SIMM Center - Report
Enabling Technologies for Sustainable and Innovative Material Management


Status:	Final report
Date:	2014-11-18
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Project number:	Ecoloop 2013025
Project title:	SIMM-Center
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SIMM CENTER

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SIMM CENTER

1. SUMMARY

The urbanization of cities around the world is increasing and this implies an increased activity in the construction of our cities and subsequently an enhanced production of aggregates and surplus materials. There is a need to increase the recycling and re-use of these materials, and there are different ways of approaching the issue. The SIMM Center Cluster has conducted two specific projects focusing on deepening and expanding the knowledge within 1) material flows and existing processing technologies, and 2) potential service opportunities through ICT solutions. The aim of these works is to increase understanding of the larger market potential in regards to the cluster's focus materials. Subsequent objectives were developed within the respective projects concerning communication, environmental consequences and economic benefits.

The results shows that the flow of material in the construction industry is rather complex and that a lot of the processing technologies are used for multiple materials in different stages of the construction process. Concerning ICT there is a potential for continuing the project and implement the suggested solution. However, even though there is support in the industry, several issues must be addressed, for example there is a frequently difficult to an owner for a project and subsequently who is responsible for the material management.

2. INTRODUCTION

The population of Stockholm is expected to increase with about 25 % by 2030 (Erman, 2013) and this phenomena can be seen all over the world since an increasing amount of people are living in the cities (Antrop, 2004). This implies an increased activity in the construction of our cities and subsequently an increased production of aggregates and surplus materials. At the same time the expected demand for aggregates in Sweden will increase by 1 % per year (Arell, 2005). Sweden has a target that preparation for re-use, recycling and other material recovery of non-hazardous Construction and Demolition Waste (C&DW), 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% (Naturvårdsverket, 2012). There is a need to increase the recycling and re-use of materials, and there are different ways of approaching the issue. The SIMM Center Cluster has conducted two specific projects focusing on deepening and expanding the knowledge within 1) material flows and existing processing technologies, and 2) potential service opportunities through ICT solutions. The aim of these works is to increase understanding of the larger market potential in regards to the cluster's focus materials. Subsequent objectives were developed within the respective projects concerning communication, environmental consequences and economic benefits.

3. MATERIAL HANDLING TECHNOLOGIES

3.1. Introduction to the project

To increase recycling of aggregates and surplus material could be a gainful investment for the client (the owner of the construction project). A good example is a small municipality outside of Stockholm which through procurement determines that the contractors involved in the municipality projects are given a recycling site for excavated rock 10 kilometers from the construction area instead of sending the material to landfill. This approach saves the municipality approximately 6,5 million SEK annually in mainly transport costs, which for the Stockholm area could imply savings of 275-820 million SEK per year (Frosth, 2014). In this example, an existing technology is used in order to increase the recycling of produced rock from construction sites. Based on this, there should be a lot of processing technologies in the construction chain that can be further used in order to reduce environmental and economic costs caused by transports and excavation of virgin materials from quarries. However, there is a need to illustrate the flow of material in the construction chain to get a more extended knowledge of these existing technologies.

3.2. Aims and Objectives

The aim of this project is to examine the material flow in the construction industry and subsequently be able to define the existing processing technologies. The objective is to visually describe the different processing technologies that are being used in the construction process.

3.3. Methods

The used method was literature studies and interviews. The project was conducted in two steps. Firstly, the material flow in the construction process was examined and, secondly, the different technologies used for processing the material within the flow was investigated.

3.4. Results

The flow of material can be described as rather complex, since the chain looks different in specific projects. However, the general flow of material can be described as virgin material is being excavated from quarries and then transported to construction sites such as building constructions or road construction projects. At the site this material are being used as mainly foundation. Further, material is also being produced at the sites (aggregates and soils) which is used at the site or transported to material terminals, landfill or other construction sites. Additionally, when buildings or roads are being dismantled the demolition waste are being transported to material terminals, landfill or other construction sites. The illustrated flow of material could be seen below (figure 1).

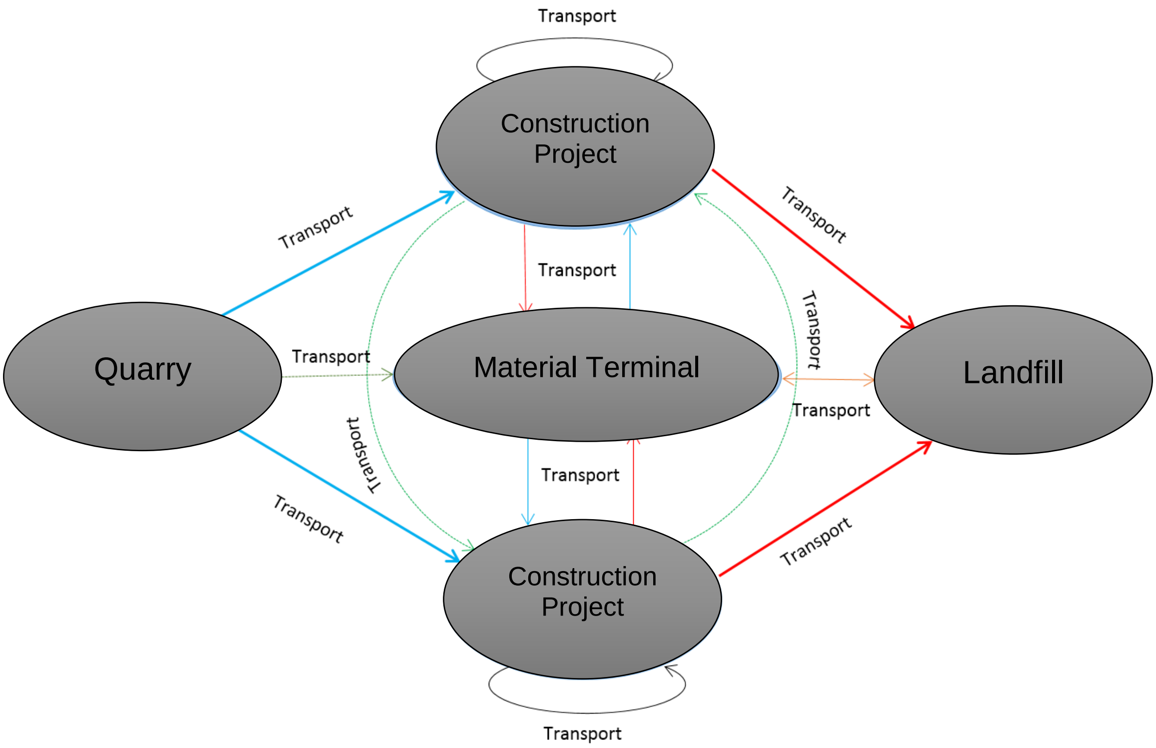

Figure 1. Illustration of material flow

In the quarry the material is first being excavated by mining, drilling, blasting, digging and lastly collection. Then the material is being transported to processing, at first stage pre-crushing where different kinds of crush facilities crushes the material. The type of crush depends on the later use and material requirements. At the next stage the material is being sorted in a sorting facility and sent to mid-crushing. This procedure is repeated for approximately three times until the material gets the desired fraction. Lastly the material is being stored and transported to either construction projects or material terminals. The activity within the quarry is illustrated in figure 2.

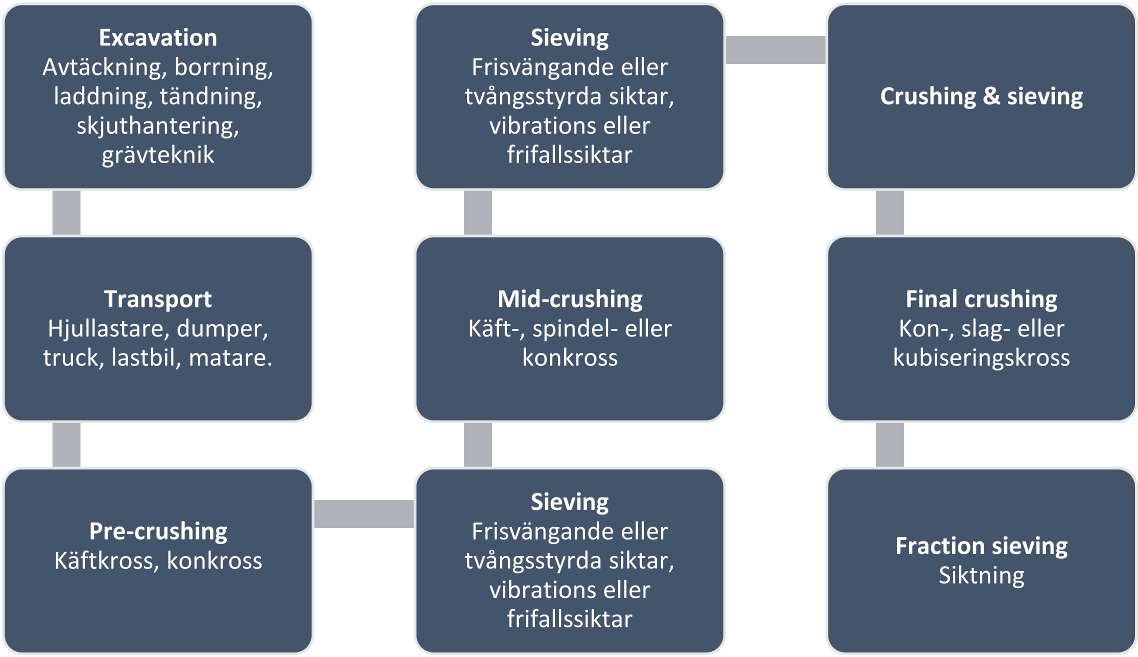

Figure 2. Activities within the quarry (main activities in English, sub in Swedish)

Building – building phase

The construction starts with excavation (same procedure as in quarry excavation) and the material produced at the site are being transported to landfill, material terminals or other construction sites or used at the site. The foundation for the building is being constructed, where various methods can be used depending on the building's purpose. The final construction activities consists of completing house frame, walls, ceiling, floor and façade. The activities within the building phase is presented below (figure 3).

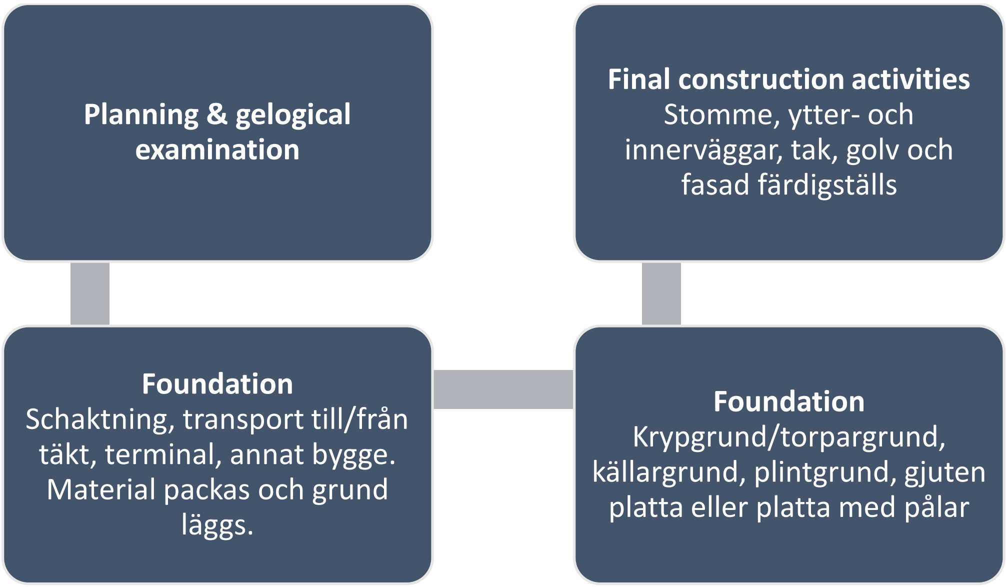

Figure 3. Building phase activities (main activities in English, sub in Swedish)

Building Technology – demolition phase

The demolition is initiated with manual demolition and continues with dismantling the construction and foundation where breakers, concrete cutters and sorting grapples are being used. The demolition waste is transported to material terminals, other construction projects or landfill. This phase is illustrated in figure 4.

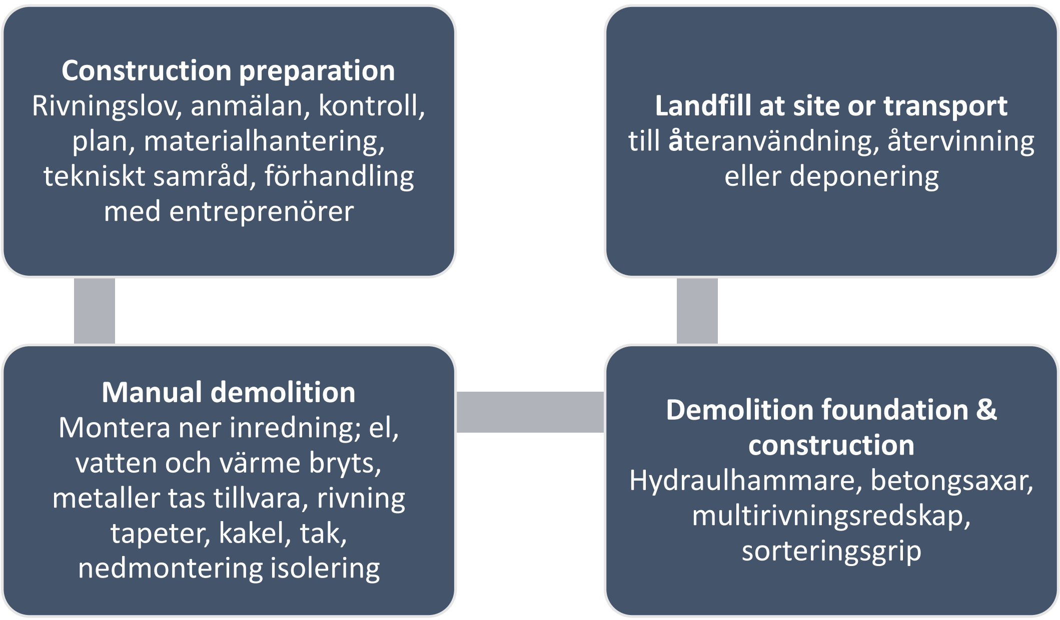

Figure 4. Building demolition phase (main activities in English, sub in Swedish)

Road Construction – construction phase

Firstly the construction site is being excavated (same procedure as in quarry excavation) and the produced material are transported to landfill, material terminals, or other construction sites or used at the site. The foundation of the road is being strengthened and the terrace is constructed. Finally, the surface, superstructure, consisting of sub base, bearing stratum and asphalt or concrete stratum are completed. The road construction phase is illustrated in figure 5.

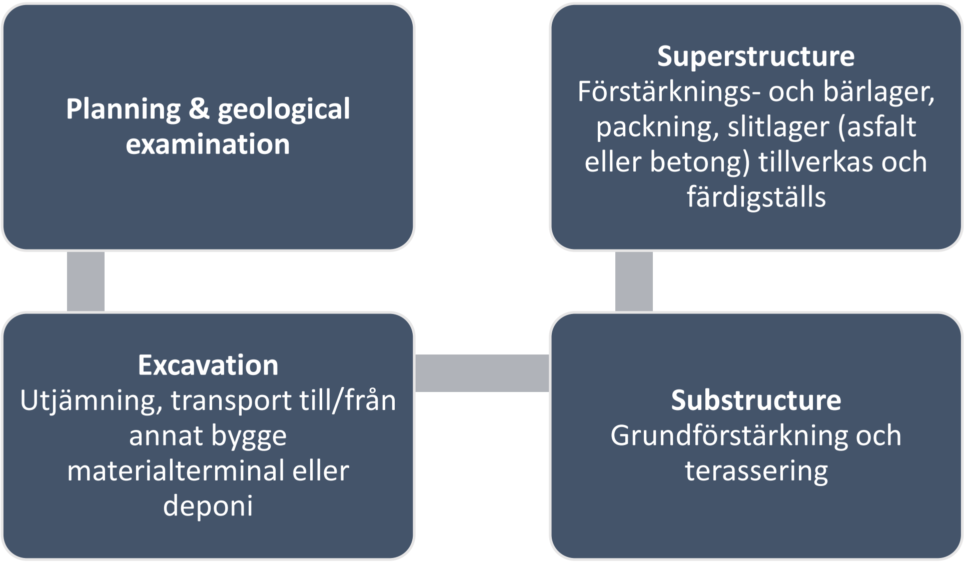

Figure 5. Road construction phase (main activities in English, sub in Swedish)

Road Construction – demolition phase

Dismantling of roads starts with removing paint from the surface, this is made by milling. The actual demolition of the road are made by milling and excavation. The demolition waste is transported to material terminals, other construction projects or landfill. This phase is illustrated in figure 6.

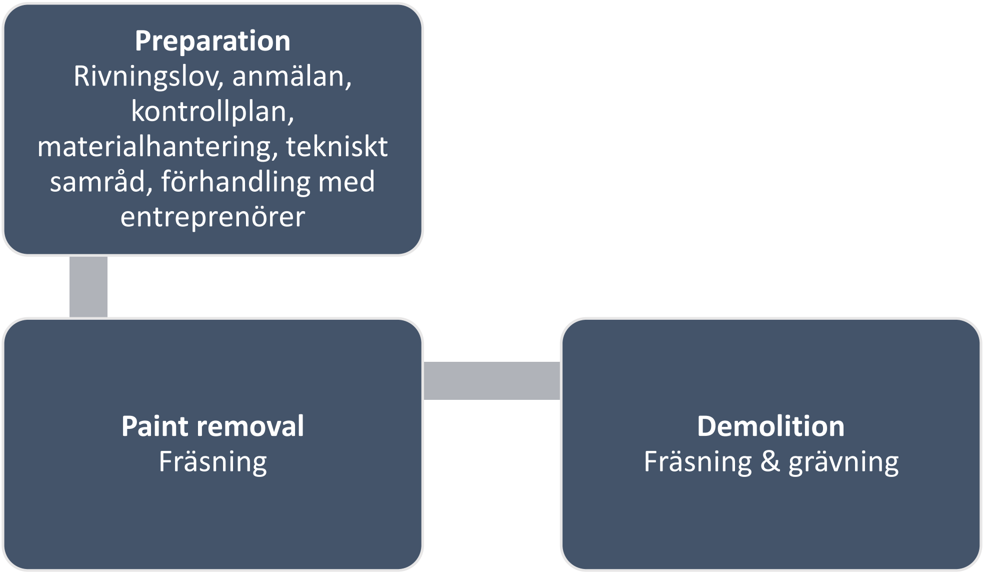

Figure 6. Road demolition phase roads (main activities in English, sub in Swedish)

Technology and equipment in the construction process

Many of the processing technologies construction processes are being used in several stages of the processing of the material from virgin material to construction sites, and are also used in the demolition process. Below (figure 7), the technologies are divided by different materials and applications, based on the material that are most commonly produced and excavated in quarries and at construction sites.

Clay/Silt

- Obehandlat: lågkvalitativ massa för utjämning och fyllnad
- Frysning: minskad vattenhalt för ökad bärförmåga
- Stabilisering (bindemedel och blandare): till kvalificerad fyllnadsmassa, asfalt, överbyggnad eller dränering

Excavated Rock

- Obehandlat: fyllnadsmassa
- Sortering (frisvängande eller tvångsstyrda sviktar, vibrations- eller frifallssiktar och/eller magnetband): till fyllnadsmassa eller vidare till krossning
- Krossning (käftkross, konkross, hammarkross): till fyllnadsmassa, grus eller sand

Moraine

- Obehandlat: fyllnadsmassa
- Sortering (frisvängande eller tvångsstyrda sviktar, vibrations- eller frifallssiktar och/eller magnetband): till bär- och förstärkningslager, deponering, utfyllnad eller vidare till kross.
- Stabilisering (bindemedel och blandare): till kvalificerad fyllnadsmassa
- Sanering (biologisk eller kemisk lakning, jordtvätt eller förbränning)
- Deponering

Asphalt

- Fräsning (lådfräsning, planfräsning eller linjefräsning): vidare till krossning och sortering
- Krossning (hammarkross, konkross eller käftkross)
- Sortering (frisvängande eller tvångsstyrda sviktar, vibrations- eller frifallssiktar och/eller magnetband): till bärlager förstärkningslager, slitlager, tillverkning av ny asfalt
- Underhållsteknik: repaving och remixing

Concrete

- Rivning (hydraulhammare, betongsax, multirivningsredskap, sorteringsgrip): vidare till krossning
- Krossnings (hammarkross, betongpulveriserare, käftkross eller konkross): vidare till sortering
- Sortering (frisvängande eller tvångsstyrda siktar, vibrations- eller frifallssiktar och/eller magnetband): till vägöverbyggnad eller fyllnadsmassa
- Deponering

Figure 7. Technologies and applications by material (materials in English, technology and application in Swedish)

3.5. Discussion and Conclusion

The flow of material in the construction industry is rather complex and therefore it could be seen as important to engage actors and learn about different premises and situations to deepen the understanding in order to coordinate the handling of material between projects and construction actors. There are a lot of technologies that can be further used in order to increase the recycling and re-using of materials that are produced at construction sites. Many of the technologies can be used for multiple materials, which even more motivates an extended use since they are applicable to different materials in different stages of the building and road construction phases.

4. ICT SOLUTIONS

4.1. Introduction to the project

The focus of this project is on ICT (Information and Communication Technology). What is the role of ICT in the construction sector? And how can ICT contribute to reach the stated goals in regards to reuse and recycling of heavy construction materials? Several ICT tools exist in Sweden and all over world, but tools of which the purpose is to increase communication and trade of surplus construction material between different actors in the industry, has experienced limited success. However, this project investigates the potential of investing further resources in developing the idea more, by evaluating the potential environmental, economic and social benefits. This report gives a summary of the findings; however please see full report for more background.

4.2. Aims and Objectives

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.

To fulfill the aim of the thesis the following objectives have been met:

A. Present the identified technologies to stakeholders involved for feedback and priorities
B. Calculate, via scenarios, the potential effects of such ICT solutions (economic, environmental, and social) with systems' assessment tools
C. Create a SWOT-analysis based on the result from previous objectives

More objectives have been presented and met in the full report.

4.3. Methods

Several methods have been used in order to collect data. First of all a literature review was done in order to describe the flow of heavy construction, the relevant stakeholder and to identify existing ICT solutions. After having identified existing solutions, several scenarios were developed. These scenarios were presented for stakeholders, which evaluated the scenarios and their potential use in the future. To calculate the environmental impact a screening LCA (Life Cycle Assessment) was performed. The base of the LCA was a MFA (Material Flow Analysis) which describes where the different flows of material go.

To evaluate the scenarios from all perspectives a SWOT analysis was performed. The SWOT summarizes all the investigated points and gives an overview of all Strengths, Weaknesses, Opportunities and Threats.

4.4. Results

The results are divided into three different parts. An Environmental Consequence Analysis where hence the name, calculations has been done in order to highlight the environmental consequences. An NPV has been presented in the next part, to show the potential economic potential. Lastly, a SWOT has been presented to summarize all advantages and drawbacks with the presented scenarios.

Two scenarios have been used for calculation:

1. Implementation of ICT tool
2. Implementation of ICT and Medium-Term Storage (MTS)

The ICT tool consists of an information flow between the different stakeholders (See full report). The tool which can be accessed via a website, an application or with a telephone call, create a platform where surplus material can be traded. The tool also includes transportation and collects statistics about material flows, publicly available.

The MTS is one or several areas where surplus material can be stored until a new owner has been found. The storage will also facilitate simple recycling processes e.g. screening of mixed material.

4.4.1. Environmental Consequences

The Figure 8 shows the potential reduction in CO2-eq. emission for the expected outcomes of the two solutions proposed and for the current situation.

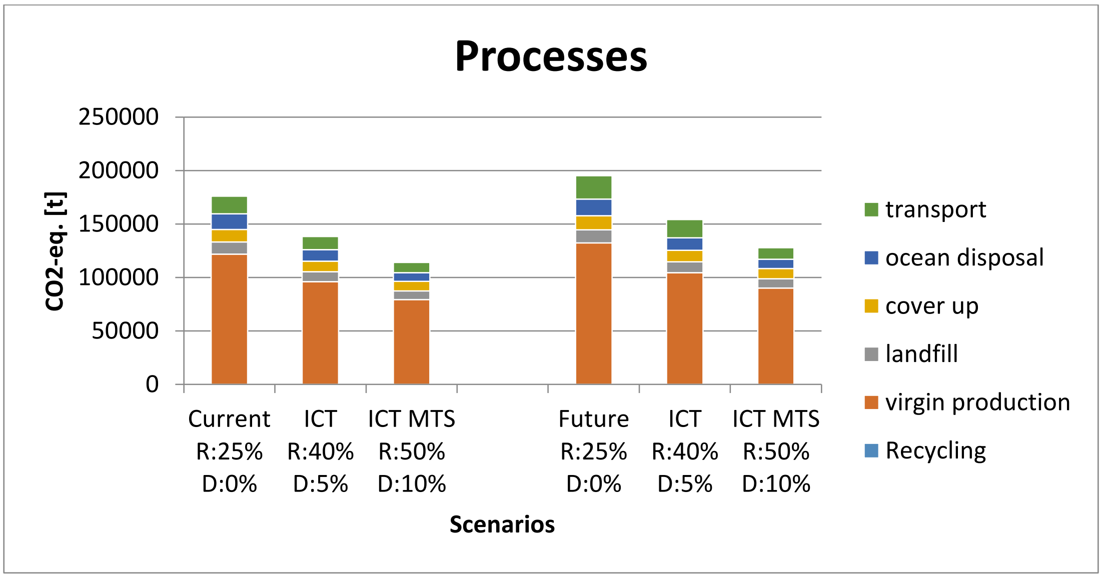

Figure 1 - CO2-eq. emission from the current situation, scenario with ICT and scenario with ICT and MTS

This figure only approaches one environmental consequence, which is CO2-eq.-emission. Other categories include natural resource depletion, aquarial marine life, wear and tear of road and noise.

The figure shows little impact from the transportation process and most impact comes from the virgin production of aggregates. To investigate the significance of the result, a sensitivity analysis has been performed. Several scenarios have been created. The analysis show the virgin production always have a great impact on the total system, however if changing parameters the picture looks different. Increasing the initial distance in the model, means that the reduction of transport becomes much more significant in the total system.

4.4.2. Economic Potential

Much material is available for reuse or recycling, this means also a large cash flow is involved in the business. To get an overview of the potential cash flow an NPV can be found in Table 1 and Table 2.

ICT solution

Table 1. 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 2. 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**				

According to the calculation, both scenarios are profitable in regards to potential saving. However, No actors has the ownership of all material streams, but Table 4 shows the potential economic gain and loss for each of the type of actor in the industry. Most actors benefit from the suggested scenarios, except transportation companies, which seems to lose business. However, the scenarios is optimizing the flows and transportation companies might have an opportunity to rethink their business plan.

Table 3. Economical Gain/Loss vs. Benefit

Actor	Economic Gain	Economic Loss	Benefits
Governments	- Potential rent of areas - Cheaper construction offers	- Funding of project	- Generation of statistics - Reducing environmental impact - better living environment
Clients	- Potential ownership of material - Cheaper construction offers	- Funding of project -	- Better corporation between their contractors - Larger insight in planning
Contractors and Sub-contractors	- Less raw material cost - Less secondary material cost - Less transportation - Less disposal cost - Financial gain on selling more material	- Funding of project - Higher secondary material cost	- Finding new business partners - Better management of material - Higher transparency internally and externally - Area for unwanted material
Transportation companies	- Fewer paying hours	- Driving less kilometers/losing work	- Being more efficient - Predicting demand - Finding new business partners
Recycling Companies	- Increase earnings on recycled material	- Less material to landfilling and backfilling	- Less material to landfilling and backfilling

4.4.3. SWOT

The SWOT analysis puts focus on Strengths, Weaknesses, Opportunities and Threats of the proposed scenarios. The SWOT summarizes the results found in the environmental analysis, the economic analysis and the responses from stakeholder interviews. The SWOT analysis can be seen be seen in Table 5. For the SWOT and elaboration, please see full report.

Table 4. SWOT-analysis

Internal	Strengths	Weaknesses
	- Optimized planning of material flow - Cost savings/earnings - Transport saving - Time saving - Cheap to implement	- Combining with current management system - Change of work routines - Finding an owner for system - Sensitive to changes - Difficult to ensure product quality
External	Opportunities	Threats
	- 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	- Alternative solution being implemented - Lack of support/use from/by companies - Only local business - Challenges in sustaining system - Business outside system. Companies going directly to the source.

4.5. Discussion and Conclusion

Based on the found results it has been evaluated that there is a potential for continuing the project and implementing the solution. Mainly the second scenario has received the most positive feedback. However, even though there is support in the industry to develop the ICT, several issues must be addressed. The ownership of the surplus material is usually the contractors' or the sub-contractors'. Due to this reason it is difficult to find an owner or initiative maker for the project. Larger construction companies has an interest in keeping the business within the companies and do not wish to share information or give business advantages to competitors. Sub-contractors are often smaller with fewer resources to invest, even though the sub-contractors will benefit the most from such an ICT solution.

Solution to the problem has been proposed by representatives from contractors. They feel to a certain degree that the client of construction or infrastructure project should be responsible for the management of material. Both contractors and the client thinks that the clients do not take much interest in what happens to the surplus material, since it is outside of their scope. However, the clients such as Trafikverket, The City of Stockholm, Boverket etc. are the ones that has the power to do a change and either to retake ownership of the surplus material or require a better management of surplus material from their contractors.

Legislation towards better management of surplus material has also proposed e.g. requirement to make material pass an MTS or requirement of documentation for placement of surplus material. However, authorities are not interest in legislation, since they prefer an open dialogue on how to solve problems.

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