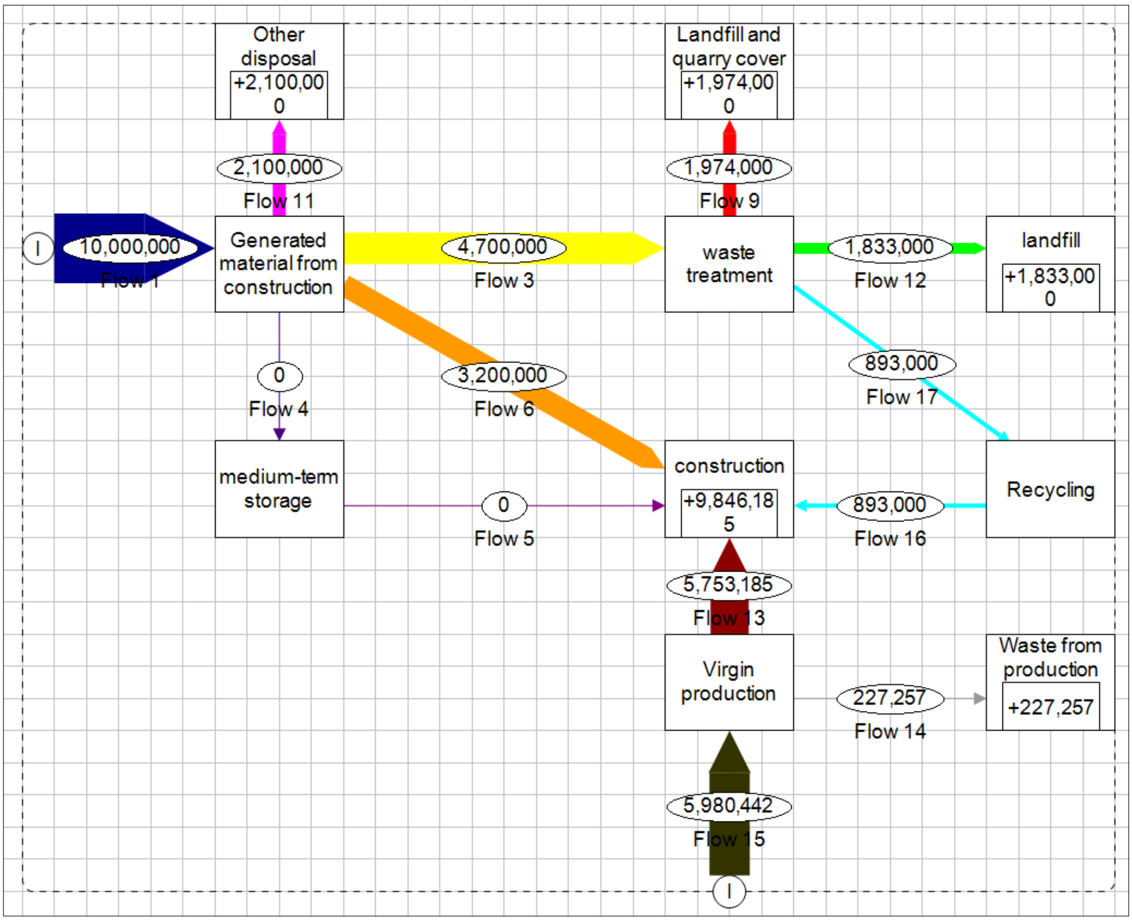


Figure 24 shows a flow with only ICT. It is here possible to see where the material flows have move to, when changing the different rates applied in the MFA. Most noticeable is the reduction in virgin material and the increase in recycling.

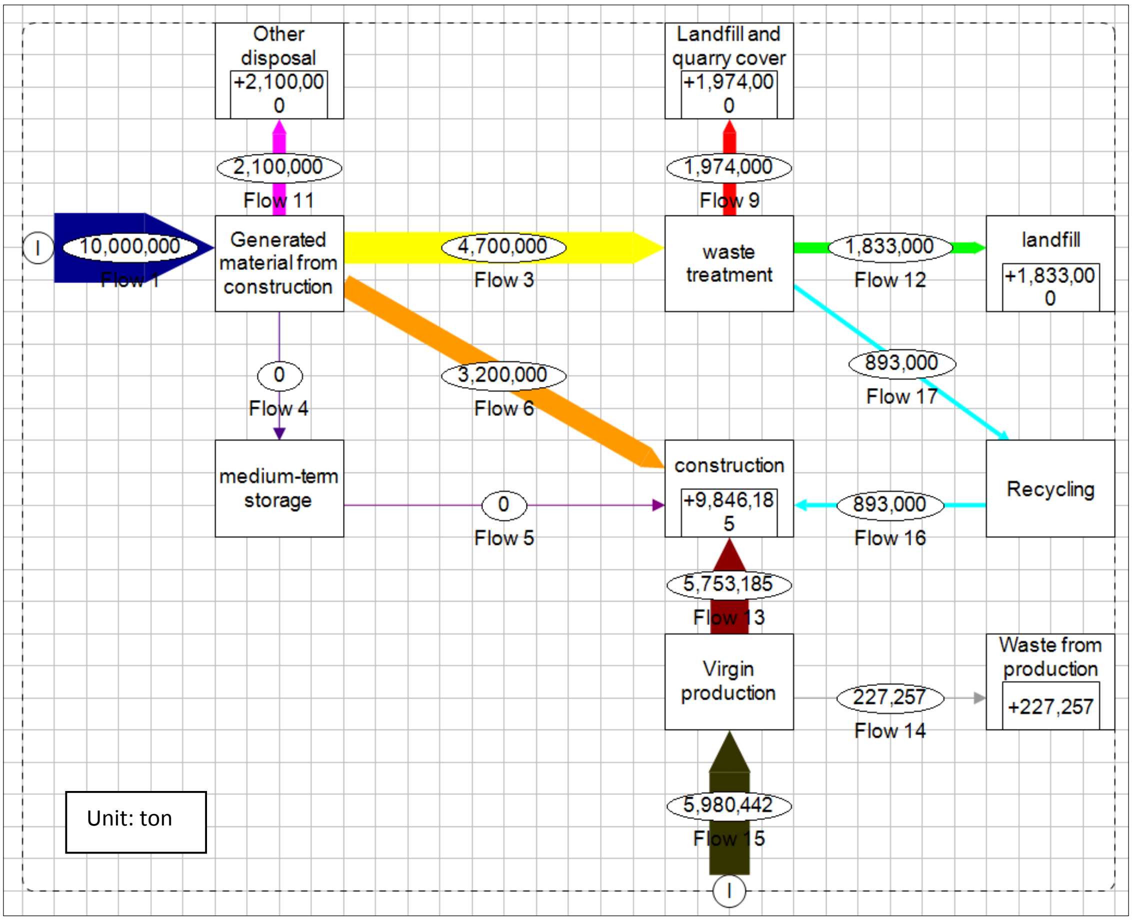


Figure 24 - MFA for ICT Scenario in Stockholm, 2012

ICT and MTS Scenario

An MFA for the ICT and MTA scenario has also been made. It is estimated, by implementing Medium Term Storages, more changes will occur. Recycling rate will increase further to 50%, truckload will increase by 50% and the distances will decrease by 10%. Figure 25 shows a flow with both ICT and MTS. This MFA is different from the first two, as material will be allocated to MTS. This means that more flows are now involved in the system and it is more difficult to see the changes. However, it is clear that still a significant amount of material is being recycled and a further decrease in virgin material is occurring.

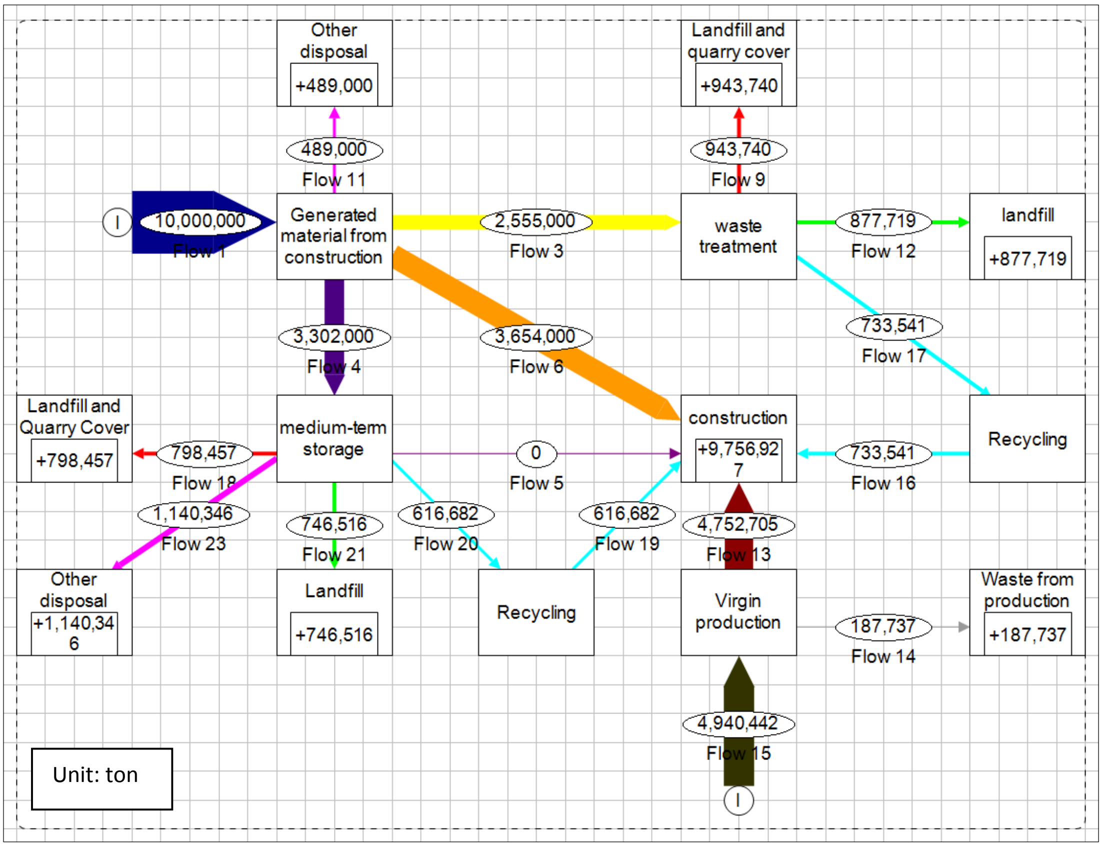


Figure 25 - MFA for ICT + MTS scenario in Stockholm, 2012

3.2.2 Screening LCA

As a part of evaluating the different scenarios a Screening LCA has been performed as described in section 1.7.

3.2.2.1 Goal and scope of the systems analysis study

As described previously in the introduction there is much transportation and material consumption associated with the construction industry. Both transportation and material are creating issues for the future society, transportation creating congestion, emissions of GHG, wearing of infrastructure and thereby a need for new infrastructure. Furthermore the world facing scarcity of material e.g. aggregates with a constant growth in population and people moving to urban areas (Erman, 2013). The purpose with possibly implementing various ICT solutions for material management of heavy construction material is to reduce the impact from transportation and material consumption. Therefore the objectives of this system analysis study are to calculate the potential change in these impacts according to various scenarios.

The impacts have been calculated based on a screening LCA, comparing different scenarios whereas one is the scenario is the business as usual (BaU) scenario and the LCA will therefore be a change-oriented LCA. Furthermore, the purpose of the study is to highlight, not only the benefits with implementing ICT solutions, but hopefully also the major issues within management of materials in the construction industry, meaning that the LCA will show the areas of significant impact in the life cycle of aggregates. As mentioned earlier the results from this study can be used for different purposes. To highlight problem areas and to evaluate possible solutions and the main audience of the study is active players within the construction industry; however the results can also be presented for public authority that can use it to consider the necessity “interfering” in the process with economic support, supporting legislation, or mandatory regulations.

Functional Unit

The functional unit is set to be one year’s production of and emerged aggregates in the Stockholm Region. This means the virgin production of aggregates and the secondary material arising after excavation and construction and demolition work.

The amount of material being a part of the construction industry in the Stockholm is very big, and therefore a functional unit of e.g. 1 tons would not properly illustrate the difference between the different scenarios. Having the total amount would illustrate the actual impact from the entire system.

System boundaries

The boundaries considered in this LCA study is illustrated in **Fel! Hittar inte referenskälla.**

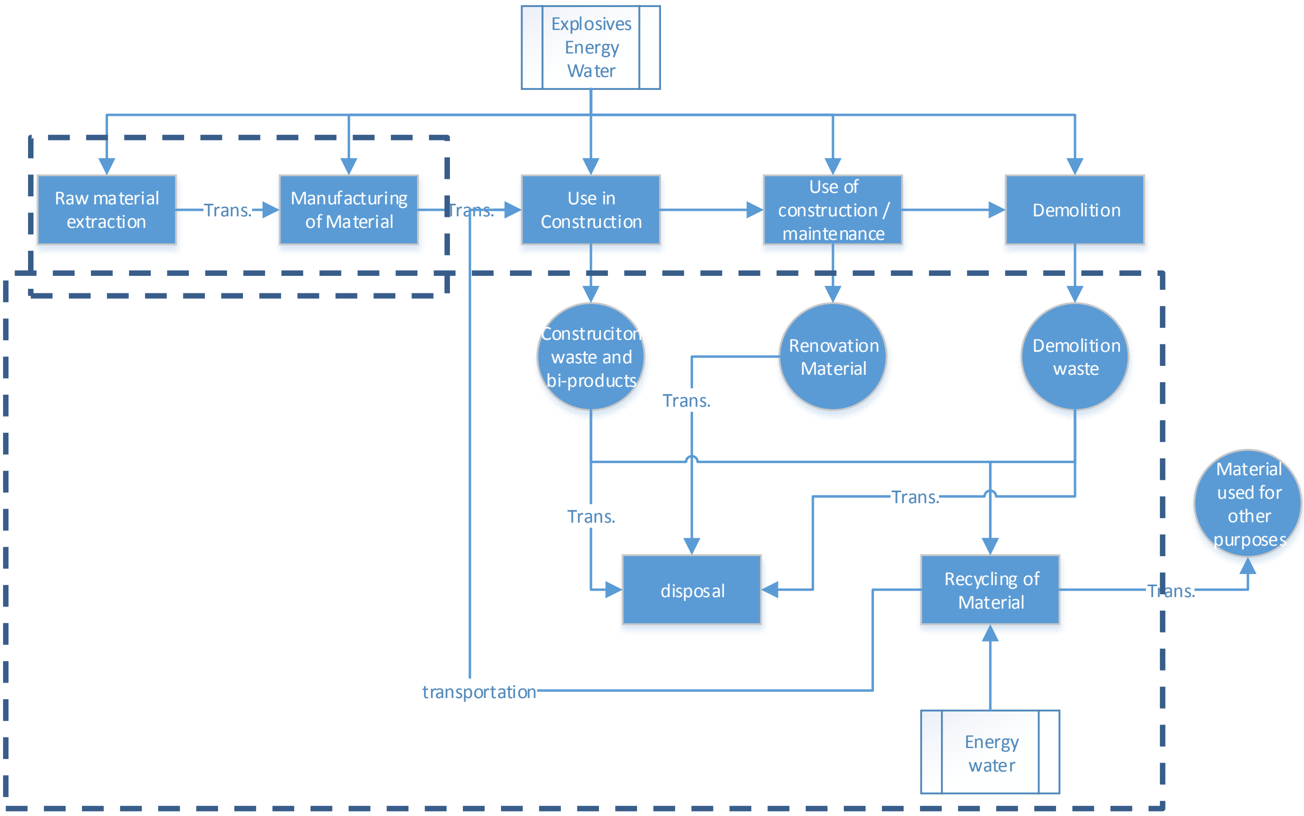


Figure 26 - System boundaries for screening LCA

The study considers all step of the aggregate life cycle from cradle to grave, and considers the recycling process and transportation after recycling. The limit is drawn however to activities and resources that will differ in different scenarios. This means that many elements in the construction and use phase will be excluded. The processes of construction will possible differ in the aspect of logistics of materials, however when constructing, the same energy, water and heat will be used, and the same goes for the use phase and demolition phase. It must however be mentioned that the flow of bi/waste products from the three phases will be considered in this study. During the research it has been brought to attention that there are several waste flows which are unknown for the public. These flows are e.g. unreported internal waste flows in companies and illegal landfilling and these will flows will estimated, however discarded from the emission calculation. Furthermore, hazardous waste is discarded from the study as it has a small potential being traded between companies.

Geographical boundaries

The project is taking place in the Stockholm region and is concerning companies in that area therefore it is assumed that most material comes from Stockholm and the Swedish way of production will be considered. However if data cannot be found specifically on Swedish methods, general data will be used. Scenarios will be created based transport routes within Stockholm region. The amount of imported aggregate will be disregarded from this study

Time horizon

The larger study looks at scenarios up to 2020 and this will also be applied for this system analysis study. It would also be interesting to look even further ahead and consider some of the factors that might change over the years, such as transport cost and the availability of aggregates. The data applied is aimed as being as up-to-date as possible preferably within the last ten years and some data will be collected directly from the source, meaning data from manufacturing, construction, recycling and transportation companies.

General assumptions for all scenarios

In order to compare the different scenarios and simplify calculation, different assumption must be made.

- In this study only truck transportation is considered, due to the geographical scope of the study. Stockholm region is considered and due to short transportation distances truck transportation g is mainly interesting to investigate.
- It is also assumed that the same sort fuel is used; however the model will adjust the fuel consumption pr. km. according to the load of the truck.
- The production and recycling of material will have the same emissions pr. kg. Of produced material no matter where the material is produced.
- The electricity will most likely be produced in Sweden, and should therefore the electricity is based on a Swedish mix (Energimyndigheten, 2011)
- Only one set of data is used for the LCA study even though the investigated life cycle includes different types of material. However, the data comes from a specific quarry which produces different types and grades of aggregate and will therefore produce an average of various materials.

Impact category

In the Screening LCA it has been chosen to focus primarily on level of CO_2-eq. associated with the different processes. What could also be relevant for the study to investigate is climate change, urban land occupation (wear and tear of roads) and natural land transformation. However, it is chosen to be excluded due to the complexity of the model

3.2.2.2 Life Cycle Inventory Analysis

Data

The data inventory will state the necessary data for determining the impact from each of the life cycle phases of aggregates, within the stated boundaries. All scenarios will go through the same life cycle, but the amounts will vary from case to case. The Inventory data considered are data from Production of virgin material, disposal, recycling and transportation (Figure 27), each of the red boxes represents the assemblies that are all a part of the aggregate life cycle and each has their own data set. The data is specified in Appendix 1.

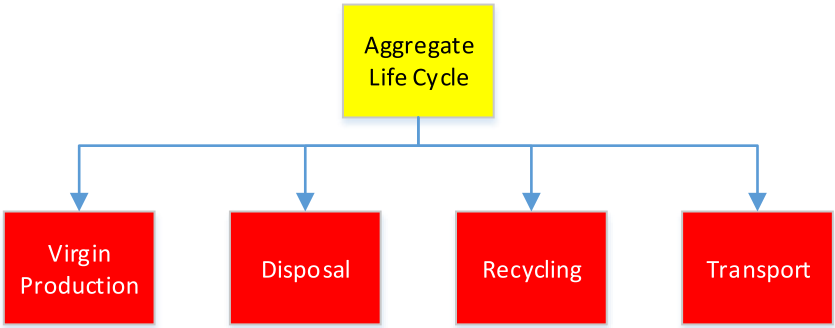


Figure 27 - Aggregates life cycle (LCA)

Scenarios

Besides the scenarios approached in the MFA a scenario regarding the future will also be investigated. There will be calculated different scenarios for this screening LCA, the scenarios are:

1. Current situation (2012)
2. ICT (2012)
3. ICT and Medium-Term Storage (2012)
4. Business as usual (2020)
5. ICT (2020)
6. ICT and medium term storage (2020)

Current situation (2012)

Status quo is the scenario that is describing the situation as it is today. Figures are calculated with focus on reaching an approximation to the actual figures.

Rock transport in Stockholm

Based on the current transportation in Stockholm, it has been calculated how many kilometers aggregates are being transported pr. year. The numbers are based on trafik analys' report over truck traffic in 4th quarter of 2013. The numbers can be seen in Table 6.

Table 6 - Transportation of aggregates in Sweden (Sveriges officiella statistik, 2014)

Total transport[km]	Total weight[ton]	Number of trips	Average truck load [ton]	Average distance [km]	Distance without load [%]
8,859,743	8,310,397	419,248	19.8	21.1	16

Based on this information the current impact from transportation can be calculated.

Production of virgin material

Production number for virgin material was presented in section 0. Together with this numbers is possible to calculate the CO_2-eq. emissions related to the production of aggregates. The recycling will give a positive impact as there is an avoided burden related to the process, however extra transportation is related to the process which will have a negative impact, it is assumed that the material will be transported with average load to an average distance.

Disposal

The last impact that is considered is the impact from landfilling the material that is not recycled. There is no current statistics on the amount of construction waste that is landfilled or recycled and much of the C&DW is not classified as aggregates.

Recycling/reuse

The recycling process will have a lower impact than production of virgin material, however the material must still be processed and some impact will occur. However no extra impact will be applied when reusing material directly in other projects.

The use of secondary can be seen in table under "current" and it is the same distribution as described in chapter 2.3.6.

ICT (2012)

The implementation of the ICT tool can have an impact on the recycling rate of aggregate waste/C&D waste, but can also optimize the logistics of transporting aggregate material.

The reduction of waste will happen because a location of a receiver of the waste/surplus material will occur faster and the subcontractor will not be forced to send the material to landfill.

Reduction of transport will also occur, as the system leaves an opportunity for transport companies reduce kilometer driven without a load because it is possible to better.

The estimated recycling rate is 40%, the load increases to 63.5% and the distance decreases by 5%. The estimations has been done based on various discussions, however the sensitivity analysis will also investigate other possible figures.

ICT and MTS (2012)
In the ICT solutions a MTS could be included. MTS already exists in the Stockholm area, however in a limited number compared to the amount of projects ongoing in Stockholm. By implementing more storage areas, the transport could be reduced, as loads would be increased, because more material will be transported to the MTS which is often closer to the construction site, than a waste treatment.

Furthermore, a MTS can contribute to an increased recycling rate of C&DW. If no recipient has been found of the waste material, the material can be placed temporary at a near-by storage area until recipient is found and simple processes can be chosen to be offered at the MTS.

The estimated recycling rate is 50%, the load increases to 75% and the distance decreases by 10%.

Business as Usual (2020)

As shown in Appendix 3 the average distance will be larger in 2020, it is based on in the future it is projected that several of the quarries close to Stockholm, will be closed due to the quarries are exhausted and the quarries will be moved further away from the cities and the transportation distances will thereby increase in the future. These cases are inevitable, but it increases also the need for solution to solve the issues. The distances are increased by 25 % which will mean around 5 km for all scenarios. This distance is moderate and is chosen due to the fairly short time span.

3.2.2.3 Results
A detailed table of the impact from the different part of the aggregates life can be found in Appendix 3. However, in this chapter graphs summarizing this tables results will also be presented

Figure 28, shows the total emissions from aggregates life cycle, both the current impact, but also the impact from the two proposed scenarios. Furthermore, the figure shows the part of the impact arising from different processing or transport. The model is easily changeable in order to calculate the consequences from various changes. The model includes reduction in transport and increased recycling. Transportation both take into consideration if a reduction in distance occur and if the load of trucks increases. Moreover, when an increase/decrease in recycling/reuse occur the material flows will correct themselves in order for a similar distribution be applied.

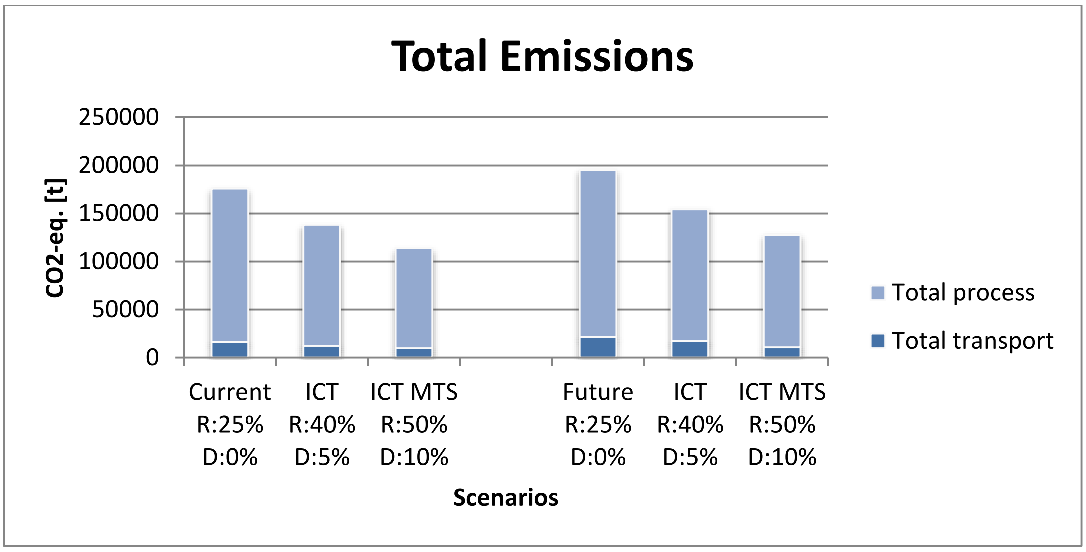


Figure 28- Impact from Scenarios (now and future) R: % recycled material used, D: Decrease distance %

In Figure 29 the total impact is divided into the respected processes of the aggregate life cycle.

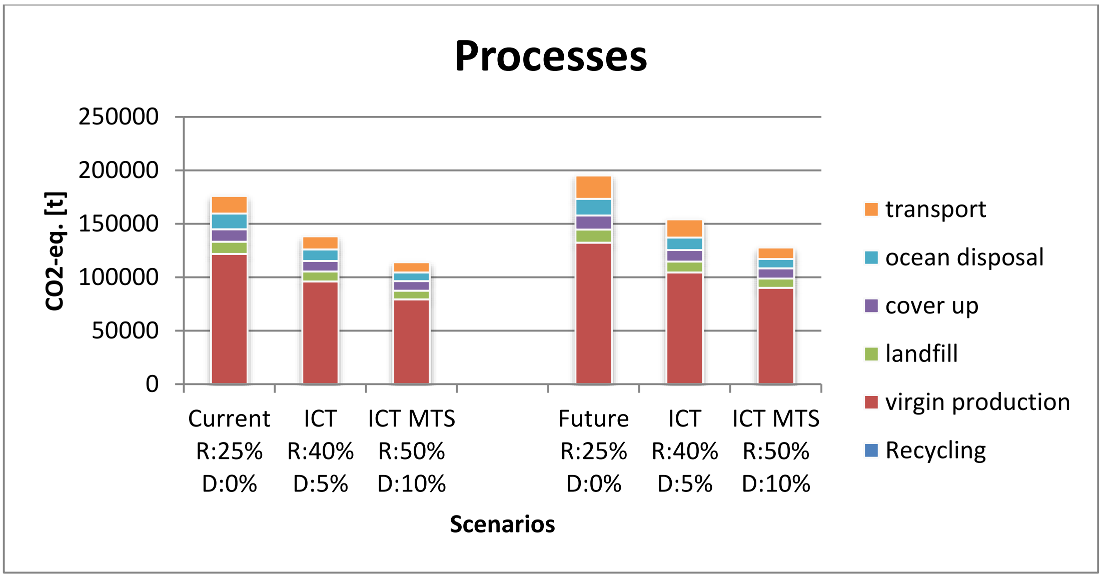


Figure 29 -Impact from scenarios divided in processes. R: % recycled material used, D: Decrease distance %

Figure 30 shows the impact from the different transportation step; this is done in order to see where the major impacts occur.

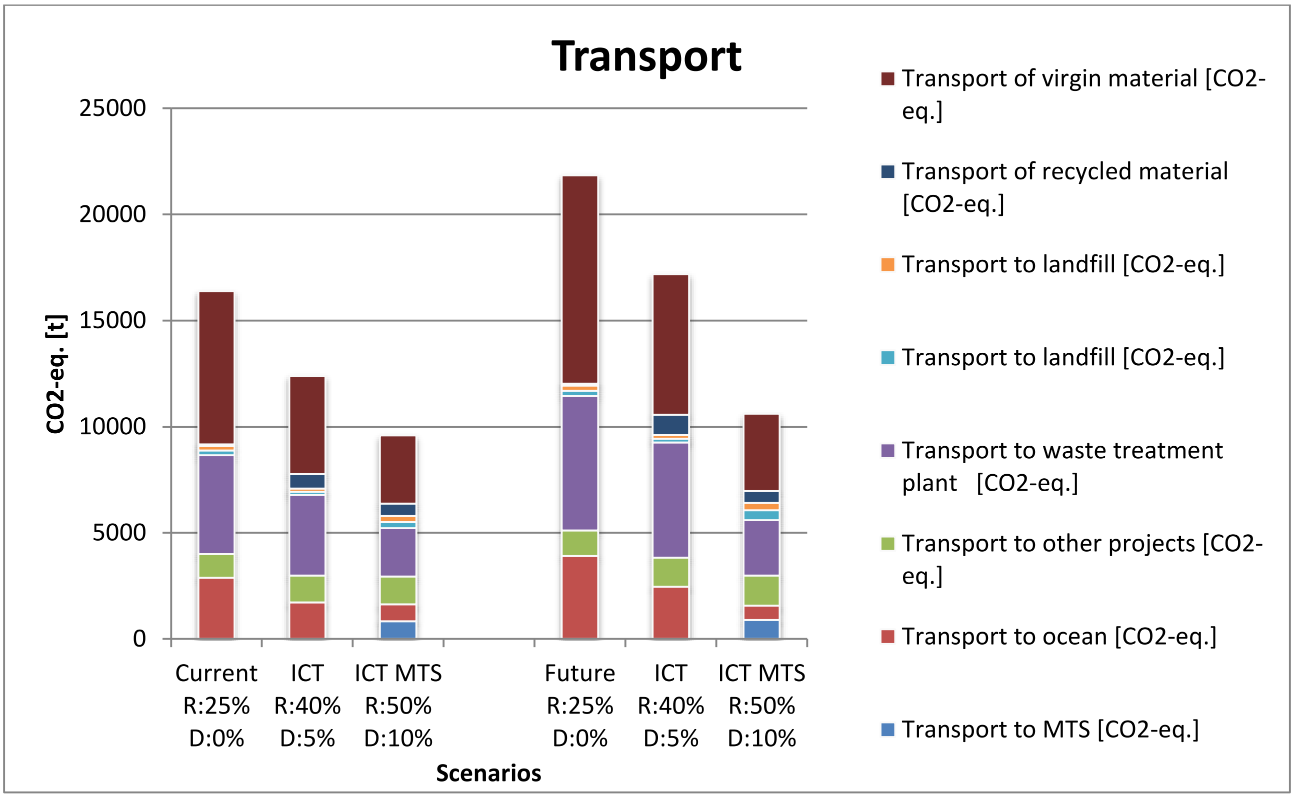


Figure 30 - Impact from scenarios, only transport. R: % recycled material used, D: Decrease distance %

Overall it is possible to see a major reduction in the total impact from the system, both regarding transport and the processes themselves.

3.2.2.4 Sensitivity Analysis

To ensure reliability of the LCA a sensitivity analysis has been performed. This is done in order to check the outcome of the results, if miss-calculation or miss-estimation has occurred in the process. Getting a strong result in the sensitivity analysis will enforce effect of the scenarios. The sensitivity analysis can also help to understand in importance of the various factors.

Only reduction in transport

First analysis is based on not having any increase in recycling rate and thereby only having a reduction in transport. The results show a very little impact on the total CO_2-eq. emissions (Figure 31). However, Figure 30 shows a potential in decrease the transportation significantly. And as only CO_2-eq. is investigated here, it is not possible to exclude the possible of other major environmental gains.

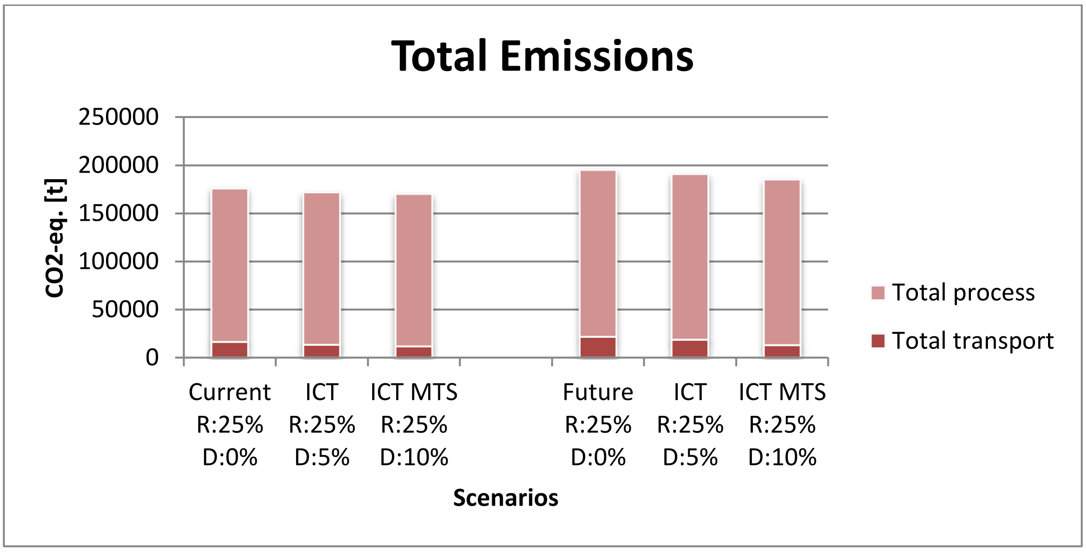


Figure 31 - Impact from just a reduction in transport. R: % recycled material used, D: Decrease distance %

High level of recycling

The second analysis is based on reaching the target of 70% and going beyond to 75% in the ICT + MST scenario (Figure 32). The result from this analysis is that there is a potential of saving around 120,000 tons of aggregates pr. year currently and bit more in the future, this corresponds to a reduction of CO_2-eq. of 67% of the current level. This shows that there is a major potential gain in increasing recycling rates and thereby reducing virgin production.

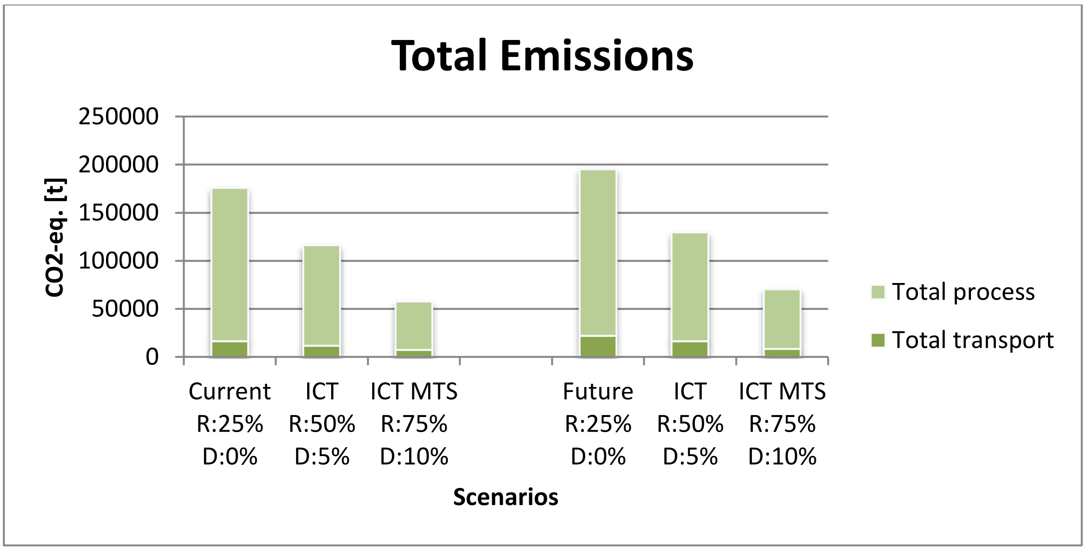


Figure 32 - Impact from increased recycling rate. R: % recycled material used, D: Decrease distance %

Decreased recycling rate

The outcome of predicting an impact of just increase in recycling to 35% will give a significantly lower reduction in CO_2-eq. (Figure 33) only around 30,000 tons in average will be saved. However, this number is still significant and again emphasizes the importance of increasing recycling and reusing rates.

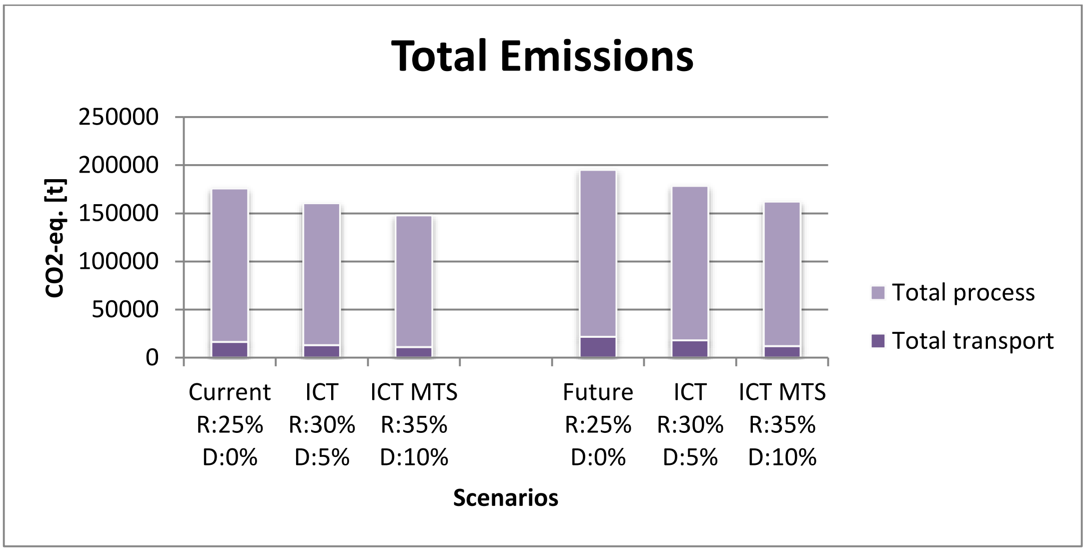


Figure 33 - Impact from decreased recycling rate. R: % recycled material used, D: Decrease distance %

Increased initial distance

One sensitivity analysis showed that transportation has a limited impact on the entire system. However, this result might be due to short distances in the Stockholm area with high density population. In other regions distances might be higher and therefore it has been investigated the effect, of an initial higher distance. In Figure 34 a scenario with an initial average distance of 100 km is presented. Due to the high distance, the potential of decreasing distances are also higher. Therefore the decrease has been estimated to be 20 % and 40% respectively. The results show, when transportation from the beginning has a larger impact on the total system, is potential of reducing the impact is much more significant, by reducing distances and increasing load percentage.

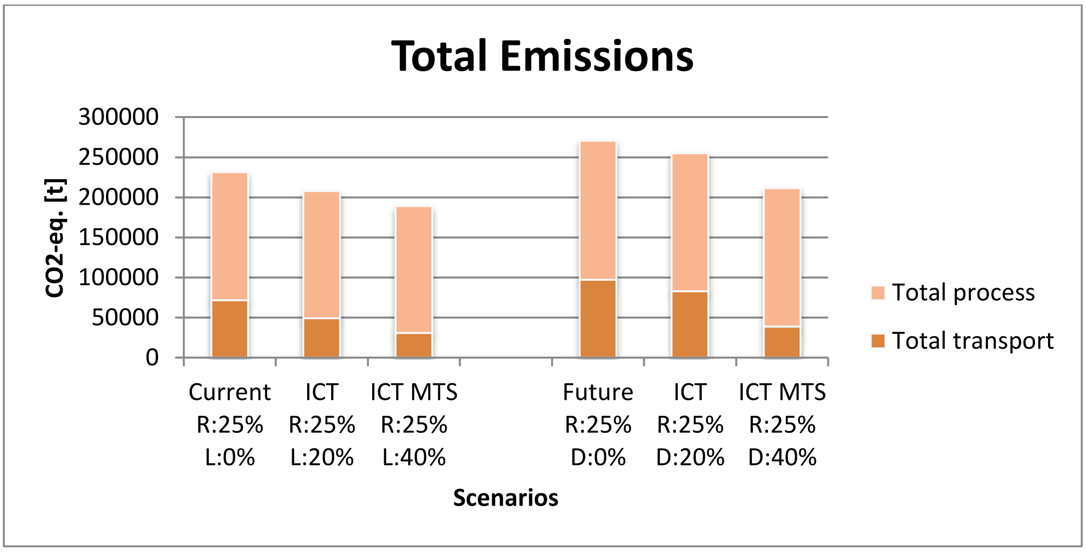


Figure 34 - Impact from high distance scenario. R: % recycled material used, D: decrease distance %

Various generated material (5.4-14.8 million)

Statistics of C&D waste and of material flow in general is uncertain in Sweden. In the life cycle assessment an average of 10 million tons has been used as an input for generated material, but the estimations report between 5.4 and 14.8 million tons. Therefore, results have been generated for both the maximum (14.8 million) case and the minimum (5.4 million). The results from the two cases can be seen in Figure 35 and Figure 36. The potential reduction for the case of 14.8 million generated materials is 45 % and for the case of 5.4 million is 21 %. These results are very different and show that the model's performance improves if the input of generated material increases.

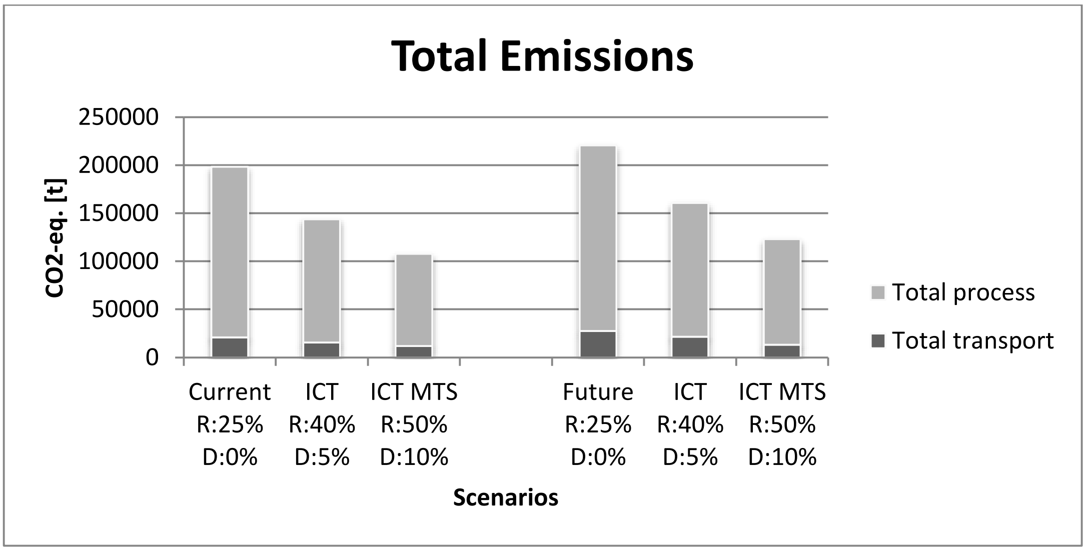


Figure 35 - Impact from 14.8 mill generated material. R: % recycled material used, D: decrease in distance %

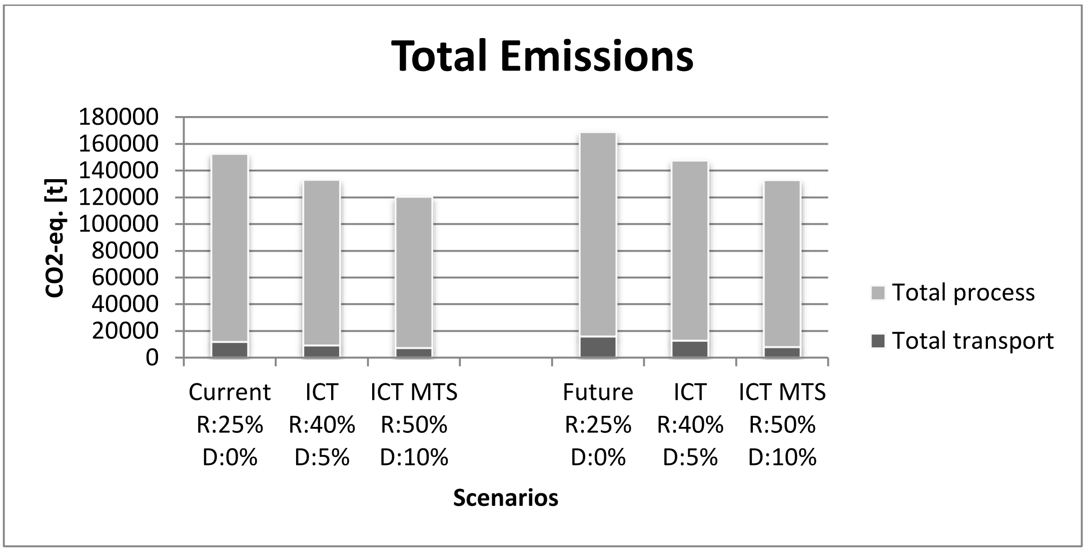


Figure 36 - Impact from 5.4 mill generated material. R: % recycled material used, D: decrease in distance %

The sensitivity analysis emphasizes the importance of increasing the recycling rate as minor improvement will have a noticeable environmental impact. Improving the transportation and decreasing distances also show an impact. However, if the region operates with large distances the impact will be significantly larger. It also shows that the model will change according the input of generated material. A high input will also give a lager potential decrease in impact. To sum up the results from the sensitivity analysis we can conclude that the model can be influenced by a lot factors and therefore the results from the model can be easily manipulated. However, all scenarios show some reduction in impact on the environment, but the difference between the largest and smallest is significant.

3.2.3 Cost of the solution

As the owner of the project is not identified it can be somewhat irrelevant to calculate the NPV and payback of the project. However, to highlight the feasibility of the project and to show potential profitability of the project NPV and payback time have been calculated and can be seen in Table 7, Table 8 and Table 9 respectively. The profit can be considered if the owner is a contractor, which is financially responsible of various activities such transportation, procurement and disposal of masses. If must also be emphasized that no stakeholder will have ownership of all the masses used in the calculation and the results are an expression of the total cash flow in the aggregates life cycle.

Net Present Value - NPV

The NPV is used to estimate the present value of the invested system in the future, for this case in four years. It is calculated based on a net cash flows which consist of expenses, profit and investments. Investment will be at project start investment of an ICT system. The profit comes from the gained advantages from the system such as reduction in transportation, reduction in production of virgin material and reduction of landfilling cost. The cost will be wages and rent. A detailed calculation for the Gain/loss and the investment and cost can be found in Appendix 4 – NPV. The gain is based on the savings in the project and includes: saved production of virgin material, saved wages, saved transportation cost (fuel) and saved landfilling cost. The numbers are based on the material flow analysis and the allocation of material and the reduction in transportation found in the estimated in the life cycle assessment. The loss includes; Recycling cost and investment cost. The Recycling cost is based on the material flow analysis and the investment cost estimations can be found in Appendix 4.

The life time of investment is considered 50 years, as maintenance is included and the RRR is set to be 15%

ICT solution

Table 7 - NPV for ICT scenario

Year	**0**	**1**	**2**	**3**	**4**
Fulltime employee(s) [SEK/year]		-520,000	-520,000	-520,000	-520,000
Office space [SEK/year]		-9,000	-9,000	-9,000	-9,000
Maintenance of platform (externally) [SEK/year]		-17,500	-17,500	-17,500	-17,500
Profit [SEK/year]		255,000,000	255,000,000	255,000,000	255000,000
Investment [SEK]	-520,000				480,000
Net Cash Flow [SEK]	-520,000	254,500,000	254,500,000	254,500,000	250,000,000
NPV [SEK]	**726,000,000**				

ICT+MTS solution

Table 8 - NPV for ICT + MTS Scenario

Year	0	1	2	3	4
Fulltime employee(s) [SEK/year]		-2,000,000	-2,000,000	-2,000,000	-2,000,000
Office space [SEK/year]		-9,000	-9,000	-9,000	-9,000
Rent of MTS [SEK/year]		-1,500,000	-1,500,000	-1,500,000	-1,500,000
Maintenance of platform (externally) [SEK/year]		-17,500	-17,500	-17,500	-17,500
Profit [SEK/year]		606,000,000	606,000,000	606,000,000	606,000,000
Investment [SEK]	15,000,000				-13,850,000
Net Cash Flow [SEK]	15,000,000	602,500,00	602,500,000	602,500,000	589,000,000
NPV [SEK]	**1,727,000,000**				

Payback Time

Table 9 - Payback time for scenarios

	ICT	ICT+MTS
Total Investment SEK	520,000	15,000,000
Total profit SEK/year	255,000,000	606,000,000
Payback	0.002	0.02
Payback (days)	0.75	9.00

Table 9 shows the payback time for the two suggested scenarios. The profit is based on difference between gain and loss. The gain and loss are based on the outcome of the LCA study. This means that the profit includes cost saving on transport (Fuel and wages), cost saving on production of virgin material and cost saving from landfilling. Of losses can be mentioned recycling cost and fixed cost for the project (wages).

In appendix 4 a more detailed calculation can be seen. The figures indicate that the project is very profitable, to check the insecurities a sensitivity analysis can be done on various factors. However, as the figures have a very low payback rate it seems even if a few factors are modified, the project will still be feasible.

3.2.4 SWOT

The SWOT-analysis is based on a combination interview responses and literature review. A description of the interviewees can be found in Appendix 1. It is done with the purpose of weighing the negative impact against positive in order to evaluate the potential of implementing the described solutions. Moreover, the SWOT-analysis is performed to predict the potential challenges if implementing the solutions and prepare a plan how to approach the challenges. The SWOT-analysis is summarized in Table 10

Table 10 - SWOT of proposed scenarios

	Strengths	Weaknesses
Internal	- Optimized planning of material flow - Cost savings/earnings - Transport saving - Time saving - Cheap to implement - Industry see a necessity of a material exchange platform - Larger organization has high level of ICT maturity	- Combining with current management system - Change of work routines - Finding an owner for system - Sensitive to changes - Difficult to ensure product quality
	Opportunities	**Threats**
External	- Reduction of environmental impact - Solving future resource demand - Generation of material flow statistics - Generation of permits - Combining with regional material planning - Creation of new business relations - Value has been created in other countries, based on similar tools.	- Alternative solution being implemented - Lack of support/use from/by companies - Only local business - Challenges in marketing the system - Challenges in sustaining system - Business outside system. Companies going directly to the source. - To involve small companies, due to being less progressive and having less investment capital - To involve big companies, because they are far in their own R&D on creating solutions for problems.

Stakeholder interviews have given an ambiguous picture of the potential of the specific suggested solutions. However, most stakeholders agree, a higher level or better integration of modern technology is necessary to obtain a better material flow. As mentioned earlier communication via a telephone network is very common and can often result in what can be referred to as a “Telephone Jungle”, where one person is calling to several places in order to buy/allocate surplus material. This system can potentially cause a lot of wasted time, because one calls up a lot people without possibilities to allocate material and information flow is not properly stored.

Strengths

Trafikverket performed in 2011 a study investigating the need for a marketplace for soil and excavated material. The preliminary results where that 74% of the interviewed stakeholders (24 in total) thought there was a certain or great use for a marketplace (Paulsson et al., 2010). However, implementing the ICT described previously in the report could eventually mean that the planning process could optimize, by having a better communication between different stages of the aggregates life cycle. When having an ICT as described, it gives the possibility to predict with a greater "preciseness" what and in which quantities what will be available in the future and needs to be taken care of.

Furthermore, it can also give an advantage in the short term as the ICT system quickly can react and find a solution for the surplus aggregates. These advantages can lead to more advantages, as a company can avoid purchasing virgin material or avoid paying a fee to get your surplus material taken care of. By having the available material in a database you will also be able to save time, as the information will be easily accessible and you will not have to search several places to find a solution for your material. Moreover, by always finding the solution nearest to you transport and thereby also time and money will be saved. As mentioned in the previous chapter the solution is cheap to implement and technically easy to implement and can potentially be very profitable.

The larger organization has a high level of ICT maturity of which it is already an integrated part of the work. An example of the maturity level 3D planning can be mentioned. 3D planning is a new method of planning for infrastructure. The method is very dynamic and updates the planning schedule automatic along the project. It follows the excavation works and regulates the plans. (Kemppainen, Mäkinen, Seppänen, & Kankainen, 2004) This maturity shows that the companies will not have issues with the difficulty level of the proposed solutions.

The database has specific uses for the different stakeholder. A database can be of value for many different reasons and it will differ from stakeholder to stakeholder. **The County administrative board** (länsstyrelsen) will be interested in statistics in order to ensure the 16 quality goal will be met as well as using it to distribute information, Furthermore they see a potential for reducing the amount of tipping in forests. **The Municipalities** see the potential from different sides. One option which can benefit the municipalities is to find a place to deposit masses of material, because currently the communication between the administrations can be bad and a database could ease the communication.

Moreover, the municipalities see both an environmental reward as an economical. **Sweden's Municipalities and Counties (SKL)** also has an interest of the database to benefit their members. They see an economical benefit for the member, but primarily an environmental reward, since the municipalities handles most of the environmental questions. The authorities such as **Swedish Geological Survey (SGU)**, The **Swedish EPA (Naturvårdsverket)**, and the **Swedish Transport Administration (Trafikverket**) have an interest in getting better statistics over the masses. They also have an interest in a better social function with lower environmental impact. **SGU** Has an interest in amounts of masses. The **EPA** wishes for better statistics and description of what the masses consists of and believes if the waste properties are presented in the database it would facilitate both the operator and the supervisory and examining authorities. Among the construction companies there is an interest of a database in order to decrease the cost of handling material as in big cities placement of material is expensive due to scarcity of space (Paulsson et al., 2010).

Weaknesses

When implementing ICT it can lead to some challenges. First of all you will have some technological challenges; how can you integrate a new system with the old system and introduce the system in way that will make the employees use it. This issue is both a technological issue, but also a social issue. The technological side is to create a well-functioning user interface, meaning the system should be easy to use for anybody also with only minimum experience in using ICT; otherwise employees will give up on using the system. Furthermore, it is necessary to adapt the ICT system to the current management system or completely replace the old system with the new; otherwise there is a risk that the system will be ignored. At the same time it is risky not to properly introduce the ICT in an organization, if employees are not aware of the change and are being taught in how to use the system.

A second problem with the system is to decide who will be the owner of the system and at which level it should be implemented. It is important to find the optimal owner of the ICT System, in order to have a driving force for the project and to lay a pressure to actually use the system, because the owner will have an incentive. Third, a problem arises with getting different companies to cooperate together and might not be interested in joining a common database. This is due to, that contractors in general not are interested in sharing information with external companies, because it is seen as business secrets, the amount of surplus material and their demand. Some companies might therefore be reluctant to joining and wishing only to have an internal system. Moreover it has been mentioned in the report of Trafikverket, that the idea is good, however due to the environmental legislation and Naturvårdsverket interpretation of it will make the handling of masses too complicated, and therefore a disposal is more beneficial (Paulsson et al., 2010).

Opportunities

Beside the initiate strength of the system, it can also lead to more positive impacts. If the system manages to reduce the amount of produced virgin material and reduce the total transportation, it will also lead to a reduction of environmental impact. Furthermore, as mentioned earlier the demand for Aggregates in Stockholm will increase in the future and resources are there, but are still becoming scarcer and some materials has quotas. If less virgin material is required, because of an optimized logistic the system will also help solving the future demand of Aggregates. If a sufficient amount of actors joins the system a good dataset will be generated and will create a great picture of the material flow, which in the long end will be possible to use for reporting and generation of material flow statistics. Furthermore, as an add in to the system, a function for generating permits for C&DW handling could be included, by having the possibility to better monitor the different companies and their actions and companies could add in their applications, when doing the planning process of a project. At the same time, companies could potentially be able to add in material requirements and surplus material of what is expected for the future, this could give a better regional planning, as the region would be able to access the system and get a picture of the upcoming requirements and spot the trends.

One of the biggest possible incentives might be the creation of new business relations. Smaller companies can become noticed and it is possible for most companies to maximize their product value and make the market more dynamic. Lastly, it must be seen as an opportunity that at least two projects have succeeded in getting a database up and running and sustaining with a positive result. Exact number from the gain of the Finnish version of "Jordbörs" is not available, but the EIS Tocycle has reported a benefit of almost 4 million USD for one project involving 570 thousand tons of surplus resources (Moon et al., 2007).

Threats

When implementing an ICT system or trying to implement an ICT many different things might threaten the success of these scenarios. First of all it is necessary to find companies to support the project, or more exact the executives of a company and this might be a challenge for the future to convince management to invest in the ICT system and with no support, no implementation. Thereby if there is some resistance, it means the marketing of the project will be challenging and an extra effort in must be put this area. Furthermore, the system described is focused on local business, meaning that material should exchange in the area and therefore to companies should be placed near each other or at least working on project near, therefore it will not work if a lot of stakeholders are found to invest in the project, but the placement is very far from each other. If the system is implemented, there will be a risk of employees working outside the system and undermining it and communicating directly with the source, this will both cause figures to be less accurate and the system will be less effective.

Moreover, for the system to be successful it requires to be well-sustained, meaning companies cannot afford the system to breakdown, or at least if the system is not reliable it system will not be popular, as companies often need to react fast. Furthermore it can be difficult to include not just small companies, but also big companies. Small companies, because they might not have resources to invest in the system and big companies because they are more interested in having an internal system and excluding other companies from their business in order to have a market advantage.

It is necessary to have several companies included in the project in order for the supply chain to work; therefore it can be a challenge to include enough. E.g. if the timing for changing management system is not right it can be hard to convince the company to join. Lastly, the system is sensitive to change. If you have already entered planned material supply and demand in order to get a time advantage, the system can easily be affected, as e.g. blasting of tunnels is very uncertain, because it is not possible to completely know which material you will reach and in which quantities and if you will reach other unexpected material that will slow your progress.

4 Discussions

In this chapter, the objectives of the master's thesis will be discussed and concluded. Furthermore, suggestions for future work.

4.1 Objective A – Quantify the amounts of secondary material available for upgrading

In section 2.2, it is stated that 7.3 million tons of virgin material is delivered to Stockholm Region per year (2012) and between 4.8 – 15.4 million tons of surplus material is generated in the Stockholm Region every year. Moreover, the demand for material is expected increase in the future, with around 1 % each year, leaving the demand in around 7.9 million ton in 2020. This number is based on the estimates that the population will increase from 2,091,000-2,500,000 by 2030. However, many construction projects are planned in the Stockholm Region and higher demand for Stockholm in the future might occur.

As mentioned in previous chapters the official waste and material flow statistics for aggregates are not very reliable. The knowledge regarding the actual flow is very little and inconsistency of data occurs. Immediate credible sources such as authorities and public agencies provide data which contradicts one another and sources from the private sector creates a third picture. This is caused by application of various definitions, but also by lack of communication.

The data presented in this thesis combination of various sources, but due to inconsistency the results will be unsure and it is necessary to look at the sensitivity analysis, when evaluating the results.

4.2 Objective B – Identify current and potential ICT solutions

In section 2.4.1 current ICT solution has been identified. The solution has a wide range of different approaches to the same problem and is based in different countries. The countries include Sweden, Finland, Scotland and Korea. The tools have different levels of success rate, but the most successful are two systems outside of Sweden; EIS - Tocyle (Korea) and Maaporssi (Finland). The reason behind the success has not been identified.

4.3 Objective C – Create potential ICT solutions for the stated problem

In section 3.1 different ICT approaches was identified and described. Based on the identified approaches two different scenarios were chosen to analyze: 1. ICT tool based on a Call Center, Website and Application 2. The same as scenario 1, but with a Medium-Term-Storage. The MTS has the purpose of storing and treating secondary material, before returning to a construction site. Both scenarios are also considered with the future demand when performing calculations.

4.4 Objective D – Present the technologies to stakeholders involved to get their feedback and priorities

Stakeholder interviews were held with 6 different stakeholders from various parts of construction industry. Moreover results were presented at the Absoils Seminar 11th of September 2014, and short discussion was initiated with two of the attendees.

First of having a stakeholder interviews is a time demanding process and it is therefore only possibly to get a limited amount of interviewees. Moreover, a limited amount response was received from desired stakeholder, when contacting by telephone or e-mails. This has caused lower amount of interviews than planned and a change of methodology. A workshop with participation of several stakeholders was planned. The purpose of the workshop was to engage in a dynamic discussion revolving around the proposed approaches. This was in order to get immediate feedback on different viewpoints of the stakeholder. With a limited amount of interviewees and not covering everybody involved in the life cycles of aggregates all opinions will not be represented. Furthermore, it is not possible to control if the response are biased and one must assume that it most likely is. To sum up, the stakeholder interviews will only cover a small group's point of view compared to the total population and some views of the issue might not be represented.

Second, during the interviews a minor language barrier occurred between interviewer and interviewer as the interview were conducted as neither has English as a first language. This factor might have created misunderstandings and limited both interviewer and interviewee to express exact opinions and responses.

4.5 Objective E – Calculate (in scenarios) the potential effects of such ICT solutions (Economic, environmental and social) with systems' assessment tools

Three different methods has been used to calculate the potential effects from the suggested solutions; MFA, Screening LCA and NPV and payback.

4.5.1 Scenarios

The scenarios described in section 4.3 were used for calculating their potential effects. In order to calculate the effects, different factors were estimated. The factors include distances between processes, the potential increase in recycling rate, the potential decrease in distances and the increase of truck loads.

The scenarios described for the systems assessment might not describe the correct picture. In the current time scenarios it is difficult to give the precise distances as it will vary from site to site. Furthermore, these distances can deviate even more for the future scenarios, as the scenario as described e.g. does not take into consideration closing of quarries, relocation of recycling facilities and change of city borders, which will all have an impact on the different distance. However, an increase in distance is assumed. Moreover, it is not possible to predict the actual impact from the scenarios as the scenarios are imagined and there is no real base for the estimated impact.

4.5.2 MFA

An MFA for the current state was created based on the current quantities of material and waste statistics provided by Naturvårdsverket. Furthermore, the MFA has been used in order to allocate the different material in the different scenarios. The MFA also visualizes the actual flow of material and makes it easier to relate to the figures calculated. As mentioned the figures presented in the MFA should not be considered exact numbers. However, the figures applied are estimated based on a comparison between relevant sources and expert knowledge.

4.5.3 Screening LCA

The MFA has worked as a base for the Screening LCA. Each of the processes and flows has an impact related to it. These impacts are presented in the Life Cycle Inventory in appendix 2. Screening LCA is a good tool for getting a good overview of the environmental impact, in this study is has only been chosen to look at the CO_2-eq. emission within the boundaries of the study. However, the life cycle of aggregates also have other sorts of impacts that are potentially significant. Of these impacts e.g. road wear and tear and natural resource depletion can be mentioned. The road wear impact comes from transport of aggregates. Transport with a truck has higher impact on the roads than regular personal transportation vehicles, as the impact is multiplying by the weight added on the truck. Furthermore, to produce virgin aggregates you will be blasting rock in quarries, this means a depletion of natural resources, therefore these are examples of other impacts that might have been relevant to study, but it has been selected not to in this, due to scope of study and time limitation. When using LCA the system boundaries will affect the final results strongly and it is therefore important to emphasize that some stages has been excluded from this LCA study. In this case the use phase has been excluded, however the use phase could potentially have proven a different result e.g. if looking into the quality of primary and secondary materials.

Furthermore is has been challenging to find data regarding the inventory of the process flow used in the screening LCA, only little information is found regarding the material and the use of the material and the data is therefore hard to verify.

4.5.4 Cost

The Methods NPV and Payback was chosen in order to calculate the cost of the scenarios. Only cost of the current material was calculated. The input to the cost calculation comes from estimated investments, cost and profits. The profits are based on the gain from decreasing transport and virgin production. Therefore the cost calculation has the same issues as calculation of environmental impact. Maybe, some relevant, but unknown costs have not been considered in the calculation, such as taxes and fees. However looking at the result from the cost calculation, the benefits outweigh the drawbacks. This could be due to low investment cost of the project.

4.6 Objective F – Create a SWOT-analysis based on the results of objective D and E

Doing stakeholder interviews provided much input to the SWOT-analysis regarding suggestions on how to approach the challenges and how to create the best system.

There are several points most stakeholders agreed on regarding the industry and implementing an ICT. The first is that the construction and infrastructure industry is a closed industry. All companies are very careful with spreading information and getting too close to their competitors or providing any business advantages. A solution to this issue could first of all be to provide anonymity for the actors in order not reveal to whom the information belongs. However, this could also create certain mistrust and a less open way of communicating, which already exists.

Another concern raised is e.g. the quality of the delivered material, is the material what the trading company says it is. How can a good quality be ensured? E.g. by legislation/documentation for the standard of the material, but a challenge is to incorporate this into the tool. Moreover, it was mentioned by several interviewees that external pressure might be necessary in order to progress. This pressure should come from either the client or from public authorities. The pressure from public authorities is suggested to come from legislation, which could include different things. One could be to simply demand the use of a specific ICT tool by regulating. Second could be to require specific information (such as planned production and planned C&D) to be entered in a specific platform/database. To legislate would also provide better detail of information to include in national waste statistics. However, public authorities are often more critical towards the idea of creating more laws. This is caused primarily by two reasons. First authorities prefer creating solutions together with the industry in order to satisfy the companies and not apply any unnecessary pressure. Second public authorities sees that if more laws are implemented it also means more laws to break and avoid and therefore the laws can create further distance between the public and private and increase mistrust.

Furthermore, pressure from a client has been suggested. More specifically Trafikverket has been pointed out as potential owner of the project, when considering infrastructure projects and for many public construction projects the City of Stockholm (Stockholm Stad), Boverket or other client are the counterparts. This is due to their major influence on infrastructure projects. As mentioned earlier Trafikverket gives their contractors the ownership of secondary material in most projects, however Trafikverket is in position where they change the routines not only within Trafikverket, but also for their contractors. Trafikverket is already monitoring their contractors and ensuring they have all documentation in place. Therefore, it could fit into Trafikverket's scheme also to monitor their contractor application if surplus material by using a suggested ICT tool. Having Trafikverket to monitor their contractors, will force the contractors to introduce the tool and contractor will be responsible for their employees use. The same case can be argued for the City of Stockholm. Stockholm undertakes a lot of big construction projects and can set many requirements when choosing a constructor.

However, if a client such as Trafikverket or the City of Stockholm is not interested in changing system a bigger internal effort must come from the company or the external owner. This means the external owner of the need to give more support, than just offering a service in form of a ICT platform. They should also support companies by fully convincing executive management that this is a feasible idea. During interviews it has become clear that management support is crucial, because a clear implementation plan should be on place. A budget and time is set aside for this specific purpose. Such action will give a company the opportunity to successfully through the implementation stage.

4.7 Objective G - Examine the potential impact of legislative measures to promote the implementation of such management systems.

The current relevant legislation has been presented in section 2.3.1. Some of these policies create frustration among stakeholders, due to a lot of paperwork and ambiguity in the interpretation. However, some stakeholders from construction companies, thinks that legislation is a very good solution in order to break the barrier between different actors in the industry or the only solution in order to make companies comply with the suggestions. On the other side, authorities and public agencies believe in a limitation of legislation as they prefer to have an open dialogue and discussion about the issues in order to find the best solutions.

4.8 Future work

Based on the result and recommendation from this study several decisions should be made and ideas developed further. First of all some issues must be approached despite the recommendations

4.8.1 Ownership and involvement

Who should be the owner of the project?
As advised major clients such as Trafikverket or the City of Stockholm seems to be the right candidate for taking upon the task. They are in the right position to change their contractors' routines and systems, by adding an external pressure. But of course the two potential owners must agree to participate and the executive management of the two organizations must be approached and ideas presented.

However, if the two organization are not ready for the challenge ideally a larger company with great influence should undertake the task.

Who should be involved?
Ideally all of the previously described "Responsible" in the infrastructure and construction industry should be involved, however some in a more active role. As just mentioned an owner is needed. However, two other important aspects should also be considered. Land must be available for creating a MTS, where an involvement from the City of Stockholm or other municipalities would be necessary as they own the land. Secondly, funding is needed to develop the project, therefore larger construction and private funds must be approached. Lastly a corporation with the mentioned existing ICT tools in Sweden could be suggested to prevent counteracting.

4.8.2 Targeting

The actors that should take use of the proposed solutions would be foremost larger construction companies. This is due to the generation of secondary material is high in a big company and therefore will have a larger total impact. However, more importantly a large company should be forerunner as their participation would eventually affect the smaller company and they would thereby also participate.

4.8.3 Development

A demo-version of the ICT must be created in order to move forward with the solution. It is necessary to corporate with creators of other ICT tools in order not to start from scratch, but building on to an already existing idea.

It is necessary to look more into the technical aspect of the system and answer the questions:

- How to build up the database?
- How to connect to current IT system to different companies and their planning phase?
- Which parameters the system should contain?
- What information should be able to be found in the database?
- Design and interface?
- Which input is necessary to enter?
- How can the tool be connected to permits and documentation?

4.8.4 Location

By location it is meant where to place potential MTS. In this case it is necessary to consider Stockholm's regions development plant (RUFS) in order to see location of planned construction and find open and available spaces near the future construction sites. The availability must be investigated and bought/rented from the owners who typically will be the municipality.

4.8.5 Further Studies

To learn from more experiences more studies should be conducted. In the following paragraphs two examples of studies are mentioned.

Finland versus Sweden

To conduct a comparative study between the two cases, first of all to get a picture of the differences how the business is approached. However, also to investigate the two different markets and see if there is any cultural difference between Sweden and Finland which makes it a challenge to enter the Swedish market. Jordbörs is a Finnish concept/website that has been translated in to Swedish and attempted implemented in Sweden. The site has been reported as a success in Finland, however despite a claimed major effort the same success has not been present in Sweden. It would be a valuable lesson to compare these two seemingly identical projects and map the exact difference. Thereby, it is possible to avoid the potential mistakes occurred in the less successful project and vice versa.

Royal Seaport

By studying the management of materials in the Royal Seaport project, the positive experiences can be transferred and the negative can be avoided. Furthermore, as the Royal Seaport is an ongoing project the experiences are fresh in memory and can be an example for how the suggested solution could work in the future. Royal Seaport is a new district in Stockholm and is built with the focus on becoming a sustainable city with great living environment, smart solutions and low energy consumption. Reportedly the Royal Seaport has had great success in reducing the amount landfilled soils increased the amount of reused material, and by that decreasing transport and environmental impact (Nygren, Pramsten, Hellgren, & Sundesten, 2014).

5 Conclusions and Recommendation

Despite the described challenges which could cause troubles in implementing an ICT solution, there is a broad support regarding the use of ICT as a measure to solve problems and improve logistic within management of heavy construction materials. It seems there is not much doubt that ICT will play a big role in the future and in current management systems. However, the integration of ICT will potentially happen very slowly. Therefore it is necessary to provide much support, and planning and especially a great solution is necessary when to integrating ICT solutions. Moreover, if focusing on larger corporations it seems clear that the technological maturity is there. 3D planning is one example of technological maturity, which proves the readiness of organization.

A specific ICT solution was described for stakeholders and feedback was given. Many elements from the suggested solution have gotten a positive response. Interviewees prefer the simple approach to the problem and simple way of handling the solution. This means that the solution should have a limited amount of function and not be multi-purposed. Another factor which is highlighted as important is the visually in the point a geographical proximity. A map makes it easier to get on overview.

Secondly, not all interviewees mentioned a MTS themselves as a solution. However, most when having the concept explained for them would agree that having MTS could increase the success rate of the project. Having a MTS would make planning easier, it would give a bigger time span for placing material and decrease distances. This would decrease the amount of rash solutions, where unwanted material is disposed in a landfill.

Before investing in a project more studies must be made. This includes investigating the success stories, but also to run a test-period before fully launching the solution.

The owner of the project should be one of the bigger clients in the markets such as Trafikverket and City of Stockholm. The clients should be responsible the suggested project, due to their high level of influence/power in the overall in construction projects. However, as clients will not be the ones using the solution, the system should be developed together with one or more of their major contractors.

Lastly, the result from the screening LCA must also be concluded. The model shows that the largest potential for reducing the environmental impact is to increase the rate recycling and decrease the production of virgin material.

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7 Appendix

Appendix 1 – Stakeholders

Available upon request

Appendix 2 – Life Cycle Inventory

Production

The data applied for the Production phase is taken from the study of Blengini (Blengini & Garbarino, 2010)

Materials/Fuels					**CO2eq. g/t**	**source**
Diesel	4.904	MJ	1,36	kWh	900	(United States Environmental Protection Agency, 2014)
Electricity*	10.803	MJ	3	kWh	2,000	(United States Environmental Protection Agency, 2014)
Light fuel oil	2.44	MJ	0,67	kWh	500	(United States Environmental Protection Agency, 2014)
Hammers/jaws	0.0112	Kg			7.84	(Hammond & Jones, 2014)
Steel Screen	0.02	T			13,227	(Okala design guide, 2010b)
Lubricating oil	0.00181	Kg			5.8	(Okala design guide, 2010a)
Steel	0.013	Kg			8.6	(Okala design guide, 2010b)
Synthetic rubber	0.0073	Kg			21.2	(Hammond & Jones, 2014)
Tap water	10.1	Kg			10.1	(Hammond & Jones, 2014)
Total CO2-emission					**16,681**	

Transportation:

Material/Fuel					**CO2eq. g/l**	**source**
Diesel (Will vary)	1	l			2,747	(Okala design guide, 2010a)
Total CO2-emission					**2,747**	

Disposal:

As production the data is taken from the Blengini (Blengini & Garbarino, 2010).

Operation of the landfill

Materials/fuels ()					**CO2eq. g/t**	**source**
Electricity*	1.14	kWh	1.14	MJ	2.1	(United States Environmental Protection Agency, 2014)
Diesel	20.23	MJ	5.62	kWh	148.,8	(Okala design guide, 2010a)
Water	2.6	M^3			780	(Hammond & Jones, 2014)
Construction of Landfill facility						
Concrete	13.85	Kg			1385	(Hammond & Jones, 2014)
Reinforcing steel	0.34	Kg			224.9	(Okala design guide, 2010b)
Gravel	47.1	Kg			226.1	(Hammond & Jones, 2014)
Polyethylene mesh	0.43	Kg			860	(Hammond & Jones, 2014)
Polyethylene pipe network	0.02	Kg			40	(Hammond & Jones, 2014)
Total CO2-emission					**4998.9**	

Recycling:

Material/fuels					**CO2eq. g/t**	**source**
Hammers/jaws	0.033	Kg			22.89	(Hammond & Jones, 2014)
Water	6.7	Kg			6.7	(Hammond & Jones, 2014)
Lube oil	0.001	Kg			3.27	(Okala design guide, 2010a)
Polyurethane screen	0.015	Kg			55,48	(Hammond & Jones, 2014)
Steel screen	0.0105	Kg			7.35	(Okala design guide, 2010b)
Synthetic rubber	0.0043	Kg			12.47	(Hammond & Jones, 2014)
Diesel	0.68	L			1.87	(Okala design guide, 2010a)
Electricity*	3.605	MJ	1	kWh	1.85	(United States Environmental Protection Agency, 2014)
Total CO2-emission					**111.9**	

*Swedish Electricity Mix (Energimyndigheten, 2011)

source	Hydro	Nuclear	Wind	Other	Average
kWh	66,000,000,000	56,000,000,000	3,500,000,000	19,000,000,000	1,255E+11
CO2-eq. (g)	11,880,000,000	2E+11	17,465,000,000	-	1.853585657

Appendix 3 – LCA results

Available on: http://goo.gl/Q2JLCC

Appendix 4 – NPV and Payback

Investment cost of ICT Approach

Investment ICT				
creation of a platform				
Phone line	1	Day[1]	1428	SEK
Website	0.5	Years[1]	260,571	SEK
application	0.25	Years[1]	130,286	SEK
training	0.25	Years[1]	130,286	SEK
total investment			**522,570**	SEK
lifetime	50	years		
Required Rate of Return(RRR)	0.15			

Investment cost of ICT+MTS Approach

creation of a platform				
Phone line	1	Day[1]	1,428	SEK
Website	0.5	Years[1]	260,571	SEK
application	0.25	Years[1]	130,286	SEK
training	0.25	Years[1]	130,286	SEK
equipment			14,540,000	SEK
total investment			**15,062,570**	SEK
lifetime	50	years		
Required Rate of Return(RRR)	0.15			

Rent of MTS (Estimation)

Rent	1,454,000	SEK

Annual Salary Cost (Sweden)

Annual salary cost[2]	521,143	SEK

[1](The)

[2](Analyse, 2011)

Gain vs. Loss

The gain and loss is based on the potential saving or additional cost if implementing solutions. The wages are calculated with the assumption that drivers drive 100 km/h.

Gain	ICT	ICT+MTS
Saved Km	40,750,761	101,290,259
Saved fuel l/y	594,794	1,313,050
Saved fuel USD/year	8,193,093	18,086,847
Saved wages USD/year	80,443,033	304,840,943
Saved production t/year	1,549,575	2,549,575
Saved production USD/year	157,157,904	258,577,904
Saved landfilling t/year	774,788	1,274,788
Saved landfilling USD/year	9,858,087	16,219,887
Loss		
Extra Recycling t/year	774,788	1,274,788
Extra Recycling USD/y	221,450	364,360
Fixed cost	547,315	547,315
Total Gain/Loss USD/year	**254,883,351**	**606,302,074**

References

fuel price	gas	1.506	EUR/l[1]
	diesel	1.494	EUR/l[1]
Recycling cost		31	EUR/Mt[2]
disposal/landfilling		1.38	EUR/t[2]
Price for aggregates		12	EUR/t[3]

[1](VPS, 2014)

[2](Spoerri, Lang, Binder, & Scholz, 2009)

[3]Between 0-225 Sek = 0-24 EUR (D.A. Mattsson, 2014)