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**SOIL MATERIAL CIRCULAR
ECONOMY IN INFRASTRUCTURE
CONSTRUCTION – CAPTURING
UNTAPPED ECONOMIC POTENTIAL**
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ABSTRACT

Antti Nokelainen: Soil material circular economy in infrastructure construction – capturing untapped economic potential
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Climate change and national emission reduction targets have driven construction companies to cut greenhouse gas emissions from their operations. To reach emission reduction targets, construction companies have recognized that cutting emissions requires improved operations, waste reduction and new circular economy solutions. In addition to emission reduction targets, the implementation of the principles of the circular economy into earthwork construction enables a construction company to gain significant competitive advantage. At present, in this research client construction company, soil recycling is part of the operational management of a project, but to maximize recycling, soil recycling planning must become an integral part of project implementation, from planning to execution.

This thesis investigated the current state of soil material recycling from the perspective of an infrastructure construction company. Also, the study examines the untapped economic potential in enhancing soil material circular economy. The aim of the study was to form an understanding of how soil recycling should be organized in order to capture the untapped economic potential. The results of the research are based on a multi-case study involving nine projects from infrastructure company and a workshop involving construction professionals from the company. The research material was collected through semi-structured interviews.

According to this study, the circular economy of soils has long been carried out in infrastructure construction companies. Today, soil recycling takes place on a project-by-project basis and the responsibility for the planning and implementation of recycling lies with the operational management of the project. There is no systematic exchange of information and planning of recycling soil between projects. At present, not all surplus soil can be recycled, but a part of the soil materials had to be disposed of in a landfill. The biggest challenges for soil recycling in a construction company are the lack of information and areas for soil reuse and storage. A major weakness of the current soil recycling operating model is that planning is part of the operational management of the project. The study made it clear that soil recycling planning should be integrated into project planning and the process should be made more systematic. Some of the projects involved in the study had successfully recycled the soil material, resulting in about two percentage cost savings of the project's budgeted costs. Based on this research, large-scale systematic recycling of soil material has significant potential to improve the economic performance of construction company.

The main result of the study is a framework, which provides a guide on how the planning and implementation of soil recycling is taken as a systematic process to a part of the project. The framework was used to address the challenges of soil recycling identified in the study. Another key finding of the study is that people working in earthwork construction have a high level of motivation and interest to soil recycling, but there is a lack of practice in how recycling is implemented. The study highlighted that, the key requirement for large-scale soil recycling is the resourcing of a soil coordinator, who would be responsible for supporting projects in the planning and implementation of soil recycling. Another requirement raised in the study was the need to develop an information system for soil management.

Keywords: Circular economy, Construction logistics, Infrastructure construction, Earthwork construction, Soil recycling, Value capture potential.

The originality of this thesis has been checked using the Turnitin OriginalityCheck service.

TIIVISTELMÄ

Antti Nokelainen: Maa-ainesten kiertotalous infrastruktuurirakentamisessa – käyttämättömän taloudellisen potentiaalin hyödyntäminen
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Ilmastonmuutos ja kansalliset päästövähennystavoitteet ovat ajaneet rakennusalan toimijoita leikkaamaan toimintansa kasvihuonekaasupäästöjä. Rakennusyritykset ovat tunnistaneet, että päästövähennystavoitteisiin pääseminen edellyttää tehostettuja toimintoja, jätteen vähentämistä ja uusia kiertotalousratkaisuja. Kiertotalouden toimintaperiaatteiden integroiminen maanrakentamiseen mahdollistaa päästövähennystavoitteiden lisäksi merkittävän kilpailuedun saamisen. Tällä hetkellä tutkimuksen kohdeyrityksessä maa-ainesten kierrättäminen on osa projektin operatiivista johtamista, mutta jotta kaikki kierrätyksen potentiaali saadaan valjastettua, tulee maa-ainesten kierrätyksen suunnittelu saada kiinteäksi osaksi projektin toteutusta aina suunnittelusta toteutukseen.

Tässä diplomityössä tutkittiin maa-ainesten kierrätyksen nykytilaa infrastruktuurirakennusyrityksen näkökulmasta. Lisäksi tutkimuksessa selvitettiin, mikä on hyödyntämätön taloudellinen potentiaali maa-ainesten kiertotalouden tehostamisessa. Tutkimuksen tavoitteena oli muodostaa käsitys siitä, kuinka maa-ainesten kierrätys tulisi organisoida, jotta hyödyntämätön taloudellinen potentiaali saataisiin hyödynnettyä mahdollisimman tehokkaasti. Työn tulokset perustuvat monitapaustutkimukseen, johon kuului yhdeksän projektia yhdestä infrastruktuurirakennusyrityksestä sekä työpajaan, johon osallistui maarakennusalan ammattilaisia kohdeyrityksestä. Tutkimuksen aineisto kerättiin puolistrukturoiduilla haastatteluilla.

Tutkimuksen perusteella maa-ainesten kiertotaloutta on harjoitettu jo pitkään infrastruktuurirakennusyrityksissä. Nykyään maa-ainesten kierrätys tapahtuu projektikohtaisesti ja vastuu kierrätyksen suunnittelusta ja toteutuksesta on projektin operatiivisella johdolla. Tutkimuksen mukaan systemaattista tiedonvaihtoa ja kierrätyksen suunnittelua projektien välillä ei tapahdu. Tällä hetkellä kaikkea ylijäämä maa-ainesta ei saada kierrätettyä, vaan merkittävä osa maa-aineksesta joudutaan sijoittamaan maankaatopaikalle. Maa-ainesten kierrätyksen suurimmat haasteet rakennusyrityksessä ovat informaation sekä maa-aineksen uudelleenkäyttö- ja varastoalueiden puute. Nykyisen maa-ainesten kierrätyksen toimintamallin suuri heikkous on se, että suunnittelu on osa projektin operatiivista johtamista. Tutkimuksessa nousi selvästi esille, että maa-ainesten kierrätyksen suunnittelu tulisi saada osaksi projektin suunnittelua ja prosessia tulisi saada systemaattisemmaksi. Osa tutkimukseen osallistuneista projekteista oli kierrättänyt maa-ainesta onnistuneesti ja saaneet tämän avulla aikaan noin kahden prosentin kustannussäästön projektin budjetoiduista kustannuksista. Tämän perusteella maa-ainesten laajamittaisessa systemaattisessa kierrättämisessä on merkittävä potentiaali parantaa projektien taloudellista suoriutumista.

Tutkimuksen keskeisenä tuloksena on viitekehys, joka toimii ohjeena siihen, kuinka maa-ainesten kierrätyksen suunnittelu ja toteutus otetaan systemaattiseksi prosessiksi osaksi projektin toteutusta. Viitekehysten avulla onnistuttiin vastaamaan tutkimuksessa esille nousseisiin maa-ainesten kierrätyksen haasteisiin. Toinen tutkimuksen keskeinen löydös on se, että maarakentamisen parissa työskentelevillä henkilöillä on korkea motivaatio ja kiinnostus maa-ainesten kierrättämistä kohtaan, mutta käytöstä puuttuu toimintatavat, kuinka kierrätystä toteutetaan. Tutkimuksessa keskiseksi laajamittaisen maa-ainesten kierrätyksen vaatimukseksi nousi maa-ainekoordinaattorin resursoiminen, jonka vastuulla olisi toimia projektien tukena maa-ainesten kierrätyksen suunnittelussa ja toteuttamisessa. Toisena vaatimuksena tutkimuksessa nousi esille tarve maa-ainesten hallintaan käytettävän tietojärjestelmän kehittämisestä.

Avainsanat: Kiertotalous, Rakentamisen logistiikka, Infrarakentaminen, Maarakentaminen, Maa-ainesten kierrätys.

Tämän julkaisun alkuperäisyys on tarkastettu Turnitin OriginalityCheck –ohjelmalla.

ALKUSANAT

Yhdeksän kuukautta sitten aloitin diplomityön, eikä minulla tuolloin ollut käsitystä siitä, kuinka hieno oppimismatka minulla on edessä. Työn tekemiseen on mahtunut pätkäilyä aina turhautumiseen asti, mutta onneksi suurimmaksi osaksi työn edistäminen on sujunut vaivattomasti. Tämän työn valmistumisen myötä useita vuosia kestänyt opintaival kääntyy loppusuoraa kohti ja taaksepäin katsottaessa voi todeta, että matkan aikana on tullut opittua monenlaista, kasvettua ja aikuistuttua.

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TABLE OF CONTENTS

1.	INTRODUCTION.....	1
1.1	Background for the research.....	1
1.2	Goals for the research and research questions.....	4
1.3	Limitations for the thesis.....	5
1.4	Thesis structure.....	5
2.	CAPTURING ECONOMIC VALUE THROUGH THE CIRCULAR ECONOMY PRINCIPLES IN INFRASTRUCTURE CONSTRUCTION.....	7
2.1	The concept of circular economy.....	7
2.2	Circular economy in business.....	11
2.2.1	Circular strategies.....	11
2.2.2	Circular business models.....	12
2.2.3	Economic value capture potential of circular economy.....	13
2.3	The circular economy in the infrastructure construction industry.....	15
2.4	The circular economy operating environment in Finnish earthwork construction industry.....	18
2.4.1	Legislation of the circular economy of unpolluted soil material in Finland.....	18
2.4.2	Challenges of the operating environment in the utilization of recycled soil materials.....	20
2.4.3	Improving reusing of soil material.....	20
3.	LOGISTICS IN EARTHWORK COSTRUCTION.....	22
3.1	Logistics overall.....	22
3.2	Logistics in construction industry.....	24
3.2.1	Elements of construction logistics.....	26
3.2.2	Logistics planning and execution in construction project.....	27
3.3	Capture economic value in construction project with logistics management.....	28
3.3.1	The effect of logistics on construction projects performance.....	29
3.3.2	Means to improve construction logistics.....	30
3.3.3	Improving earthwork construction logistical performance.....	32
3.4	Combining circular economy principles and logistics management for more efficient soil material recycling.....	34
4.	DATA AND METHODOLOGY.....	36
4.1	Positioning of the study, research strategy and methods.....	37
4.2	Data collection.....	38
4.2.1	Case study.....	38
4.2.2	Workshop.....	41
4.3	Data analysis.....	42
4.4	Research validity and reliability.....	43
5.	RESULTS.....	45
5.1	Current status of soil material circular economy.....	46

5.1.1	Soil material sourcing and disposing.....	46
5.1.2	Soil material recycling.....	49
5.1.3	Soil material logistics management.....	57
5.2	Challenges in soil material recycling	59
5.2.1	Lack of information sharing and co-operation	60
5.2.2	Soil material recycling logistics challenges	63
5.2.3	Legislation and quality challenges	66
5.2.4	Environmental challenges in soil material recycling	67
5.3	Economic value capture potential of soil material recycling.....	68
5.4	Organizing soil material circular economy in YIT.....	70
5.4.1	Simple solution	70
5.4.2	Systematic soil material management	71
5.4.3	Potential of UAV photogrammetry in soil material management.....	73
6.	DISCUSSION.....	74
6.1	Comparison current status of soil material circular economy in YIT with previous academic literature	74
6.2	Framework for designing soil material systematic recycling	81
6.2.1	Contract-based projects.....	83
6.2.2	Self-developed projects	85
6.2.3	Requirements for proposed operations model	87
6.3	Overcoming soil material circular economy challenges	88
6.4	Future development for the YIT.....	91
7.	CONCLUSION	92
	REFERENCES	96
	ATTACHMENT A.....	105
	ATTACHMENT B.....	107

LIST OF FIGURES

<i>Figure 1 Circular economy framework (Lieder & Rashid, 2016).</i>	10
<i>Figure 2 Circular economy across the building life cycle (Adams, et al., 2017).</i>	15
<i>Figure 3 The directive administrative procedure of unpolluted soil material usage in Finland presented in application directive by Finnish Ministry of the Environment (Finnish Ministry of the Environment, 2015; Infra Ry, 2020).</i>	19
<i>Figure 4 Logistics cost share (The Establish Davis database 2016).</i>	24
<i>Figure 5 Logistic process in the construction industry. Edited from the sources (Vrijhoef & Koskela, 2000; Wegelius-Lehtonen, 2000).</i>	25
<i>Figure 6 Logistics through the construction project (Serra & Oliveira, 2003).</i>	28
<i>Figure 7 Combining circular economy and soil material logistics literature into entirety following Serra & Oliveira (2003) view of phases in construction project.</i>	35
<i>Figure 8 Research process of the study.</i>	36
<i>Figure 9 Case projects revenue in relation to each other.</i>	45
<i>Figure 10 Person in responsible of mineral aggregate and soil material and soil material procurement.</i>	46
<i>Figure 11 Share of projects disposing of clay and silt material.</i>	48
<i>Figure 12 Share of projects disposing of potentially reusable material.</i>	48
<i>Figure 13 Success factors in soil management.</i>	57
<i>Figure 14 Soil material recycling challenges in site's perspective.</i>	59
<i>Figure 15 The framework for soil material recycling in contract-based business.</i>	84
<i>Figure 16 The framework for soil material recycling in self-developed projects.</i>	86

TERMINOLOGY

3PL	Third-party logistics in logistics and supply chain management is an organization's use of third-party businesses to outsource elements of its distribution, warehousing, and fulfillment services.
BIM	Building information model that contains information of building and construction process.
Blasted rock	Natural stone generated during quarrying. The grain size of the material is so large that it needs to be processed smaller. When processed, it produces crushed stone.
Business premises	YIT segment focused on construction of business premises
Circular economy	An economic model that aims to eliminate waste and keep materials in the value chain as long as possible.
Clay	Clay is a very fine mineral particle mass that is difficult to utilize when wet.
Concrete aggregate	Recycled concrete used in civil construction
Crusher stone	Crusher stone is a material that is formed when natural stone is processed to be more compact.
CSCMP	Council of Supply Chain Management Professionals.
Gravel	Gravel is a rock material with a grain size ranging from two millimeters to about sixty millimeters.
Housing	YIT segment focused on construction of residential buildings
Infrastructure projects	YIT segment focused on construction of infrastructure projects.
Loading berm	A pile of soil used to preload a plot to stabilize low-bearing structures such as clay. Thanks to Load berm, for example, clay does not need to be stabilized or removed separately during construction.
Mass hauling	A mass haul movement is the movement of excavated material from where it arises to where it is to be used, treated or disposed of.
Mineral aggregate	General insight for building material like gravel or crushed rock that has been mined or quarried.
Non-cohesive soil	Non-cohesive soil is a generic name for different soil materials, like sand, gravel, moraine and rocks. Non-cohesive soil can be stored in a pile without tipping over.

Silt	Silt is a fine and soft soil that is a mixture of clay and sand.
Sludge	Sludge is a semi-solid soil material that is very moisture. The material occurs near water and groundwater.
Soilcrete	Soilcrete is soil treatment methods to create structures for load bearing and sealing in geotechnics. In the method, a mixture is injected into the soil to make the soil loadbearing.
UAV	Unmanned aerial vehicle, like drone chopper used in site photogrammetry.

1. INTRODUCTION

1.1 Background for the research

Urbanization is a remarkable phenomenon that is taking place all over the globe. Today more people live in urban areas than in rural areas, and in 2018, 55 percent of the world population lived in urban areas. When looking back to 1970, when 70 percent of the world population lived in rural areas, the growth of the urban population has been significant. Recent studies predict that by 2050 approximately two-thirds of the world population will live in urban areas. (DESA, 2019) A similar development can be observed in Finland. It is predicted that in 2040 85 percent of the Finnish population will live in urban areas. The same research predicts that half of the Finnish population will live around Helsinki, Turku and Tampere metropolitan area. (Aluekehittämisen konsulttitoimisto MDI, 2019) For this reason, urban infrastructure like light railways, business premises like shopping malls and residential construction in Finland are strongly concentrated in those cities during last few years.

In addition to accelerating urbanization, global warming is a real concern today. To meet the goals of emission reduction, emissions should cut 80 percent of all emissions by 2050 (Sitra, 2019). At the same time, the Finnish Ministry of the Environment says that the construction industry causes a third of all greenhouse gas emissions in Finland (The Finnish Ministry of Environment, 2018). Today, urbanization and emission reduction targets strongly guide the operating environment in the construction sector.

This research's client corporation YIT, has recognized the significance of urbanization and construction industries emission. YIT has addressed the core of its strategy to address to respond to the challenges of urbanization and YIT's core business is based on sustainable urban development. (YIT, 2019) To respond to the challenge of global warming YIT has written into its strategy three sustainability goals which are "halving CO₂ emissions of own operations and self-developed projects by 2030 compared to 2019, aiming for carbon-neutral use of buildings, as well as starting to report project-specific CO₂ indicators of self-developed projects from 2020 onwards" (YIT, 2019). YIT has recognized that halving CO₂ emissions requires, for example, more efficient operations and reduced waste, and new types of circular economy solutions.

According to research conducted in the United Kingdom (C40 Cities, Arup & University of Leeds, 2019), up to 16 percent of total construction emissions contribute to the supply chain. A way to lower embodied emissions in the construction supply chain is to adopt circular economy principles. (C40 Cities, Arup & University of Leeds, 2019) Virgin rock material will have to be brought to the construction site farther and farther away as the resources in the excavation sites near the urban area are decreasing. Of the total aggregate costs, transport and distribution account for the largest share, about two thirds. Longer distances will not only increase costs but also significantly increase emissions to the atmosphere. (Lonka, et al., 2015) YIT has recognized the significance of construction logistics emissions as part of a construction project's emissions. As a part of the strategic sustainability program, there is a goal to develop excavated soil material circular economy to reduce CO₂ emissions and gain cost savings.

The construction industry is one of the most significant consumers of natural resources. It has been widely recognized in the literature that following the principles of the circular economy, it can reduce the resource use of construction and increase the efficiency of construction operations. (Benachio, et al., 2020) However, there is a research gap on the assessment of the current state and challenges in implementing circular economy in construction industry. In order to implement the circular economy in the construction industry, new information must be generated. (Bilal, et al., 2020)

Ghisellini et al. (2018) have presented that implementing circular economy principles to construction industry can generate both costs and environmental savings. In this study, the assessment of the impact of the circular economy is limited to the economic dimension, as the analysis of environmental impacts is not actively done in construction due to fragmented supply chain. In a circular economy, cost savings are achieved by capturing economic value utilizing materials as efficiently as possible (Ghisellini, et al., 2018).

Lepak et al. (2007) have presented that there are several dimensions in value capturing and at the level of a single organization. The amount of value captured is not easily calculated, because it involves several different factors (Lepak, et al., 2007). This research seeks to find out what features does economic value capture potential include in soil material recycling. Also, to achieve untapped economic value capture potential companies need to adopt circular economy principles. To do so, companies need to change their operations towards circular economy principles. (Lieder & Rashid, 2016)

The dense settlements in Finland's most significant urban centers have made soil recycling challenging, due to the lack of storage and processing areas. Today, the long transportation distances of virgin materials, the high cost of material disposal, and

significant emissions from the supply chain drive earthwork construction toward circular economy innovations. In order to implement circular economy operating models for earthwork construction, the problems of both resource use and logistics management must be solved.

As mentioned earlier, YIT has recognized that achieving emission reduction targets requires improved operations, waste reduction, and circular economy solutions. This study seeks to address how soil recycling activities can be made more efficient and reduce the amount of soil waste generated through circular economy solutions. It has been identified in the academic literature that for a company to adopt circular economy operating models, they need to shape their operations (Lieder & Rashid, 2016). This study examines how YIT should modify soil material management processes to establish a profitable circular economy mechanism. In addition to this, it has been recognized in the academic literature that by following the operating principles of the circular economy, it is possible to capture economic value (Ghisellini, et al., 2018; Korhonen, et al., 2018; Lepak, et al., 2007). This study seeks to determine whether YIT has the potential to capture value by developing a soil material circular economy mechanism. Besides, as mentioned earlier, densely populated areas and limited space of construction sites pose challenges for soil logistics management. The constraints imposed by the operational environment on soil logistics must be considered when developing a solution mechanism for the soil material circular economy.

The dimensions of the problem are how to shape an organization's business model to support the principles of a circular economy and how to manage operational logistics effectively in a challenging operating environment. In the academic literature, the circular economy and logistics in the construction industry have not been treated as a single entity, however circular economy in construction and the intensification of operational soil recycling have been treated as separate entities. A lot of research have been done into the optimization of soil material logistics within a single project, such as a road project (De Lima, et al., 2013; Son, et al., 2005; Choudhari & Tindwani, 2017; Liu & Lu, 2015; Moselhi & Alshibani, 2009; Sobotka, et al., 2012). However, there is no research on earthmoving operations and logistics optimization between several projects or within a construction project portfolio. This study aims to combine the development of circular economy business models with logistics planning at the project portfolio level into an entity by stating that both play an essential role in the development of soil material circular economy.

1.2 Goals for the research and research questions

YIT has a wide range of projects taking place in a small geographical area. YIT has projects which produce excavated rock and soil material and at the same time, YIT has projects which need excavated soil material to refill or rock material to reinforce ground. Today, excavated rock and soil materials are not managed centrally at YIT, but construction managers handle soil material recycling independently. There is lack of transparency between projects which project produces, and which needs excavated material. There is no common operating model for soil material information reporting and sharing. Today soil and rock material end up to another site a case-by-case basis and, at the same time many projects source soil and rock materials from outside of YIT. Today it is challenging to find a recovery site for surplus material, and as a result, clean soils end up in landfill sites.

YIT has recognized the issue and has started to do actions towards more coordinated soil material recycling. This thesis concerns the evaluation of soil material recycling current status and what is economic value capture potential in soil material circular economy. This research also involves how operations should be managed to capture economic value embedded in soil material as widely as possible. This thesis's research questions are as follows:

1. What is the current status of soil material circular economy in YIT?
2. What is captured economic potential that can be reclaimed by improving soil material recycling?
3. How can YIT organize construction operations in a way that it can reuse relevant surplus soil material at YIT's projects?

The objective of this research is to find out what is the current status of soil material circular economy in YIT and how to improve it. The study also seeks to determine the economic impact of soil recycling on individual projects. The aim of this study is to form a suggestion of an operating model that can be used as a basis for further development of soil material circular economy within YIT.

This study was carried out as a case study, in which sample was nine YIT projects in which soil management has been an integral part of the project. In the case study, semi-structured thematic interviews were conducted with the persons responsible for the management of soil materials. In addition to the interview study, a workshop was organized in the research to try to find ways to solve the challenges of soil management.

In addition, the amount and cost of soil information obtained from the projects studied were used in the study to evaluate economic value capture potential.

1.3 Limitations for the thesis

This research concerns only recycling of unpolluted soil materials. Improving the circular economy of contaminated soils and other building materials is out of this research scope.

In this research literature review, the circular economy deals only with the circular economy of materials and not the circular economy associated with biological processes. For this reason, the literature review excludes the study of the circular economy of biological processes. Also, the platform economy phenomenon has not been addressed in this thesis's circular economy literature review. In the case of the circular economy of construction, this thesis deals only with the circular economy phenomena related to earthwork construction, as it is not relevant for this study to examine the circular economy of the whole construction industry.

This study focuses on the economic benefits of the circular economy. The circular economy provides direct and indirect economic benefits. Direct economic benefits include, for example, cost savings from reduced resource use. In turn, indirect benefits are not directly related to circular operations. An example of an indirect economic benefit is the increase in sales brought about by the improved brand image. (Ellen MacArthur Foundation, 2015, p. 74) In this research, the value capture potential of the circular economy consists of the achieved economic benefits of shaping operations to a more sustainable direction.

This thesis does not address accurately to legislation related issues on the use of recycled materials in earthwork construction. In this study, only the operating environment of soil material circular economy and its legislative limitations are presented in section 2.4.

1.4 Thesis structure

In chapter two, there is a literature review on the circular economy in earthwork construction. First, the chapter focuses on the circular economy as a phenomenon, followed by a discussion of the circular economy business models and strategies. After that, the chapter focuses on the circular economy of earth construction. With the help of chapter two, I seek to understand how the circular economy can improve efficiency in the construction industry and thus improve construction project's economic performance

In chapter three, there is a literature review of construction logistics. The purpose of chapter three is to find a way to enhance the circular economy of earthwork construction by focusing on developing logistics management. The literature review seeks to answer the question, what is the role of earthwork logistics in the construction projects' performance and what is the impact of earthwork logistics improvement for the whole construction project.

Chapter four presents the research methodology. The chapter presents the research strategies and specific methods used in the study. In addition, the fourth section presents the data used in the research and its analysis methods.

The fifth chapter presents the results of the study, and the sixth chapter examines the results of this study. The sixth chapter compares the results of the study and the previous literature and offers improvement proposal for the circular economy of soil materials in YIT. Also, there are some further development suggestions presented in the sixth chapter for the case company. In the seventh chapter the research conclusions are presented.

2. CAPTURING ECONOMIC VALUE THROUGH THE CIRCULAR ECONOMY PRINCIPLES IN INFRASTRUCTURE CONSTRUCTION

In this chapter, a literature review of the circular economy is conducted with a focus on improving the economic performance of the construction project by following business models and strategies of the circular economy. The economic benefits of the circular economy to the national economy has been a subject of a few studies (Arponen, et al., 2015; European Commission, 2015). However, there are not many pieces of research that addressed the circular economy's economic benefits for a single company. First, with this literature review, the aim is to answer the question of what economic benefits can be reached within one company using circular economy models and strategies. Second, the aim is to find a definition of the circular economy's features, especially in the construction industry. Third, the aim is to find out which factors regulate the circular economy of soils in Finland. Fourth, the aim is to find characteristics of circular business models that can support the circular economy in earthwork construction.

The primary source for this literature review was peer-reviewed production, business, or construction journals. There are many publications on the circular economy, so I chose publications based on the number of citations. For the acquisition of written material, I mainly used keywords: *Circular economy*, *circular economy business potential*, *circular economy business model*, and *circular economy in the construction industry*.

First, this section presents the circular economy concept and provides a comprehensive definition of it. After that, there are considered typical business models and strategies of the circular economy. Third, there is considered what the circular economy in the construction industry is and how to improve it. Fourth there is considered the operating environment and regulating factors of circular of soil material circular economy in Finland, and last, there is considered the benefits of the circular economy for the economic system and a single company.

2.1 The concept of circular economy

The circular economy is currently a popular concept that has been promoted by several factors, including the national government and many businesses worldwide (Korhonen, et al., 2018). The concept of the circular economy is presented to work as a solution to

a series of challenges such as waste generation, resource scarcity, and sustaining economic benefits (Lieder & Rashid, 2016).

The popularly used concept, circular economy, is considered from the perspective of scientific research of sustainable development (Korhonen, et al., 2018). The circular economy is a relatively new concept fragmented based on the collection of ideas derived from different scientific fields, like industrial ecology, industrial ecosystems, cleaner production, the concept of zero emissions, and others. Sustainable development was originally defined as a development that meets the needs of the present without compromising future generations' ability to meet their needs (World Commission on Environment and Development, 1987). The main challenge of sustainable development is a linear (one-way) physical flow of material and energy between nature and the human economy (Korhonen, et al., 2018).

Today economics is based on a linear economic model where materials and goods are produced, used, and disposed of right after usage (Ellen MacArthur Foundation, 2015). The linear economy is a process that is flowing like a river, turning natural resources into raw materials and products for sale through a series of value-adding steps (Stahel, 2016). The linear economic model causes a non-sustainable “take-make-dispose” operating model that will eventually reach a sustainability dead-end as the Earth's resources will be overloaded (Antikainen & Valokari, 2016).

Some may think that the circular economy is a concept invented during the last few years due to increased number of academic research. The truth is that the circular economy was invented at the turn of the 1970s and 1980s. One of the early definitions is presented by Walter Stahel (1982), who presented product life-extension activities – reusing, repairing, and recontinuing. These activities create a spiral loop system that minimizes matter, energy-flow, and environmental deterioration without restricting economic growth or social and technical progress (Stahel, 1982). Thirty-four years later, Stahel (2016) still presents the same that the circular economy is all about system thinking and closing loops. The circular economy turns goods that are at the end of their services into recourse to others, closing loops in industrial ecosystems, and minimizing waste (Stahel, 2016). Alternatively, the circular economy is an economic system that is restorative and regenerative by nature and aims to preserve or even upgrade products, components, and material and value always between cycles (Ellen MacArthur Foundation, 2015; Antikainen & Valokari, 2016).

To sum up these definitions, the circular economy includes two factors: closed loops of material in the whole economic system, (Geng & Doberstein, 2008) and improving

resource efficiency by reducing, reusing, and recycling materials through the value chain. (Yuan, et al., 2006)

There are multiple features and benefits made possible by adopting the circular economy. Korhonen et al. (2018) present that there is a win-win-win potential in the circular economy that refers to improving one factor of sustainable development improves other factors as well. The circular economy contributes all three features of sustainable development: economic, environmental, and social (Korhonen, et al., 2018). In a larger picture, adopting the circular economy needs to be a combination of all circular economy features. Bocken et al. (2014) underline that responding to environmental challenges will necessarily need to be in parallel with economic and social change.

As mentioned above, the circular economy furthers three features of sustainable development. In table 1 there are definitions for the features of sustainable development, which are furthered by the circular economy and authors who present these viewpoints.

Table 1 Features of sustainability which are furthered by the circular economy.

Effect of implementing circular economy	Definition	Authors
Environmental benefit	Resources are used many times, which reduces the use of virgin material and energy input. Reducing waste and emissions.	<ul style="list-style-type: none"> • Korhonen et al., 2016 • Stahel, 2016 • Antikainen & Valokari, 2016. • Ellen MacArthur Foundation 2015
Economic benefits	The value in resources is used many times that reduce raw material and energy costs. New markets are found for the value of resources.	<ul style="list-style-type: none"> • Korhonen et al. 2018 • Lieder & Rashid, 2016 • Ellen MacArthur Foundation 2015
Social benefits	New employment opportunities through new use of the value embedded in the resources.	<ul style="list-style-type: none"> • Korhonen et al. 2018 • Stahel, 2016 • Ellen MacArthur Foundation, 2015

Table 1 presents the benefits of the circular economy. Lieder and Rashid (2016) have presented a comprehensive framework for the circular economy, which can be used to present the circular economy's benefits. The framework presents that circular economy is a combination of resource scarcity, considering environmental impact and economic benefit. According to Lieder and Rashid (2016), these three factors are intrinsically linked to each other. The framework is presented in figure 1 below.

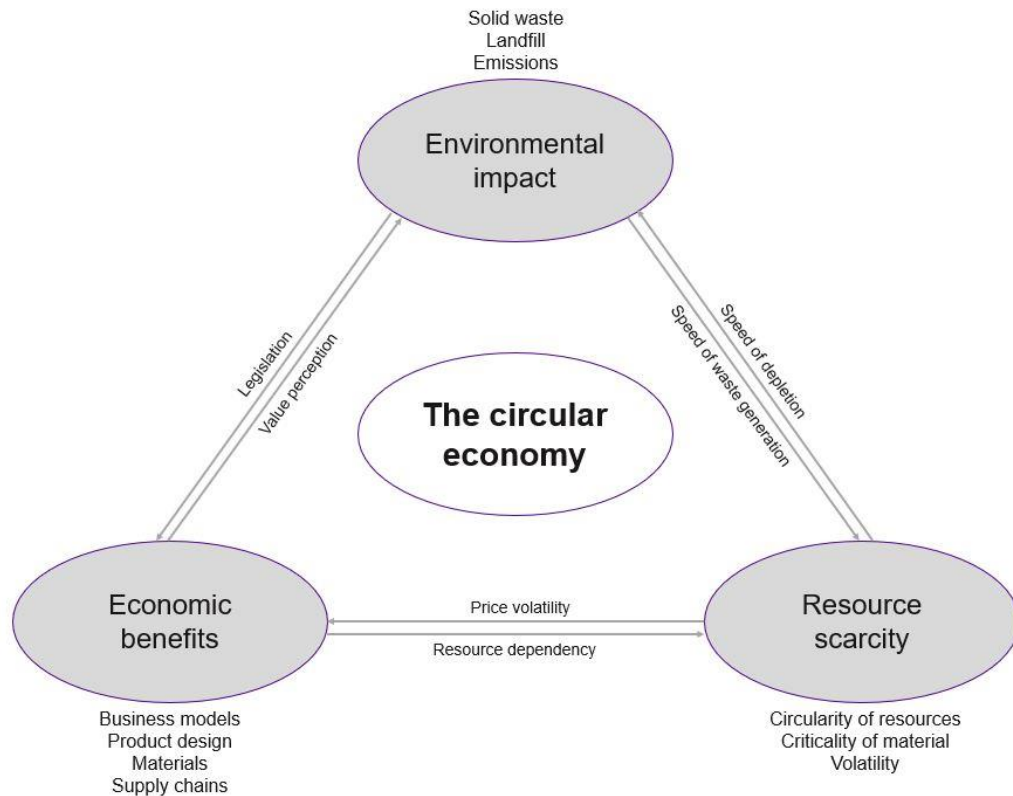


Figure 1 Circular economy framework (Lieder & Rashid, 2016).

The circular economy aims to reduce solid waste, landfill sites, and emissions through reuse, remanufacturing, and recycling. Economic value perception affects the environmental impact because while pursuing economic benefits, companies influence the environment. The speed of resource depletion affects natural environments because resource depletion sets the pace for not wanted environmental effects. (Lieder & Rashid, 2016)

The industrial business world is today focusing on achieving economic benefits, so it is important to include economic benefits to the circular economy framework. Companies are trying to generate business models, and products that are feasible in the sustainable point of view between the constraints given by legislation. Also, price volatility and supply risks have a direct influence on the competitive edge of companies and their capability of performing their operations profitably and sustainably. (Lieder & Rashid, 2016)

The circular economy aims at improving the circularity of resources and balance the volatility of critical material. The speed of waste generation and resource dependency effect are factors that influence how the value of resources committed can be maintained for as long as possible. Understanding end-of-life products as resources rather than waste involves the management of resource values as part of standard business operations. (Lieder & Rashid, 2016)

The deepest essence of the circular economy is the formation of an economic model that is simultaneously environmentally and economically regenerative. To pursue that, the nation must adjust its society, legislation, and policies to support that. Simultaneously companies need to adjust their manufacturing practices to a sustainable way to obtain competitiveness and profitability. (Lieder & Rashid, 2016)

2.2 Circular economy in business

Business ideas and technology by itself, has no objective value. The economic value of innovation remains hidden until it is commercialized through the business model. (Chesbrough, 2010) The essence of a business model is defining ways by which an organization delivers value to its customers, attracts customers to pay for the value, and converts the payment to profit (Teece, 2010). The core of the business model can be compiled as a representation of how an interrelated set of decision variables in the areas of venture strategy, architecture, and economics are addressed to create sustainable competitive advantage in the chosen markets (Morris, et al., 2005). The generic business model consists of two sections. First partner network, where company sources key activities and resources, which form the basis for the company's cost structure. Second, the generic business model consists client's segment, which includes client relationships and distribution channels, which form the basis for the revenue model. (Osterwalder & Pigneur, 2010) To sum up these definitions, the strategy answers the question of what and where a company wants to be, and the business model is answering a question of how the company is going to achieve the objectives defined in the strategy.

2.2.1 Circular strategies

To shift business towards a circular economy company needs to shape its strategy. The circular economy strategy has three characteristics: slowing, closing, and narrowing resource flows. (Bocken, et al., 2016) Bocken et al. (2016) have formed three strategic measures for the circular economy based on definitions in the literature.

1. Slowing resource flows includes designing lifelong goods and product life service loop to extend the product's life. Concrete actions are, for example, repairing and remanufacturing of goods.
2. Through recycling, the loop between disposal and production is closed, resulting in a circular flow of material.
3. Narrowing resource flow is improving production resource efficiency aiming to use less material to products.

These factors have been featured in literature in the 1990s. However, these factors were not part of companies' strategic decisions, but they have been more of an operational objective for the companies. To get the circular economy to work, companies need to incorporate larger-scale circular economy strategies into their strategies and decision-making process. (Bocken, et al., 2016)

2.2.2 Circular business models

In the literature, several business models can be detected on how the circular economy can be featured. Circular business models are based on sustainable business models. (Bocken , et al., 2014) have compiled archetypes of sustainable business models based on previous literature. The eight archetypes of sustainable business models are (Bocken , et al., 2014):

- “1. Maximize material and energy efficiency
2. Create value from ‘waste’
3. Substitute with renewables and natural processes
4. Deliver functionality, rather than ownership
5. Adopt a stewardship role
6. Encourage sufficiency
7. Re-purpose the business for society/environment
8. Develop scale-up solutions”.

All these archetypes are not relevant in the context of excavated rock and soil material circulation inside a civil construction company. In this research, the most relevant ones are material and energy efficiency, value creation from waste, and usage of renewable materials. On top of eight archetypes, Bocken et al. (2016) completed the view that shaping product design towards circularity is an essential feature of the circular business model (Bocken, et al., 2016). In addition to these features, a collaboration between different factors is also an essential in creating the circular business model (Witjes & Lozano, 2016). Table 2 summarizes the features of the circular business models that are relevant for soil material circular economy and the authors who promote these views.

Table 2 Features of sustainable business model.

Archetypes of circular business models	Definition	Explanation
Minimize material and energy usage	It is aiming at minimizing material usage and energy consumption in processes.	<ul style="list-style-type: none"> • Ellen MacArthur Foundation 2015 • Bocken et al. 2014
Maximize material value through the value chain	It is aiming to minimize the loss in processes and to keep materials at their highest value all times.	<ul style="list-style-type: none"> • Ellen MacArthur Foundation 2015 • Bocken et al. 2014 • Stahel, 2016
Substitute with renewables and natural processes	It is aiming to find renewable resources to replace non-renewable resources.	<ul style="list-style-type: none"> • Bocken et al. 2014
Shaping products design to support the circular economy	Products are designed by intention to be consumed by the economy and regenerate new resource value.	<ul style="list-style-type: none"> • Ellen MacArthur Foundation 2015 • Antikainen & Valokari, 2016 • Stahel, 2016
Collaboration between different players	An ideology that presents that the full potential of the circular economy can be harnessed by collaborating.	<ul style="list-style-type: none"> • Witjes & Lozano, 2016

Table 2 shows that several researchers have presented the same business models for the circular economy. All in all, implementing the circular economy's business models is a way of striving for efficiency across the value chain of products. It is essential to be aware of the role of co-operation and to look at the effects of activities outside of the organization's activities (Witjes & Lozano, 2016).

2.2.3 Economic value capture potential of circular economy

There is no academic case study of the actual benefits of a circular economy for one company. However, some estimates have been made of the benefits of the circular economy for the national economy. European Commission (2015) has presented that adopting the circular economy may generate savings of €600 billion for businesses inside the EU. Also, Ellen MacArthur Foundation (2015) has estimated that annual material cost-saving opportunity is the same €600 billion in the advanced circular economy scenario. That is equivalent to 8 percentage of European Union countries' turnover. However, this assumption is entirely based on estimates, and there is little convincing evidence of its reality. Adopting the circular economy, it can create 600 800 new jobs and reduce the EU's carbon emissions by 450 million tons by 2030 (European Commission, 2015). Ellen MacArthur Foundation (2015) also presents that adopting the

circular economy can create economic growth, material cost savings, new employment opportunities, and increased innovation.

According to Korhonen et al. (2018) in the circular economy, new value capture opportunities are created because the value embedded in materials is used many times instead of only once as is usually the case in the modern global economic system. Also, in circular economy cost savings are gained by capturing economic value utilizing materials as efficiently as possible (Ghisellini, et al., 2018). For a single company, the circular economy's economic value capture potential stems from the reduction of material cost and improvement of their product's demand. Once the raw material is produced, it makes economic sense to keep the produced value in the circle as long as possible. (Korhonen, et al., 2018)

The cost-effectiveness of circular economy operations is key to a successful circular economy business (Ranta, et al., 2018). As Korhonen et al. (2018) and Ghisellini et al. (2018) previously show the most significant cost saving potential consists of material cost savings obtained through recycling. Lepak et al. (2007) suggest, however, that estimating the economic case in terms of material cost savings alone is not possible in the construction industry. Lepak et al. (2007) argue that in the construction industry, profitability is indeed essential in the implementation of the circular economy from the construction company's perspective. The profitability of circular economy business models cannot be justified solely by material costs saved, but the review must consider a number of variables, such as the suitability of the recycled material, transport distances and the political context. For example, a long transportation distance can make recycled material more expensive than virgin raw material. (Lepak, et al., 2007) Thus, in order to implement a successful circular economy business, the operation must be profitable, so in the early stages of development, several factors must be considered to assess the economic value-capturing potential (Ranta, et al., 2018; Lepak, et al., 2007).

In evaluating exact economic value capture potential, several factors need to be concerned. On top of direct cost savings that are more easily calculated there are a lot of indirect benefits that make estimation of economic value capture potential very complicated. (Lepak, et al., 2007) For example, with the help of circular economy business models, a company can improve its cost efficiency and thus strengthen its position in the market.

In addition to direct cost savings, the circular economy operations create new business opportunities for the organization. There is also a business opportunity for a company to improve its image by marketing green products and services. (Korhonen, et al., 2018)

As a conclusion company can improve the competitiveness of its operations by introducing circular economy business models. Improving competitiveness in the longer term can be seen, among other things, in increasing a company's market share. (Stahel, 2013)

However, there is a lack of research on how adopting the circular economy operating model can help the construction company to capture economic value. The literature has only identified at the conceptual level how economic value is captured by circular economy operating models, but there is no conducted a case study of how much real cost savings would result from implementing a circular economy operating model. This study's empiric section aims to provide an estimate of what is the actual economic value capture potential in implementing the circular economy business model in earthwork construction.

2.3 The circular economy in the infrastructure construction industry

The application of the circular economy to the construction industry has not been very much studied in the academic literature. In Finland, various actors have published studies since the early 2000s on the use of various recycled materials in construction (Torniainen & Sikiö, 2018; Tiehallinto, 2007). The same principles apply to the circular economy of construction as to any other industry: reducing material usage and increasing the recycling of materials (Adams, et al., 2017). Adams et al. (2017) have been presented the circular economy's opportunities in the construction industry. Different aspects can be divided across the project life cycle. Aspects are presented in figure 2.

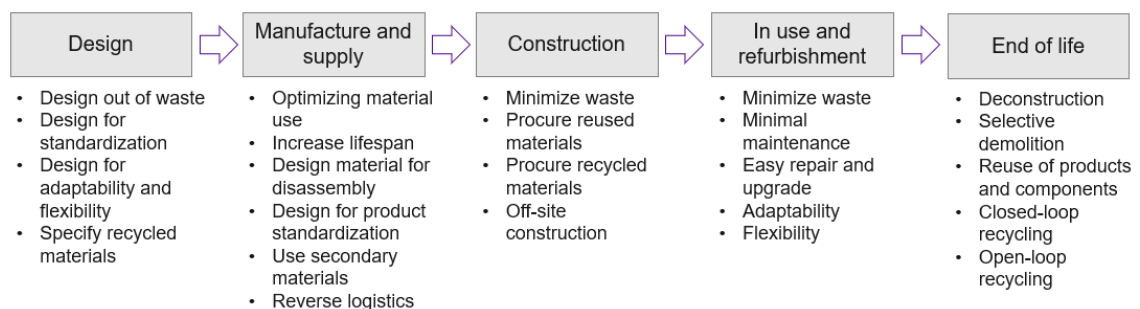


Figure 2 Circular economy across the building life cycle (Adams, et al., 2017).

The most relevant actions in terms of earthwork construction are specifying recycled materials, optimizing material use, logistics optimization, minimizing waste, using recycled materials, and selective demolition (Adams, et al., 2017; Torniainen & Sikiö, 2018).

The circular economy of soil and rock material is necessary in Finland. In Finland, approximately 100 million tons of natural stone are used annually in construction, of which 70-80% is imported from natural stone processing sites, and 20-30% is obtained directly from the construction site. Most of the aggregates are used in the construction of roads, streets, and railways. (Lonka, et al., 2015) According to Lonka et al. (2015), the construction of an apartment building requires about 100 tons of aggregates, and the construction of a one-kilometer motorway requires about 50 000 tons of aggregates.

Improving resource efficiency, using recycled materials, and utilizing industry by-products are remarkable ways to improve soil and rock material circular economy. Finnish road administration has been publishing a report of using by-products and recycled materials in road construction. In road construction potential by-products are crushed concrete, asphalt waste, slag products from the iron and steel industry, ash from coal combustion, ash from organic material combustion, and fiber sludge. Each of these products has a potential use case. (Tiehallinto, 2007) By-products that could be used in infrastructure construction and their use cases are presented in table 3.

Table 3 *Recycled materials for use in earthwork construction (Tiehallinto, 2007; Tornainen & Sikiö, 2018).*

Material	How product is created	Use case
Crushed concrete	The product is generated as demolition waste.	Crushed concrete can be utilized in the structural layers of the road.
Asphalt waste	The product is created during the renewal of asphalt pavements.	Asphalt Waste can be recovered in new asphalt.
Slag products from the iron and steel industry	The product is created as a by-product in the steel manufacture process.	It can be utilized in the structural layers of the road.
Ash from coal and organic material combustion	Generated as an end product of combustion of organic material.	The material can be used as a moist soil binder.
Ash from coal combustion	Generated as an end product of combustion of coal.	It can be utilized in the structural layers of the road.
Fly ash from coal combustion	Generated as an end product of combustion of coal.	The material can be used as a moist soil binder.
Fiber sludge	The product is created as a by-product of pulp production.	Together with cement and ash, it forms a load-bearing structure.
By-products of the mining industry	The product is created as a by-product of mining.	The product can be utilized in the structural layers of a road.

There are numerous challenges in implementing a circular economy in the construction industry (Adams, et al., 2017). Adams et al. (2017) conducted research on challenges in the application of the circular economy in the construction industry. Ten challenges that they have found are presented below:

1. Lack of interest
2. Limited awareness across the supply chain
3. Lack of circular economy knowledge
4. Lack of incentive to design for end of life (products)
5. Lack of consideration for end-of-life issues (buildings)
6. Lack of market mechanisms for recovery
7. Unclear financial case
8. A low value of material/products at the end of life
9. Fragmented supply chain
10. The complexity of buildings. (Adams, et al., 2017)

In Finland, the use of recycled materials is subject to stringent environmental legislation, which partly contributes to the challenges of the construction circular economy. If some project wants to use concrete aggregate as a building material or other material that is categorized as waste, the project must apply for specific permission from the environmental authority. (Torniainen & Sikiö, 2018) According to Torniainen and Sikiö (2018), using recycled materials causes much additional work for projects, which is an obstacle for circular economy implementation.

There are several areas for improvement in the development of the circular economy in the construction industry. The most significant enablers for implementing circular economy in the construction industry presented by Adams et al. (2017) are:

1. Clear business case
2. Viable take-back schemes
3. Development of higher value secondary markets
4. Development of enabling technologies to recover materials
5. Awareness-raising campaign
6. Assurance schemes for reused/secondary materials
7. Best practice case studies
8. Financial incentives to use secondary materials
9. Measure the value of material/product
10. Design tools and guidance.

According to Torniainen and Sikiö (2018), the commercialization of recyclable materials would reduce the additional work involved in using them, making them a more attractive option for projects. Commercialization of recyclable materials would benefit from not requiring a separate environmental permit for the use of recycled materials, which would greatly facilitate their use. (Torniainen & Sikiö, 2018)

2.4 The circular economy operating environment in Finnish earthwork construction industry

The construction industry plays a significant role in Finland's circular economy implementation (Simons, et al., 2018). Simons et al. (2018) have suggested that utilizing the full potential of the circular economy in the Finnish construction sector requires the use of political measures as a means of control. Political means can be used to promote solutions that support the circular economy at all stages of the value chain (Simons, et al., 2018). There is no separate legislation for the reuse of soils in Finland, so the general definition of the waste legislation applies to it. According to the legislation waste means a substance or object which the holder has disposed of, intends to dispose of or is required to dispose of. (Infra Ry, 2020; Finnish Ministry of the Environment, 2007). This section reviews unpolluted soil material reusing legislation and adjustments to the operating environment that can promote soil reuse.

This section deals with soil reuse legislation that is presented in the application directive published by The Finnish Ministry of The Environment (Finnish Ministry of the Environment, 2015). The application directive is not a legally formal document that can be used in the assessment of legislation factors in practice. The aim of this research is not to take a position to legislation, but this section aims to provide a picture for the reader of the legal framework in soil material recycling. It is noteworthy that there are several exceptions in the legislation and in practice, the application of legal obligations always requires the consideration of the environmental authority. Legislative interpretations of soil recycling cannot be made on the basis of this section.

2.4.1 Legislation of the circular economy of unpolluted soil material in Finland

According to Finnish waste legislation, in principle, all material excavated from the ground is waste when it is going to be disposed of. A material is not classified as waste if it can be proved that the material does not require processing and it has a precise, certain and planned reuse location (Finnish Ministry of the Environment, 2015, pp. 7-9; Infra Ry, 2020).

The directive administrative procedure of unpolluted soil material reusing in Finland is presented in figure 3.

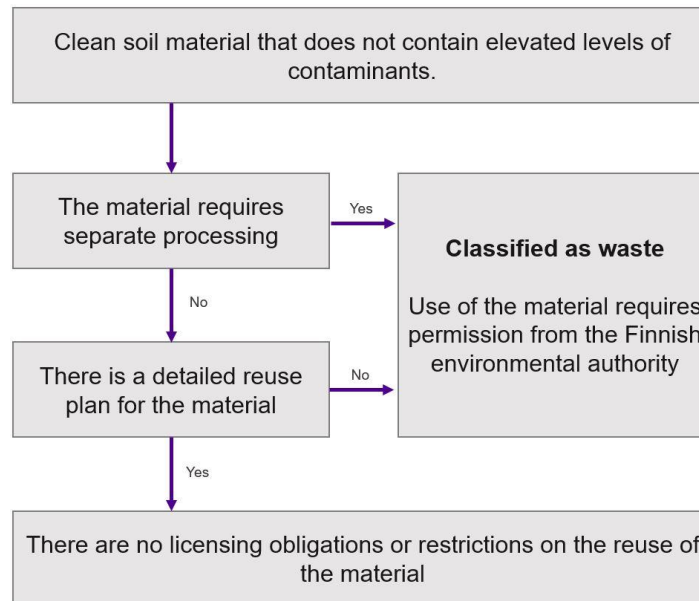


Figure 3 The directive administrative procedure of unpolluted soil material usage in Finland presented in application directive by Finnish Ministry of the Environment (Finnish Ministry of the Environment, 2015; Infra Ry, 2020).

Concentrations of contaminants in the soil must not cause environmental pollution or danger for it. In order to the soil to be re-used, non-contamination must be demonstrated by an examination of soil excavated from an area, if it is known or suspected to be contaminated due to the area's usage history. If the soil contains harmful substances, and it requires separate processing, it is classified as waste and possibly requires usage permission from the Finnish environmental authority. (Finnish Ministry of the Environment, 2015, pp. 7-9)

The further use of the excavated surplus soil must be guaranteed. The guaranteed use must be demonstrated by the fact that the soil is delivered directly from the excavation site to the application or is stored only for a short time before use. Use cannot be considered guaranteed if the soil must be stored for a long time. Generally, storage lasting more than one year is considered long-term, but storage time is considered on a case-by-case basis. (Finnish Ministry of the Environment, 2015, p. 8)

The use of soil must also be planned. Based on the plan, it must be possible to demonstrate that there is a real need for the use of the soil and that the technical conditions for its use have been defined at a general level. (Finnish Ministry of the Environment, 2015, pp. 8-9)

2.4.2 Challenges of the operating environment in the utilization of recycled soil materials

Nowadays, the utilization of recycled earthwork construction materials in Finland is regulated by the MARA-decree issued by the Finnish government. In addition, a MASA-decree is currently being prepared with the aim of promoting the recovery of soil waste in soil recycling. (Finnish Ministry of the Environment, 2019). A major challenge in the soil material circular economy in Finland is that the use of recycled materials is not perceived as attractive due to the ease of use and affordable price of virgin raw materials. Many organizations find environmental permitting processes too time-consuming and complicated to reuse material, resulting in usable recycled materials not utilized. (Simons, et al., 2018, pp. 12, 28).

The Finnish Ministry of the Environment is drafting a MASA-decree to promote the utilization of waste in the earthwork construction following the circular economy principles. The decree is due to be completed during 2020. (Finnish Ministry of the Environment, 2019) Simons et al. (2018) envision that construction raw material reuse can be promoted by changing taxation. According to Simons et al. (2018), the reuse of all industry by products and surplus materials should be more attractive than using virgin materials. They also suggest that public organizations can contribute to the usage of recycled materials, as public organizations are a major customer of earthwork construction projects. Organizations could favor recycled materials in their competitive bidding. (Simons, et al., 2018, p. 13)

2.4.3 Improving reusing of soil material

Simons et al. (2018) present that the main challenge for reusing construction materials is the low prices of virgin materials and the poor and irregular quality of recycled soil material. Besides, the lack of treatment and storage areas, especially in densely populated areas, poses challenges for soil recycling. (Härmä, et al., 2010)

In order to increase the recycling of recycled soil material utilization, the storage of unpolluted soils should be made more accessible. As discussed earlier, unpolluted soils may be stored if the material has an accurate plan for utilization (Finnish Ministry of the Environment, 2015). This creates a situation where unpolluted soils end up as waste if they cannot be assigned a reuse area during excavation. This challenge could be overcome if clean recycled soils could be stored without necessarily being able to show the material for reuse. As mentioned earlier, the lack of treatment areas causes logistical challenges because of treatment areas located far from the location of the excavation or

application. A suggested solution is that the number of soil treatment areas should be increased, especially in areas where much construction takes place. (Härmä, et al., 2010)

Productization of recycled soil material can be seen as one solution to the problem of soil recovery. Through productization, recycled soil materials are excluded from the scope of waste regulation when the materials can be recovered as designated products. A prerequisite for productization is that the excavated soil material is standardized. (Makkonen, et al., 2010)

3. LOGISTICS IN EARTHWORK COSTRUCTION

The productivity increase in the construction industry has been slow for decades (Vrijhoef & Koskela, 2000). Improvement of construction logistics has been suggested as a solution to the construction industry's profitability dilemma (Tischer, et al., 2013; Vrijhoef & Koskela, 2000). In earthwork construction, logistics generate significant cost due to large volumes transported and large fleets of vehicles. Also, in earthwork construction logistics cost is significant compared to the value of material due to material's low value density. (De Lima, et al., 2013) Optimizing earthwork construction logistics can generate significant cost and time savings (De Lima, et al., 2013; Choudhari & Tindwani, 2017; Sobotka, et al., 2012).

This chapter provides a literature review of infrastructure construction logistics and its development. First, this chapter examines construction logistics and ways to improve it at a general level and then delves deeper into earthwork construction logistics and ways to improve it. Construction logistics is a topic that has been a lot researched in the construction industries and logistics' magazines. However, earthmoving construction logistics has not been much researched in the literature. The main source of this literature review is peer-reviewed construction magazines. For the acquisition of written material, I mainly used keywords: *construction logistics*, *logistics in the construction industry*, *construction logistics improvement*, *earthwork construction*, and *earthwork construction logistics*.

The purpose of this literature review is to find a way to enhance the circular economy of earthwork construction by focusing on developing logistics management. This literature review seeks to answer the question, what is the role of earthwork logistics in the construction projects' performance and what is the impact of earthwork logistics improvement for the whole construction project. Also, this literature review seeks to answer the question of what the methods are to improve and optimize earthwork construction performance.

3.1 Logistics overall

Rushton et al. (2017) define that logistics include physical material flow, process, and information. Physical material flow is goods and supplies delivering between different actors in the supply chain. Process and information include tools and procedures that are needed to manage physical material flow such as information systems and

warehousing. (Rushton, et al., 2017, pp. 4-5) The same elements are in the Council of Supply Chain Management Professionals' (CSCMP) (2016) definition. According to CSCMP "Logistics is the part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customer's requirements" (CSCMP, 2020). According to Coyle et al. (1996), the basis for logistics is the 7r definition. That means that the central aim of logistics is to get seven criteria right. They are right product, place, price, customer, condition, time, and quantity. (Coyle, et al., 1996, p. 29)

Different authors are not agreed on what is the difference between logistics and supply chain management. Rushton et al. (2007, pp. 4-5) present that logistics is part of supply chain management alongside suppliers and customers. Supply chain management is a bigger picture of material flow which considers relations between different actors in the supply chain. (Rushton, et al., 2017, pp. 4-5) Logistics is mainly based on moving materials, while supply chain analysis looks at how companies gain a competitive advantage by managing material flows between companies (Rushton, et al., 2017, pp. 14-15; Li, et al., 2006). In this research, I will keep my focus on logistics, so I don't observe different actors' relationships in the supply chain, but I will focus on economic the benefits of efficient material movement.

In the 21st century, companies have woken up to the fact that logistics is not only a cost item but an added value to their operations (Rushton, et al., 2017, p. 9). Due to the logistics role as a significant cost and service factor, effectively managed logistics can provide a major competitive advantage for the company (Christopher, 1998).

Logistics costs can be divided into five categories: transportation, tied-up capital, warehousing, customer service, and administration (Rushton, et al., 2017, p. 11). One survey in the United States undertake by Establish Davis (2016) indicated that transportation is the most important cost of logistics. The results of logistics costs dividing are presented in figure 4.

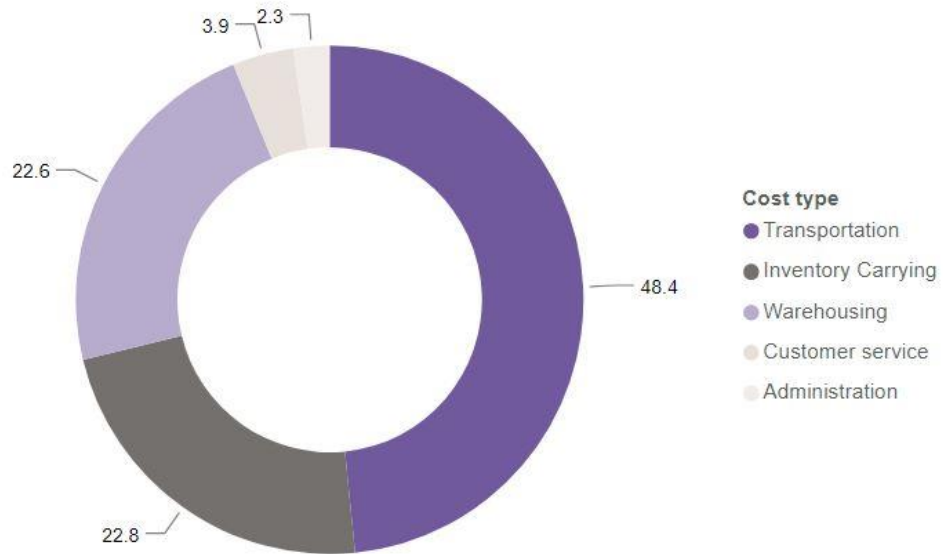


Figure 4 Logistics cost share (The Establish Davis database 2016).

The actual share of each cost element depends a lot on different industries. For low-value density products, logistics costs have a significant share in products totals cost. For example, one survey in the United Kingdom indicated that 46 percent of cement cost is generated from logistics. (Rushton, et al., 2017) In the Finnish infrastructure construction, transport and distribution account for the largest share, about two-thirds of the cost of aggregate material (Lonka, et al., 2015).

3.2 Logistics in construction industry

Construction logistics is considered as a physical flow of materials which is related to construction projects. No common definition of construction logistics has been established until today in the academic literature nor in practice (Tischer, et al., 2013). When combining definitions, construction logistics deals with the planning, operating and managing of material, personnel and information flows from the point of view of, optimizing, schedule, costs, and quality. (Tischer, et al., 2013; Behera, et al., 2015; Serra & Oliveira, 2003; Vrijhoef & Koskela, 2000)

Construction logistics differs significantly from manufacturing industries logistics. In the construction project environment, the point of demand is geographically variable (Vidalakis, et al., 2011). The construction process is project-based and carried out by temporary organizations requiring the establishment of temporary supply chains (Behera, et al., 2015). Due to a temporary structure the construction supply chain needs to be modeled and optimized on case-by-case basis (Vidalakis, et al., 2011). In the construction industry, many raw materials and services are outsourced from different

consultants and subcontractors (Miller, et al., 2002). In a typical situation, each subcontractor is responsible for its individual supply chain to provide materials required for its scope of works (Sobotka, et al., 2005). Due to that structure, construction projects' main contractors are heavily reliant on other actors in the construction supply chain, e.g. subcontractors and suppliers (Vrijhoef & Koskela, 2000). The construction logistics process and the network are illustrated in figure 5.

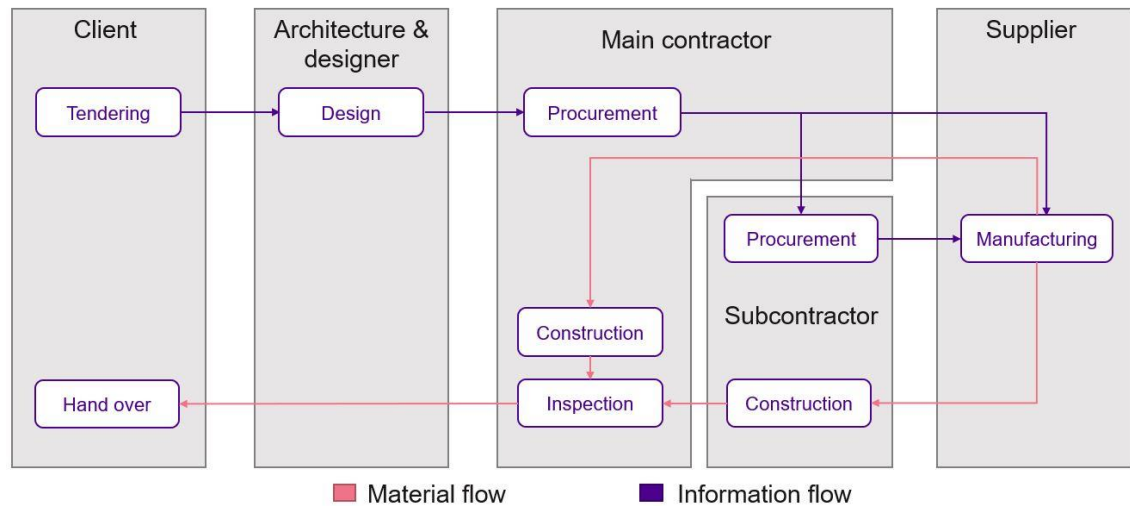


Figure 5 Logistic process in the construction industry. Edited from the sources (Vrijhoef & Koskela, 2000; Wegelius-Lehtonen, 2000).

Due to the many different actors in the construction supply chain, the supply chains are complex and difficult to control (Fellows & Liu, 2012). The logistical challenges of a construction project include caused by delayed deliveries, moving vehicles, inefficient storage management and unnecessary on-site material handling (Tischer, et al., 2013). Vrijhoef and Koskela (2000) argue that logistical challenges and the organization's complexity are one of the main reasons why the construction industry is suffering from both low productivity and rising production costs. Recently, the role of logistics has become more prominent in cutting construction costs and lead times, (Tischer, et al., 2013) and also an environmental impact of construction (Hedborg Bengtsson, 2019).

It is argued that value creation is a process for why companies exist. Value creation can be seen as a conscious and purposeful pursuit of activities that create value. (Bowman & Ambrosini, 2000) The value chain is a concept that describes the gradual transformation of a commodity from the raw material into a finished product. In manufacturing industry logistics has a significant role in the company's value chain. (Porter, 1985) In Porter's value chain model, primary activities consist of inbound logistics, operations, outbound logistics, marketing, sales and services (Porter, 1985). However, value creation in the construction industry has not been a popular topic in

literature. The role of logistics in the construction project has not been emphasized by some authors who have focused on value creation in the construction industry. Typically, the value creation in construction is thought to be limited to construction, whereby the role of logistics in delivering value is neglected (Barima & Rowlinson, 2010; Hjelmbrække, et al., 2016; Kadangwe & Emuze, 2017; Heredia-Rojas & Liu, 2015). Some authors have discussed the role of supply chain management and interaction between different actors in the supply chain for the construction industry's value creation (Kadangwe & Emuze, 2017; Heredia-Rojas & Liu, 2015). Based on that, it seems that logistics have been ignored in the construction industry's value chain. Next, this chapter discusses the literature on construction logistics, paying attention to the role that logistics plays in the value creation of construction.

Earthwork construction logistics differ a lot from housing and business premises projects logistics. Earthmoving operations represent a significant role in construction projects (Hajji & Lewis, 2013), especially in infrastructure construction (Moselhi & Alshibani, 2009). Earthwork is a broad concept that refers to all the excavation and quarrying related to construction. Earthmoving operations require very extensive equipment fleets, so the optimum use of the equipment is crucial for task for contractors. (Moselhi & Alshibani, 2009) In addition to equipment intensiveness, construction logistics deals with an extensive amount of soil material, so efficient management of supply and on-site logistics is very critical for project performance (Sobotka, et al., 2012). De Lima et al. (2013) present that earthmoving operations are one of the most expensive components of the total cost of road construction. Due to high fleet intensity and a massive amount of material transported it is necessary that the transportation between excavation or quarrying and landfill sections need to be carried out in a rational manner to achieve the lowest construction costs (De Lima, et al., 2013). It is very important to be able to optimize earthwork moving operations not only in the planning phase but in near real-time (Moselhi & Alshibani, 2009).

3.2.1 Elements of construction logistics

Elements of construction logistics can be seen consisting of four parts. Parts are construction execution system, supply logistics, on-site logistics and construction projects as a part of project network. (Sobotka, et al., 2005) First, construction logistics includes building a production system where many logistics chains and complex processes are executed within the same space and time. (Sobotka, et al., 2005) Serra and Oliveira (2003) present that construction logistics in a complex process applied to a given site to ensure the supply, storage, processing and availability of the material

resources. Also, construction logistics is about managing the production's physical flow of material.

Second, supply logistics is a part of construction logistics which includes delivering goods and products from external sources to the building site. (Sobotka, et al., 2005) The most important activities of supply logistics are planning and processing purchased items, supplier management, transportation of resources to the site, and maintenance of the material resources foreseen in the planning (Serra & Oliveira, 2003).

Third, On-site logistics is the co-ordination of material flows inside the construction site. That is the construction site is a fundamental part of construction logistics alongside supply logistics. (Sobotka, et al., 2005) On-site logistics involve the management of the physical flows and information associated with on-site activities. The most important activities are managing of the material flow related to the execution, interface management between different players and physical management of the site internal goods flow. (Serra & Oliveira, 2003) The waste disposal logistics of a construction project can also be seen as part of the construction logistics (Tischer, et al., 2013). Fourth, in a logistics way of thinking logistics parts of a construction project are interacting with other projects at the same time creating complicated logistics networks (Sobotka, et al., 2005).

As compared to the traditional manufacturing industry logistics chains in the construction industry are considerably more difficult to manage and optimize (Sobotka, et al., 2005). Sobotka et al. (2005) present that challenges of managing the logistics of construction projects stem from the diversity of projects, technical complexity and the number of participants in the project. Also, Sobotka et al. (2005) present that managing subcontractors procurement procedures and adjusting each project member's logistics routines to the logistics system causes complications to construction projects logistics management.

3.2.2 Logistics planning and execution in construction project

A construction project can be divided into four phases: design, planning, procurement, and execution. There are different logistics tasks in each phase. (Serra & Oliveira, 2003) In the design phase, project production is designed. That includes for example what techniques are used by the construction team. In the design phase also construction site is designed and that is defining the logistical framework. Production and construction site design are not subordinate to each other but are designed in parallel. (Serra & Oliveira, 2003)

In the design phase, logistics routes are planned. In the planning phase several factors need to be considered. The most important thing is to plan physical movements, material consumption and equipment and labor needs. In procurement phase it needs to make decisions of material specifications and supplier qualification. Also, accurate plans for deliveries to site needs to be planned in procurement phase. In execution phase decisions are operative by nature, for example monitoring material movement. Also measuring logistics operations performance is an important task in execution phase. (Serra & Oliveira, 2003; Moselhi & Alshibani, 2009) present that a plan conducted in design phase need to be often adjusted near in time. Logistics production plan guidelines is presented in figure 6.

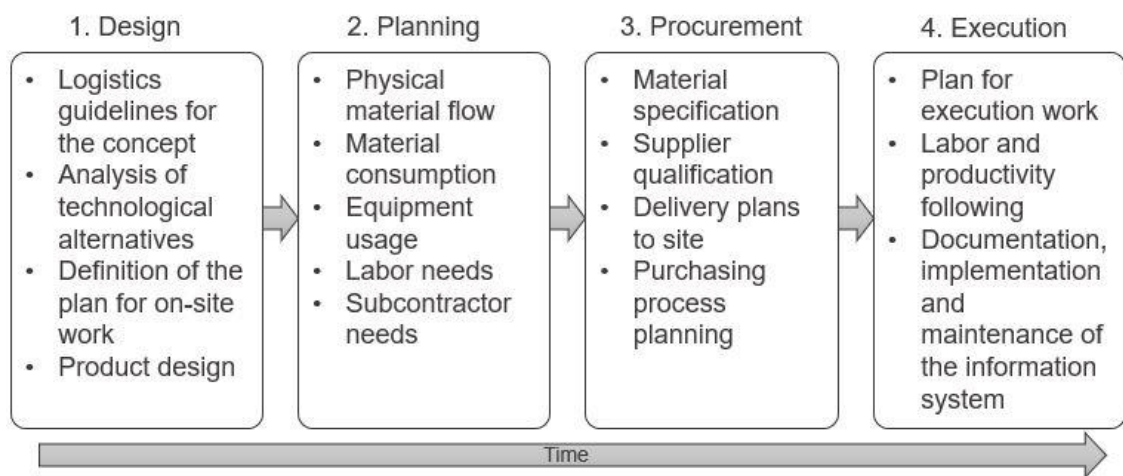


Figure 6 Logistics through the construction project (Serra & Oliveira, 2003).

A carefully developed logistic plan describes all possible relationships between the project participants. (Serra & Oliveira, 2003) The success of the project depends on the co-ordination of the on-site and external logistics in all project phases. A lot of management work is needed to bring the consensus of all participants to the project to succeed. (Stevens, 1989)

3.3 Capture economic value in construction project with logistics management

Improving construction logistics has been seen as a solution to the problems of construction efficiency for decades (Vrijhoef & Koskela, 2000). Construction project's logistics performance can be measured in cost measures and time of delivery chain (Wegelius-Lehtonen, 2000). Various actors in the construction industry have argued that coordinated construction logistics will improve construction productivity, reduce costs and lead times and encompasses aspects of occupational safety and environmental sustainability (Hedborg Bengtsson, 2019).

(Wegelius-Lehtonen, 2000) present that competitive bidding is deeply rooted in the construction industry. Traditionally, in the construction industry, different companies have competed against each other for contract work and the lowest bidder has got the contract. Also, contractors have been accepted or rejected based on technical specifications. Other performance measures that relate to the process itself, like logistics measures, are neglected or at least assigned to a distant secondary position of importance. (Wegelius-Lehtonen, 2000) According to Wegelius-Lehtonen (2000), construction companies should turn their mindset from project orientated business to a process-orientated approach. Christopher (1992) present that process view is the main element of logistics and each construction project can be seen as an order-delivery process where all the parties along the logistics chain are involved.

In the construction industry, logistics costs are a significant part of the overall cost of a construction project and, unlike other areas, the majority of logistics costs are related to material management within the site compared to external transportation costs. On-site logistics, in particular, is thus an important area of improvement for contractors. (Seppänen & Peltokorpi, 2016)

3.3.1 The effect of logistics on construction projects performance

Looking at the purchase price alone is typically misleading when looking at the economic performance of a construction project. Wegelius-Lehtonen (2000) argue that total logistics cost would be a more suitable measure than purchasing price for estimating different material options. According to Christopher (1998) larger purchase and delivery batches lower logistics cost and because of that it generates cost savings. Wegelius-Lehtonen (2000) argued, that standard materials have the biggest logistics cost of material flow as a percentage of the purchasing price. For example, the total logistics cost of the plasterboard was 27 percentage of the purchasing price. Even 60 percent of total logistics cost was caused by on-site material handling and transportation cost was only 24 percentage and suppliers' cost were 13 percentage of the total cost of logistics. (Wegelius-Lehtonen, 2000) However, in a typical situation, standard materials are sourced in large order batches which results inefficient storage management and unnecessary material handling, which in turn results in higher on-site logistics costs (Wegelius-Lehtonen, 2000; Vrijhoef & Koskela, 2000). Vrijhoef and Koskela (2000) have shown that increasing the order batches increases the total logistics cost much more than the economies of scale that can decrease procurement costs.

In urban areas construction projects have a very limited space to operate. Due to limited space logistics operations need to be designed more accurately. According to Mossman (2007) better production planning results in an overall improvement in the construction process and especially logistics. In a case study conducted by Wegelius-Lehtonen (2000) there were observed that delivery of materials and material installation were not synchronized which resulted in unnecessary storage and material handling.

Efficient construction logistics also has an impact on labor productivity (Seppänen & Peltokorpi, 2016). According to some estimations, work performed on-site, measured the amount of direct value-adding time a construction worker performs to 17.5 percent. At the same time, indirect value-adding time was 25 percent. The root cause for the poor rate of productive work was mainly logistical challenges e.g. unnecessary searching for materials. (Josephson & Saukkoriipi, 2005)

3.3.2 Means to improve construction logistics

Logistics can be seen as one of the most important processes in the construction project. It is widely recognized in the literature that not all logistics potential has been applied to improve the performance of a construction project. Several solutions to the challenges of construction logistics have been suggested in the literature. Centralized logistics centers for construction project logistic management combined with just-in-time deliveries and improved scheduling was the most commonly proposed solution. On top of these, digital tools, such as building information (BIM) solutions and simulation-based solutions have been presented in the literature. Also, other solutions, including 3PL company, preassembly, and material inventory size adjusting were presented in the literature. There is a summary of construction logistics improvement tools, their definition, and authors who represent these tools in table 4.

Table 4 Means to improve sites logistics performance.

Logistics tools to improve project performance	Definition	Authors
Centralized logistics	A center that is separate from the construction site and manages the site logistics. The center reduces the need for on-site storage and reduces unnecessary material handling, material breakdown, and potential vandalism. Enables just-in-time deliveries to sites and buffer against variability.	Arbulu & Ballard, 2004 Elfving, et al., 2010 Hamzeh, et al., 2007 Kalsaas, et al., 2011 Sobotka & Czarnigowska, 2005

Just-in-time deliveries	Material deliveries are synchronized with the production schedule so that the materials are delivered so that they can be installed immediately.	Arbulu & Ballard, 2004 Arbulu, et al., 2005 Hamzeh, et al., 2007 Ng, et al., 2009
Improved scheduling	Site scheduling site that minimizes wastage and maximizes value-adding time. Tools are for example using planning tools and storage optimization based on space constraints.	Arbulu & Ballard, 2004 Arbulu, et al., 2005 Kalsaas, et al., 2011 Mossman, 2007 Said & El-Rayes, 2013
Safety stocks	A storage used to ensure the continuity of the construction process in the event of an interruption.	Caron, et al., 1998
BIM-based solutions	Data models can be used, for example, to optimize storage space and simulate logistics using 4D models.	Bortolini, et al., 2015 Cheng & Kumar, 2015 Said & El-Rayes, 2013
Simulation based solutions	Simulation can be used to help design the logistics of complex projects, considering many different factors. Simulations can, among other things, improve delivery scheduling.	Cheng & Kumar, 2015 Ng, et al., 2009 Said & El-Rayes, 2013
Pre-assembly	Pre-assembly products are used to improve the logistics process because they reduce the time needed for work at sites.	Bortolini, et al., 2015 Arbulu & Ballard, 2004
Web-based logistics software	With the help of the web-based system, logistics can be planned and scheduled so that information is passed on to different actors in the supply chain.	Arbulu & Ballard, 2004 Arbulu, et al., 2005 Elfving, et al., 2010
Third party logistics service provider	By entrusting the logistics of a construction project to a logistics company, the logistic performance can be improved. This allows the construction contractor to focus on its core component, construction.	Ekeskär & Rudberg, 2016 Mossman, 2007

Logistics improvement tools presented in the table above alone do not guarantee the development of logistic operations. The best possible solution could be a combination of centralized logistics, just-in-time deliveries, improved scheduling, web-based logistics software and pre-assembly (Arbulu & Ballard, 2004).

Wegelius-Lehtonen (2000) says that performance measurement in construction logistics is an essential part of construction logistics development. Wegelius-Lehtonen (2000) presents that: "if you do not know your current practices, you cannot develop your operations further effectively." It is important that performance measures developed in a way that they measure total logistics cost (Wegelius-Lehtonen, 2000). Tischer et al.

(2013) conducted a case study where they estimated that carefully planned logistics in the refurbishment project improved logistic performance by 9 percentage but in turn increased logistics cost. However, in the study, they did not take a stand on the impact of efficient logistics on the economic performance of the entire project.

3.3.3 Improving earthwork construction logistical performance

A lot of research has been done on the optimization of soil material logistics within a single project, such as a road project (De Lima, et al., 2013; Son, et al., 2005; Choudhari & Tindwani, 2017; Liu & Lu, 2015; Moselhi & Alshibani, 2009; Sobotka, et al., 2012). On the other hand, there has been no research on earthmoving operations and logistics optimization between several projects or project portfolios. In the following, there are motivational factors and ways to improve soil material management within a single project.

Contractors have a great motivation to pay attention to earthmoving logistics operations, as it carries tons of excavated material and requires a large number of transportation equipment. Thus, it is justified that a lot of attention is paid to the planning and management of earthmoving logistics, as the activities have a direct impact on the cost of the construction project. (De Lima, et al., 2013) Earthmoving operations in the temporary project involve four categories of cost: excavation and loading cost, haul cost, placement and compaction cost and logistics network set up cost (Moselhi & Alshibani, 2009).

Kaliba et al. (2009) present that inadequate material procurement is one of the main factors affecting cost and time overruns of a road construction project. In addition to direct cost savings, optimizing the soil material logistics can generate significant time savings, which have a direct impact on the fixed costs of the project due to the high indirect equipment costs (Moselhi & Alshibani, 2009). Sobotka et al. (2012) present that road construction projects consume very large amounts of aggregates, so even a small improvement in material flow management and logistics optimization are bound to bring substantial economic benefits.

Technical solutions can provide significant improvement in earthmoving construction logistical performance (Moselhi & Alshibani, 2009). Son et al. (2005) present that required elements for determining an earthwork estimate are the quantity of soil to be moved, the haul distances to move the material, and the soil type that must be hauled over. Moselhi and Alshibani (2009) add that construction site conditions, resources and

time constrains need to be consider when designing excavated material logistics. Factors that need to be taken in to account in optimizing are presented in the following:

1. Availability of resources
2. Time constrains
3. Amount of soil to be moved
4. Hauling distance between cut and fill
5. Construction site conditions
6. Soil type
7. Equipment characteristics and constraints.

Based on that, to find the optimal logistics solution, it needs to be defined what material needs to be delivered, when it needs to be delivered, and where it needs to be delivered. Taking these constraints and variables into account, each job is defined in terms of source, destination, volume, shortest hauling path between source and destination to define optimal solution for soil material logistics (Liu & Lu, 2015).

Sobotka et al. (2012) present that in infrastructure construction projects where volumes are massive the optimal structure for the construction logistics cannot be found by a rational manner. Choudhari & Tindwani (2017) and De Lima et al. (2013) found as well that the output of the optimization model indicates substantial savings in logistics cost over some feasible solution obtained by any other common-sense method. Optimizing aggregate material logistics requires optimization software which usability needs to be confirmed with practitioners (Sobotka, et al., 2012; Choudhari & Tindwani, 2017).

Optimizing earthmoving operations in construction projects has witnessed the development of many different techniques (Moselhi & Alshibani, 2009). In table 5 are presented methods used in soil material optimization logistics.

Table 5 Tools to optimize soil material logistics within single construction project.

Tool	Definition	Authors
Linear programming	A method to achieve the best solution, like the lowest cost, in a mathematical model whose limitations are presented by linear relationships. It allows determining the best possible transport route.	Moselhi & Alshibani, 2009 Liu & Lu, 2015 Choudhari & Tindwani, 2017 De Lima, et al., 2013 Son, et al., 2005
Computer simulation	Computer modeling of material flows in a construction project and determination of an optimal solution using a program.	Moselhi & Alshibani, 2009 Marzouk & Moselhi, 2003
Genetic algorithm	The genetic algorithm is an optimization method used in computer science to find a solution.	Moselhi & Alshibani, 2009 Liu & Lu, 2015

Linear optimization is the most commonly used tool in optimizing soil material logistics. Linear optimization is not a perfect method in itself because it does not take into account geographical constraints such as topography. Also, linear programming should not take into account the limitations of site design. The most suitable solution is a system that involves a genetic algorithm, linear programming, and geographical features. (Moselhi & Alshibani, 2009) The optimization system should not be used solely to support operational decision-making. The system has the greatest potential to be unleashed when it is integrated into the entire project, from bidding to operational management of soil logistics (Moselhi & Alshibani, 2009). De Lima et al. (2013) present that information accuracy has a remarkable effect on the accuracy of the results of estimation. Therefore, it is important to have accurate information on volumes and distances when estimating cost and time savings. (De Lima, et al., 2013) Today UAV (Unmanned Aerial Vehicle) technology can provide very accurate data on cut and fill volumes in infrastructure construction, (Siebert & Teizerb, 2014) which can be used in optimizing excavated material logistics.

3.4 Combining circular economy principles and logistics management for more efficient soil material recycling

The relationship between soil circular economy and logistics has not been studied widely in the academic literature. Especially in the construction industry, both issues have been studied in the literature as separate entities and the aim of this study is to combine these two entities.

The focus of the circular economy literature is on the development of business principles at the concept level. The concrete conclusions of the circular economy literature consist of the practice of changing the design to support the recycling of materials and reduce resource usage. (Bocken, et al., 2016; Lieder & Rashid, 2016)

However, the literature focusing on soil material logistics management, has focused mainly on how soil management logistics is planned and implemented at the operational level (De Lima, et al., 2013; Son, et al., 2005; Choudhari & Tindwani, 2017). When circular economy literature focusing on the early phase of a construction project and logistics literature is focusing on the executing phase of construction project, these two perspectives are substantially complementary, forming a coherent view of how soil recycling can be enhanced from project design to the physical transfer of soil material. This entirety is illustrated in figure 7.



Figure 7 Combining circular economy and soil material logistics literature into entirety following Serra & Oliveira (2003) view of phases in construction project.

As can be seen from figure 7, the circular economy and logistics management play an essential role in enhancing soil recycling. The aim of this study is therefore to find out how the recycling of soils can be made more efficient by following the principles of more efficient circular economy and logistics management. By combining circular economy principles and soil material management, an operations model is created that enable company to capture untapped economic potential.

4. DATA AND METHODOLOGY

This chapter discusses the research methodology. When trying to increase understanding of a problem or phenomenon, an exploratory research design is often used. Exploratory research is useful when you wish to formulate an understanding of a phenomenon and find insights about an object of interest. Typically, exploratory research consists of two parts. First, there is a literature review to gain an understanding, what research has been conducted around the topic. Second, exploratory research conducts expert interviews that aim to form a deep understanding of the topic. (Saunders, et al., 2016, pp. 174-175) In this research, the research setting is exploratory, as it allows searching for new perspectives, asking questions, and focusing on phenomena that are relevant to the research. Also, the strength of exploratory research is that it allows the study design to be changed as the research progresses (Saunders, et al., 2016, p. 175). A detailed description of this research process is presented in figure 8.

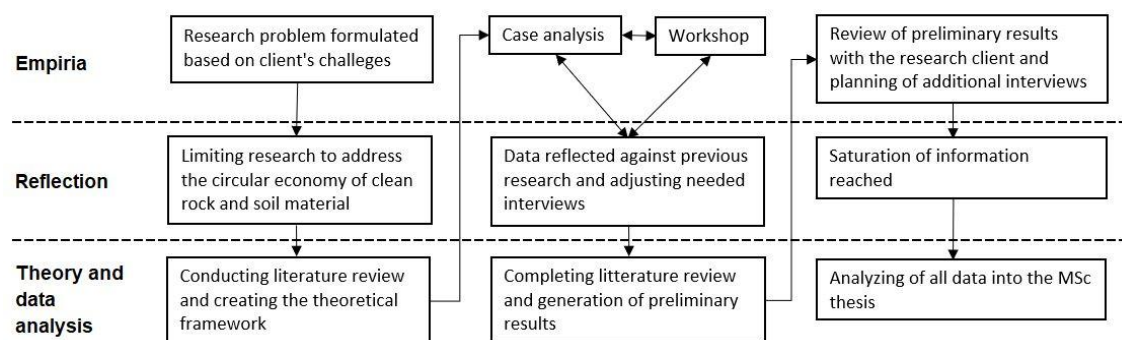


Figure 8 Research process of the study.

First step in this study was the formation of the research question, and the research problem was delimited together with the research client. Based on this, a literature review was conducted, either serving as a basis for case studies and interviews. During the case analysis and interviews data was reflected against previous research and interviews were adjusted as development needs emerged. When all data were collected, a literature review was completed, and preliminary results were generated and analyzed together with the research client. When the client was satisfied with the level of analysis, the saturation of information was reached. Finally, it was time for data analysis.

First, this section discusses the positioning of the research and research strategies. After that, this section considers data collection. Last, data analysis is described in this section.

4.1 Positioning of the study, research strategy and methods

The aim of the study is to gain an understanding of the necessary and realistic investments in the soil management process in order to utilize the value committed to soils as efficiently as possible within YIT. The aim is to form an understanding of the current state of soil management, the biggest challenges, unused potential and development opportunities and needs, in order to maximize the utilization of soils in YIT's projects.

The research problem is practical, so the appropriate research philosophy for this study is pragmatism. According to a pragmatic approach, research begins with a problem that aims to contribute a practical solution that can be put into practice. In pragmatism, knowledge is valuable when applied in a practical context. (Saunders, et al., 2016, pp. 142-143) Saunders et al. (2006) say that pragmatic research is typically value-driven, but this research seeks to get as objective image as possible of the phenomena being studied.

The research methods of pragmatic research are chosen in such a way that they provide the most reliable, well-founded, and relevant information possible to be collected to conduct the research (Saunders, et al., 2016, p. 144). In this study, the aim is to generate a practical theory based on findings, so the study follows the model of inductive approach (Saunders, et al., 2016, p. 51). In order to achieve as reliable result as possible, the methodological choice of this study is mixed method research (Saunders, et al., 2016, p. 169). Saunders et al. (2016) defines mixed method research as follows: "Mixed methods research is the branch of multiple methods research that combines the use of quantitative and qualitative data collection techniques and analytical procedures". In this study, selected research strategy is case study (Saunders, et al., 2016, p. 164).

The purpose of the case study is to delve deeper into a specific real-world phenomenon. A case study strategy can produce insights from intensive and in-depth analysis into the study of a real-life phenomenon, leading to rich, empirical descriptions and the development of theory. (Yin, 2014) Case studies often consist of the use of both quantitative and qualitative methods in order to understand the dynamics of the case properly (Saunders, et al., 2016, p. 185). In this research, the economic and other quantitative information related to the cases is analyzed quantitatively and the information obtained from the interviews is analyzed qualitatively. Due to the secret nature and inaccuracy of cost and volume information, the focus of this research analysis is of qualitative data. When using the case study strategy, a precise delineation of the case is essential. Typically, in case study strategy cases research can be divided into a

single case or multiple cases. (Saunders, et al., 2016, pp. 184-186) In this study, the case is outlined to consider multiple cases. Each case is an individual project where soil material management has been an integral part of the project.

In addition to case study there is a workshop included in this research. Because there are some professionals in the YIT's organization that have a remarkable input to research topic but are not working with case projects that were interviewed, as part of this study, a workshop was held where earthwork construction professional was invited.

Due to research case nature, the sample to be studied in this study is formed using non-probability sampling. Under non-probability sampling there is used purposive sampling is selecting case projects. (Saunders, et al., 2016, pp. 301-302) Case study projects are selected based on the essential role of soil material management in that project. The case study revealed professionals with potentially relevant insights into the study. To include these professionals in the study, snowballing was applied to the study, where the interviewees instructed the researcher who could have possible content for the research (Saunders, et al., 2016, pp. 303-304).

In this case study the most suitable interview method for this research is semi-structured interview. According to Saunders et al. (2016) semi-structured interview is suitable when it is necessary to understand reasons for the decisions that research participants have taken. A semi-structured interview also provides an opportunity to focus certain aspects in interviewees answers by asking more specific questions (Saunders, et al., 2016, p. 394). More detailed description of the interviews is in section 4.2.1.

4.2 Data collection

Data collection for this study was conducted in two parts. First, there is a case study of projects in which soil material management has been an integral part of project execution. The case study consists of two parts. First, the case project's soil management professionals were interviewed, and the second case projects cost, and volume information related to the soil material management was analyzed. Each project studied provided cost and volume information for the study. As a second part of data collection, there was a workshop held for earthwork construction professionals.

4.2.1 Case study

The case study is divided into nine sub cases. The top-level case study is YIT's infrastructure projects, which are divided into nine sub-cases, which are individual YIT projects. Each project studied in the study was examined as an independent case, so the study is by its nature multiple case study.

In selecting the case projects to be studied, the relevance of soil material recycling to the project was assessed. Projects in which soil management has been an integral part were selected for the study and at the same time projects were selected from each division of YIT Infrastructure projects in order to form a comprehensive picture from the perspective of different parts of the organization. The aim was to select as many different types of projects as possible. In this research it was studied projects from different types of construction, such as street, foundation and environmental construction. In addition, the study wanted to create a variation in the scope of projects, so projects with a contract value of more than one hundred million euros were included in the study, as well as projects with a contract value of a few million euros. The research client requested that the projects in the research would focus on the Helsinki metropolitan area, as the challenges of soil recycling are greatest there.

The study analyzed nine projects. Two of the projects were light railway construction projects, two street construction projects, three foundation projects as well as a subway station project, and a landfill closure project. Five of the projects are ongoing and four are finished when this research was conducted. Case projects are presented in table 6.

Table 6 Case projects.

Project	Division	Project type	Status
Light railway project 1	Traffic infrastructure	Alliance project	Ongoing
Light railway project 2	Traffic infrastructure	Alliance project	Ongoing
Street project 1	Traffic infrastructure	Contract based project	Finished
Street project 2	Traffic infrastructure	Contract based project	Finished
Subway station project	Structural engineering	Contract based project	Ongoing
Parking facility foundation project	Rock and special engineering	Contract based project	Ongoing
Landfill closure project	Rock and special engineering	Contract based project	Finished
Apartment building foundation project 1	Rock and special engineering	Contract based project	Ongoing
Apartment building foundation project 2	Rock and special engineering	Self-developed project	Finished

Semi-structured interviews were conducted as part of the case study. For the interview study, I invited people from that project who have been responsible for soil material management. The job titles and numbers of people who participated in the interview study were soil material coordinator (1), environmental engineer (1), project manager

(5), construction manager (3), earthwork construction engineer (1). Interviewees were invited to interviews either by email or telephone. In most projects, one responsible supervisor participated in the interview, but in a few projects, more people were able to participate in the interview.

The target duration of the interviews was 60 minutes. The duration of the interviews ranged from 34 minutes to 61 minutes. Interviews were conducted with Microsoft Teams due to remote working caused by COVID-19. All interviews were recorded. Table 7 presents case project's interview information.

Table 7 *The research interviews.*

Project	Interviewee code	Duration (min)
Light railway project 1	A, B	56
Light railway project 2	C	61
Street project 1	D	49
Street project 2	E, F	61
Subway station project	G	34
Parking facility foundation project	I, J	47
Landfill closure project	K	57
Apartment building foundation project 1	L	51
Apartment building foundation project 2	M	60

The interviews were based on a pre-planned questionnaire frame. The interview framework was created based on the research questions and research objectives. The frame of the interview was improved based on the first interview. The interviews discussed soil material procurement, disposal, and recycling. In addition, the interviews discussed the organization of soil material management and the desired state of the future of soil material management. The questionnaire frame of the interview was provided to the interviewees in advance so that they could get acquainted with the topics in advance. The frame of the interview is presented in the attachment A. Projects interviewed differ quite a lot from each other, so the structure of the interview was adapted to suit that interview. Following the interviews, a form was emailed to the interviewee asking for information on the cost and volume information of soil material on the project. The form is presented in attachment B. The study revealed that not all projects had an accurate calculation of soil material management, so the quality of the information varied a lot between different projects. For this reason, the focus of the study shifted to the analysis of the interviews.

Interviews aim to gain an understanding of what are the critical factors for successful soil management. Despite the diversity of the different projects, the same themes emerged in all interviews. In every interview, a new perspective on the topic was gained, but towards the end of the interviews, the amount of new information began to decrease, indicating that the number of case projects was appropriate for the study. In this research 9 interviews were conducted, and a total of 12 people were interviewed.

4.2.2 Workshop

In addition to case analysis, I conducted a workshop on which agenda was the main challenges and future development needs and wishes for soil material circular economy. Workshops are usually being used as a tool to create knowledge (Geissdoerfer, et al., 2016). The aim of this workshop was to create an understanding of what people are expecting on soil material circular economy and create a conversation of soil material circular economy's biggest challenges and future wishes.

I organized and facilitated the workshop. The workshop participants were selected together with the supervisor of the foundation unit. The job title of people who participated in the workshop were: development director, environmental manger, construction manager and Vice President. The invitations were sent by email. Due to the COVID-19, situation the workshop was held with Microsoft Teams. The coronavirus situation has caused exceptional urgency among site personnel so four of the six people invited were able to attend. Workshop participants are presented in table 8.

Table 8 Workshop participants.

Attendant code	Role to soil material management
N	Responsible for aerial photography development and operations at YIT.
O	Responsible of whole soil material circular economy development project.
P	Responsible of earthwork construction projects.
Q	Responsible for all foundation projects where earthwork construction is essential part of the project.

The workshop focused on four different themes 1) challenges caused by the case company's own operation model, 2) challenges caused by legislation, 3) soil material circulation operating model, and 4) challenges and wishes for soil material circulation model. The workshop lasted one and a half hours. Participants discussed the topic very

actively and commented on each other's ideas and perspectives, as well as the perspectives I presented that had come up in previous interviews.

4.3 Data analysis

As presented earlier, three different types of information were utilized in this study, information from the case projects interviews, information from the workshop, and secondary information from the case projects. The information from the interviews and the workshop was qualitative by nature and secondary information was quantitative information. The role of each part of information for this research is presented in table 9.

Table 9 Summary of the information sources for this study.

Information	Information type	Information role in the study
Case projects through interviewing	Qualitative	The aim of the interview with Case projects was to identify what is the current state of soil reclamation, as well as the most significant challenges.
Workshop	Qualitative	The workshop discussed the challenges of soil recycling identified in the interviews and sought to develop solutions to the challenges.
Secondary data	Quantitative	Secondary data was used to gain an understanding of the economic value capture potential in soil recycling. Secondary data was cost, and quantity information related to soil material management and recycling.

The data analysis of this research follows qualitative content analysis. Content analysis is a systematic way to analyze qualitative data in order to seeking discover using interpretations. In the Content Analysis, the information to be examined is organized and conclusions are sought from the data. (Saunders, et al., 2016, pp. 608-611) Inductive reasoning is more suitable than deductive for the analysis of qualitative data, so in this research the purpose of the analysis was to form new perspectives on the subject (Saunders, et al., 2016, p. 570).

The interview questions were structured into five categories that were soil material sourcing, disposing, recycling, soil material operations management and wishes for future soil material circular economy organization. Each category was further subdivided into a subcategory, which allowed the data of the interviews to be formulated in a structural form at the level of the answer to a single question. Each question in interview frame was one subcategory. I sorted the information presented in the workshop into the

data structure of the interviews, so that the information in the workshop could be viewed in the same way as the interviews. Same topics were repeated in both the interviews and the workshop.

Each interview and workshop included information that could not be placed in the above structure. This information was typically ones that only came out in one or a few interviews, so it didn't have to modify original data structure to fit this new information. This information was dealt with separately.

For each interview, a database structure was formed in Microsoft Excel, the attributes of which were question number, project, interviewee, category, question and answer. For the workshop the data structure was question number, category, subcategory and answer. All projects and workshop information were on their own sheets in the data table. Each project's and workshop's data table were uploaded from Excel to Microsoft Power BI where I was able to build tables where all projects answers to all question were presented together. With the help of this data structure and Power Bi report I was able to see transparently all projects answers to each question.

In addition to the database structure and Power BI report, I identified interviews and workshops with relevant internal quotes. I categorized the citations according to the results sections structure. All relevant quotations are presented in the result section.

Quantity information was analyzed in Excel and Microsoft Power BI. However, the study revealed that the quantity and cost information were not in an easily usable form that it could not be widely used in this study. Thus, the study could not provide estimates of cumulative soil procurement, disposal, and recycling volumes.

4.4 Research validity and reliability

Validity describes whether a study measures what it is intended to measure (Saunders, et al., 2016, p. 730). In the study, when examining the current state of soil management, the most significant challenges and future development targets, the study's validity is at a good level. The study includes a large sample of different parts of the organization and interviews interviewed project staff working daily in soil management. The interview questions were comprehensive, showing that the discussion hardly went beyond the interview frame of the interviews. The validity of the evaluation of economic value capture potential is at a moderate level due to quantitative cost, and volume data would have been a more appropriate method. Comprehensive quantitative analysis could not be conducted due to the cost, and volume information could not be gathered and converted to an analyzable format. The economic value capture potential was evaluated based on

individual interviews, and comprehensive data analysis was not conducted. For this reason, the validity of economic capture potential is at a moderate level.

The reliability of a study describes how well the research is reproducible and how well another researcher would get similar results with the same methods and sampling (Saunders, et al., 2016, p. 726). I estimate the reliability of the research to be high, as I expect that the study could be re-implemented in a different organization using the same research methods. Besides, the research's reliability is increased by the fact that the analysis was carried out as objectively as possible so that the research client's interests, and activities did not affect the research but allowed the researcher to work independently in the organization. Besides, the researcher did not already know most of the interviewees in the study, and the researcher was not part of the parts of the organization that were studied in the research.

5. RESULTS

This section presents the results of the research. First, in this section, the current status of soil material recycling is shown in the case company. Second, there are presented the main challenges of soil material recycling. Third, there are presented estimations of economic value capture potential and interviewees' opinions on how it should be organized.

The projects studied in this research differ a lot in the volume of soil management. Soil material volume information were not easily compiled into an analyzable and comparable format, so I couldn't compare each projects soil material moving volumes. However, the contract price of projects indicates how much the projects differ from each other. Figure 9 shows the values of the project contracts in proportion.

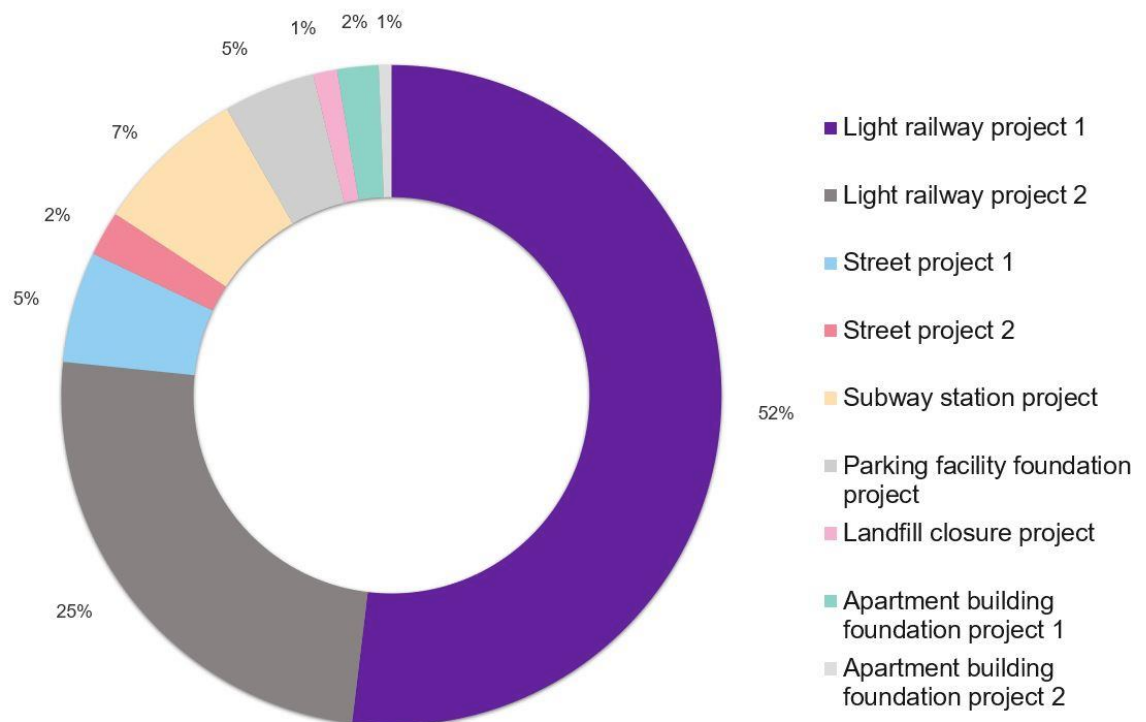


Figure 9 Case projects revenue in relation to each other.

As seen in figure 9, light railway projects are massive when compared to other projects. Due to the considerable variation in the size of the projects, they had significant differences in how well they were able to recycle the soil themselves.

The author has translated all direct citations in this section from Finnish into English.

5.1 Current status of soil material circular economy

The projects under study differ significantly in scope, so the project's potential to recycle soil material within the project varied widely between projects. For example, a project which builds a 25-kilometer tramway has much better chance of recycling soil material within the project than a project which makes a few kilometers of street. This section is divided into three subsections. First, this subsection considers soil material sourcing and disposing of, second, there is presented the current status of soil material recycling at YIT, and third, there is presented soil material logistics management.

5.1.1 Soil material sourcing and disposing

Every project in this study sourced soil material or mineral aggregates and soil material from suppliers. The operation model of soil material sourcing varied a lot between projects. In practice, three operating models were identified for soil material procurement. First, the project has a procurement engineer who is responsible for tendering out suppliers and sourcing material. Second, construction managers were tendering suppliers themselves and handle soil sourcing independently, among other jobs. Third, YIT's infrastructure project procurement function has tendered suppliers, and construction managers have taken care of soil purchases themselves. The share of different procurement models is presented in figure 10.

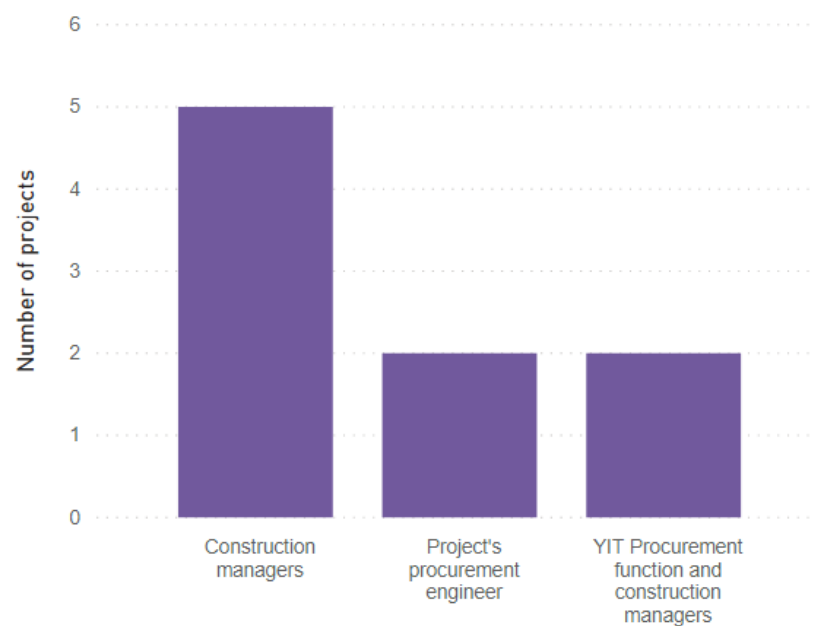


Figure 10 Person in responsible of mineral aggregate and soil material and soil material procurement.

Both light railway construction projects had a procurement engineer in the organization, who was in response to tendering out suppliers and sourcing material. For two projects, parking facility foundation project and subway station project, the YIT procurement function tendered mineral aggregate suppliers and projects sourced material individually. Apartment building foundation project 1, street project 2, and landfill closure projects tendered mineral aggregate suppliers separately. Apartment building foundation project 2 and street project 1 sourced mineral aggregates from another YIT project which had overhead aggregates. Also, the apartment building foundation project 2 sourced mineral aggregates from an external supplier because the supplier located near the project, so the cost of sourcing from the YIT project was the same as sourcing from an external supplier.

The study revealed that there are no standard operating models for the procurement of soil materials at the level of YIT's infrastructure projects, but that each project organizes the supply of soil and rock materials in the way it deems best. In the procurement of soil materials, the choice of suppliers is based mostly on economics. However, the environmental impacts of soil logistics are recognized, and subcontractors are tendered for the shortest possible transportation distances. However, the final deciding factor in choosing a transportation company is based on the lowest cost.

This study revealed that sludge, clay, and silt materials have had to be carried away from each project. Not all projects have succeeded in utilizing clay and silt materials, so materials have been disposed of on landfill sites. If there has not been any recovery site available, clay and silt material have been disposed to a landfill. Five of eight projects have been disposing of clay and silt materials on landfill sites. Projects located in Helsinki disposed of their clay and silt materials to private landfill sites because Helsinki city doesn't have landfill sites for soil materials, and other cities don't receive soils from Helsinki. Most of the clay and silt material was transported around fifty kilometers to a landfill in Ohkola, Mäntsälä. Projects located in Espoo disposed of their clay and silt material on Espoo city's own landfill site when the transported distance was from ten to twenty kilometers. Light railway project located in Tampere disposed of soil material on Tampere city landfill sites which located relatively near the project area. Street project 2, located in Espoo, disposed of their clay and soil material on a private landfill in Karjaa. Share of projects studied which have disposed of soil and clay material to landfill sites is presented in figure 11.

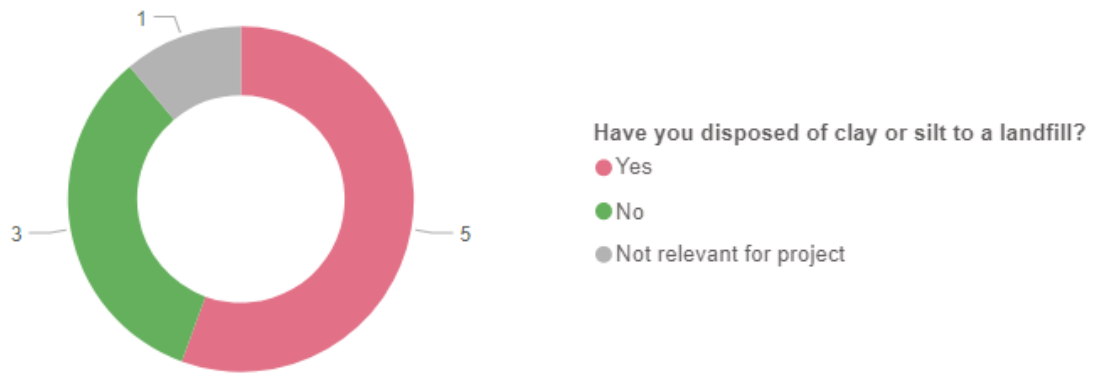


Figure 11 Share of projects disposing of clay and silt material.

The disposal of clay and silt lands did not concern the landfill closure project, as that project was a receiver of clay and silt material. Three of the projects studied succeeded in recycling clay and silt soils. Two of the projects that have disposed of clay and silt on landfill sites have also managed to recycle those materials, but due to the large volume of clay and silt, they have had to be disposed of on landfill sites.

In addition to moist clay and silt soils, potentially reusable non-cohesive and moraine soils have had to be disposed of on landfill sites, as no suitable recovery site has been found for the material. The share of projects disposing of potentially reusable materials is presented in figure 12.



Figure 12 Share of projects disposing of potentially reusable material.

All three projects that have been disposing of potentially reusable soil materials on landfill sites have also recycled soil material. The disposal of usable materials on a landfill sites has taken place because it has not been possible to find recovery sites for the material, in which case the project had no choice but to dispose of the soil on the landfill. In Helsinki, usable soil material has been disposed of on a private landfill in Ohkola, Mäntsälä. Apartment building foundation project 2 has disposed of its usable soil materials to Espoo city landfill site. Table 10 shows which materials each project has disposed of on landfill sites.

Table 10 *Materials that have been disposed of from projects.*

Project	What material were disposed
Light railway project 1	Clay, silt and non-cohesive soils
Light railway project 2	Clay, silt
Street project 1	Clay, non-cohesive soil
Street project 2	Sludge, clay, silt
Subway station project	Clay, silt
Parking facility foundation project	-
Landfill closure project	-
Apartment building foundation project 1	Non-cohesive soil
Apartment building foundation project 2	-

The study found that most of clay and silt soils have been disposed of on landfill sites. However, potentially reusable clean non-cohesive soil material has had to be disposed of to landfill because no suitable recovery site has been found for them. Light railway project 1 has had to dispose of significant amounts of non-cohesive soil on a landfill site due to the large volume on non-cohesive soils. Smaller projects have managed to recycle good non-cohesive soil more easily.

Several interviews revealed that the projects seek to avoid landfilling due to its high cost. The study found that long distances from sites to landfill sites and expensive reception fees have a significant impact on a project's economic performance if no suitable recovery site can be found for the materials. This study revealed that the motive for recycling soil material is primarily to save costs.

5.1.2 Soil material recycling

The study revealed that soil material recycling is currently planned on a project-by-project basis. Each project is in responsible for finding recovery sites for surplus soil material. Today there is no coordinated soil material recycling system within YIT. Each project is independently responsible in designed soil material recycling operations. In the two projects under study, soil recycling had been successfully organized so that no material had to be driven to landfill. However, not all projects had succeeded in finding a location for the extra soil, and potentially reusable material has had to be landfilled.

The quality of the soil material defines how it could be recycled. In this study, soils are classified into seven categories. In Table 11, the most common soil materials which are recycled in YIT are presented.

Table 11 On the basis of interviews different recycling materials and their reuse at YIT.

Material	Features	Reusing opportunity
Sludge	Sludge is a semi-solid soil material that is very moisture. The material occurs near water and groundwater.	Material is re-used in field construction and substrate production.
Clay	Clay is a very fine mineral particle mass that is difficult to utilize when wet.	Material is re-used in field construction, substrate production, landscaping, and in noise barrier construction.
Silt	Silt is a fine and soft soil that is a mixture of clay and sand	Material is used in field construction, substrate production, landscaping, and noise barrier construction.
Non-cohesive soil	Non-cohesive soil is a generic name for different soil materials, like sand, gravel, moraine and rocks. Non-cohesive soil can be stored in a pile without tipping over.	Can be used in landfill or in a structure that does not have high-quality requirements.
Gravel	Gravel is a rock material with a grain size ranging from two millimeters to about sixty millimeters.	For example, it can be used in retaining walls, load-bearing structures, or other structures with higher quality requirements.
Crusher stone	Crusher stone is a material that is formed when natural stone is processed to be more compact.	It can be used, for example, in road construction or other load-bearing structures.
Blasted rock	Stone material generated during quarrying. The grain size of the material is so large that it needs to be processed smaller. When processed, it produces crushed stone.	Can be used in crushed stone production.

In street project 2 interview it rides that sludge is very difficult to recycle due to its high-water content. In a few projects, sludge was found from the soil where the excavations were made below the groundwater level. Street project 2 delivered sludge material to a private landfill where it was dried, processed, and used in substrate production. Street project 1 reused sludge to a field construction project where YIT is a contractor. The rest of the projects delivered sludge material to a landfill, without further recycling plans. The interview revealed that it is challenging to utilize sludge, as the material, for example,

does not stay in a pile due to its high-water content. Interviews revealed that field construction projects or the production of a substrate are the only ways to utilize sludge without further treatment.

Clay is more solid than sludge, making it easier to recycle. Silt is, in turn, a material that is a combination of clay and sand. Clay and silt can be recycled to field construction projects as well as sludge. Apartment building foundation project 1, parking facility foundation project, and street project 1 have been recycling clay to a field construction project where YIT has been a contractor. Street project 2 has been recycling clay and silt to private landfill sites where the material has been used in substrate production. Light railway project 2 has been recycling a remarkable amount of clay and silt material in noise barrier construction. Also, light railway construction project 1 has been recycling small quantities of clay and silt to noise barrier construction projects, and they have sold clay and silt to substrate producers. In the Landfill Closure Project, clay and silt were utilized in the structure, stabilizing it with fly ash from power plants. Apartment building foundation project 2 and subway construction projects didn't have a remarkable amount of clay and silt material in the site, and they weren't able to find recycling sites for the small amount of clay and silt material. Also, both light railway construction projects have been disposing of clay on landfill sites because they haven't been able to find a recycling location for all the material. The interviews revealed that clay soils could also be used in the construction and landscaping of green areas, but no project had recycled the material in this way. Also, interviews revealed that clay material could be stabilized with loading berm, where some material, like non-cohesive soil, is piled over clay or silt and kept there for more than a year. In this case, the clay material condenses under pressure, and there is no need to dig it out of the construction area and fill the ground with another material.

Non-cohesive soil is a generic name for different soil materials, like sand, gravel, moraine, and small rocks. The name of non-cohesive soil tells that material can be stored on a pile without tipping over. The non-cohesive soil feature allows for much wider recycling possibilities. Non-cohesive soil can be utilized in fillings and terrace construction. All projects recycled non-cohesive soil material, some were able to recycle within the project, and some were able to recycle it to another YIT project or another company's project. In several projects, non-cohesive spoils were excavated from the site, stored on the site or at a site nearby, and later utilized in fillings. Apartment building project 2 was able to recycle extra non-cohesive soils to two other YIT projects and street project 1, which had a shortage of filling material. Apartment building foundation project 1 was able to recycle non-cohesive soils to another company's project, which had a shortage of filling material. As mentioned, street project 1 source non-cohesive soil from

apartment building foundation project two, but there was a fault in the calculations, and some of the non-cohesive soil had to be disposed of on the landfill site. Landfill closure project utilized non-cohesive soils from other YIT project in filling structures. Despite the possibilities of utilizing the non-cohesive soil, many projects had to drive the non-cohesive soils to a landfill site, as no suitable recovery site could be found for them. The study revealed that at the same time, as the soil was disposed of at the landfill, other projects purchased mineral aggregates from suppliers. In these cases, the quality requirements of non-cohesive soil would have been sufficient.

There are several recycling opportunities for gravel and crushed stone. Interviews revealed that crushed stone and another mineral aggregate are relatively easy to recycle because there is a high demand for them, especially in the Helsinki metropolitan area. In the Helsinki metropolitan area, delivery distances from mineral aggregate production sites are relatively long, which makes virgin material more expensive than recycled. Mineral aggregate processors are very reluctant to purchase extra crusher run and blasted rock material from construction sites. Materials can be used, among other things, in load-bearing structures of roads as well as in other structures with higher quality requirements. This study revealed that gravel and crusher run materials had not been disposed of in the landfill, but all surplus material has been reused within the project or other projects or sold to mineral aggregate processors.

Subway station construction, apartment building 2 foundation, and parking facility foundation projects reused its gravel, which was quarried from the site. Gravel was stored at the site and used in fillings and in load-bearing structures. Apartment building foundation projects 2 sold out the blasted rock to a mineral aggregate processor, which the project didn't need itself. Also, the project sold material to street project 2 and light railway construction project 2. The other apartment building project sold all excavated rock to a mineral aggregate processor because the project didn't need the material itself.

The parking facility foundation project is located in an area where soil reclamation has been carried out and for that reason, the soil material in the area is processed natural stone. Due to the high quality of soil material the project was able to restore the material to its fillings after the construction of underground structures.

Both tram projects had massive rock excavations in the projects. Both projects had processing stations for blasted rock, and projects reused the material in light railway structures. Light railway project 2 told in the interview that the project has been self-sufficient in mineral aggregates due to their massive excavations and ability to process the blasted rock.

This study revealed that several projects delivered their blasted rock and crusher run directly to the processor without mapping the needs of YIT's other projects. The study showed that the organizational structure had been formed in a way that the projects are only responsible for their own activities and are therefore looking for solutions that are most favorable and easy to the project itself instead of the whole company. Table 12 shows a summary of which materials were recycled by the projects studied.

Table 12 Soil material recycling in each project.

Project	Recycled material within the project	Material recycled outside the project	Recycled material sourced outside
Light railway project 1	Blasted rock and crusher stone Gravel Non-cohesive soil	Clay and silt to noise barrier construction Non-cohesive soil to noise barrier construction	
Light railway project 2	Blasted rock and crusher stone Gravel Non-cohesive soil	Clay and silt to noise barrier construction and substrate production	Crusher stone from apartment building foundation project 2
Street project 1	Non-cohesive soil	Clay and silt to field construction	Non-cohesive soil from apartment building foundation project 2
Street project 2	Blasted rock and crusher stone		Crusher stone from other company
Subway station project	Crusher stone and non-cohesive soil	Crusher stone from another YIT projects Non-cohesive soil to another company	
Parking facility foundation project	Crusher stone	Clay and sludge to field construction	

Landfill closure project	Clay and silt		Non-cohesive soil from other YIT project and other companies' projects Clay and silt from other companies' projects
Apartment building foundation project 1	Non-cohesive soil Crusher stone	Clay and silt to field construction Non-cohesive to other company Blasted rock to mineral aggregate processors	
Apartment building foundation project 2	Crusher stone Non-cohesive soil	Blasted rock to mineral aggregate processor Crusher run to Light railway project 1 and Street project 2 Non-cohesive soil to street project 1 and to another YIT project	

The study showed that there is no standard approach to soil recycling in YIT. The identification of soil material recycling opportunities is the responsibility of the project's operational management on each project. Identifying soil recycling opportunities is an integral part of the project's executive management. All projects identified that soil recycling planning should start much earlier than in the production phase, as currently, soil recycling planning puts a significant strain on project's operational management. In several cases where soils were successfully recycled, it emerged that the recycling was successful when the construction managers of the two projects knew each other and happened to be in touch, thus talking about their soil material needs. Interviewees found it challenging to find out soil recycling contacts, as there are numerous people and projects. The construction manager of the street project 2 described the current status of soil material recycling communications as follows:

"It would make sense if there were a system found in the Intranet, and you wouldn't have to call a million places. YIT should have its own system, where sites would

announce what surplus soil material they have and when. Also, sites could report, how much soil material they can receive and when.”

The fact that the projects do not know the construction managers of other projects and that there is no approach to reporting soil needs and surpluses were perceived as a significant problem for the projects. The project manager of the street project 2 demands that clients should consider soil material recycling beforehand because the time from tendering to execution might be relatively short. Then project executive management needs to make rash decisions that are not the best in terms of resource usage.

All interviewees think that soil material recycling planning should be implemented as early as possible. However, a few projects have implemented the soil recycling in tendering or production design phase, but soil recycling plans have not been exact. For example, the aggregate from the project's excavation is planned to be utilized by the project, but there has not been made detailed plans for recycling for other soil material. For example, the recycling of non-cohesive soils has not been designed. Projects have typically developed soil recycling solutions during implementation to achieve cost savings. For example, during the construction, the light railway project 2, together with the client, came up with the possibility of building noise barriers to reduce transportation distance and landfill costs, and the street project 2 came up with the idea of getting non-cohesive soils for landscaping from the apartment building foundation project 2. These changes in operational activities were aimed at cost savings.

Interviewees acknowledged that improving the efficient use of soils saves natural resources and cost savings. However, soil recycling requirements have not emerged in the client's requirements. In only one project with the client involved with the contractor in the alliance, the clients had set requirements for soil recycling. Interviewees believe that even more in the future, clients are placing demands on soil recycling, and thus the environmental impact of soil material management needs to be examined more closely.

Some interviewees were cautious of the systematic recycling of soil material. The challenge of planned recycling is when planned recycling opportunities do not work due to some unpredictable issues. For example, in the calculation of street project 2, it was expected to get crusher run there from an apartment building foundation 2 from six kilometers away. However, the start of the apartment building foundation project was delayed by six months due to the presence of flying squirrels on the construction projects area. For this reason, the time frame for blasted rock processing granted in the decision concerning temporary activity causing noise and vibration for the apartment building site could not be utilized due to the late start.

For this reason, street project 2 had to procure aggregates from outside YIT. Still, fortunately the aggregates were obtained by chance from another company's tunnel site, which was located next to street project 2. Eventually, apartment building foundation projects sold blasted rock to a mineral aggregate processor.

All interviewees that were a bit skeptical in the planned recycling of soils suggested that the possibilities for soil recycling should be identified in advance already at the planning and tendering phase. Contracts should not be counted only on the identified recycling opportunities. Soil management cost allocations should include the opportunity of recycling soil material and not the risk that the soil may not be recycled. Thus, if soil recycling plans could not be implemented, the project would not perform poorly financially since the contract price would have been calculated based on the cost savings from soil recycling. In a situation where recycling is not successful, the effects on the economic performance of the project may be significant. The project engineer of the subway station construction project thought that mass hauling in huge road construction projects is an essential part of the projects. He believed that it would be feasible to plan mass hauling in urban construction as well.

The recycling of soil materials within YIT is complicated due to commonly used contract model, in which the client takes over all high-quality soil materials such as blasted rock and crushed stone. In this case, the contractor does not have the opportunity to utilize the material on its own project. However, in the commonly used contract model, the contractor is responsible for disposing of low-quality soil materials like clay and silt to landfill sites or utilizing them in other projects. Apartment building foundation projects told in the interview that the client was determined utilization site for projects surplus non-cohesive soil and crushed run. Still, the client canceled land utilization in its projects, and the project had to find new utilization sites for the material quickly. Eventually, the non-cohesive soil was sold to a competitor and blasted rock to an aggregate processor.

This study revealed that people responsible for soil material management think that co-operation with competitors, clients, and cities is needed to manage soil material efficiently. For example, the light railway construction project 2 told that one of the main reasons for their successful soil material management was co-operation with project client. Also, interviewees had good experiences of competitor co-operation in soil recycling. Many interviews revealed that recycling soil with competitors creates a win-win situation where a company that wants to get rid of the soil and a company that needs it will benefit from recycling. Several interviewees think that co-operation with competitors and cities should be developed.

The success of soil management has primarily depended on the operational management of the project. For nearly all projects, the project organization was alone in investigating soil recycling opportunities. A very experienced project manager of apartment building foundation project 1 answered as follows in the question, "Do you feel that the project would have needed help with soil recycling?"

"I'm used to being with the soil management problems alone, so I did not need help. Of course, some controller would have been good who had information on other projects soil material needs."

Other critical factors for successful soil management were identified as soil storage capacity and collaboration with cities, authorities, and competitors. In the research, it was asked from projects what factors made the project successful in soil management. The answered factors are presented in Figure 13.

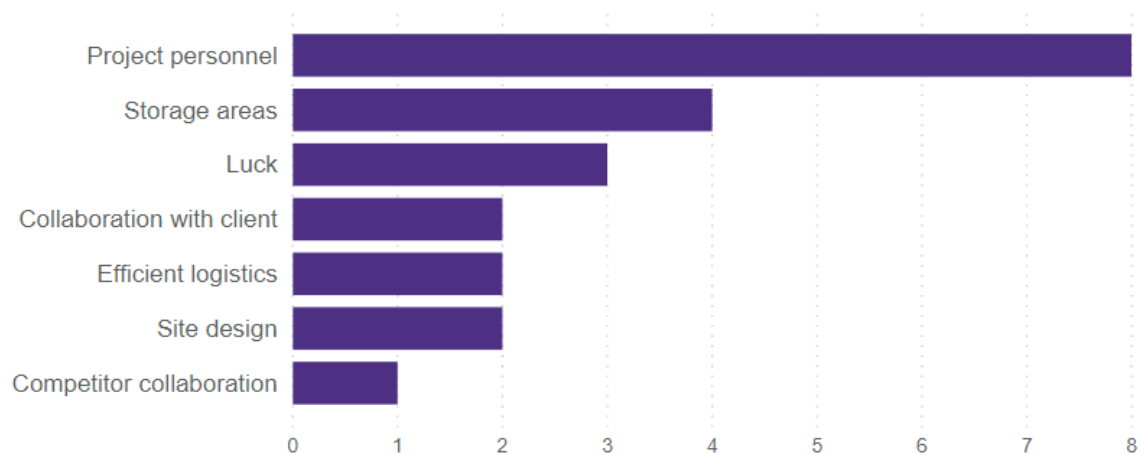


Figure 13 Success factors in soil management.

It is noteworthy that the role of human resources and good luck in soil recycling success is significant. Also, the successful exploitation of soil storage areas had a significant impact on several projects. Besides, a few projects identified stakeholder collaboration as a significant enabler of successful soil recycling.

In infrastructure construction, soil management plays an essential role. Projects that succeeded in recycling the soil material said it resulted in significant cost savings for the project. Similarly, projects, where soil could not be recycled, incurred significant costs from disposing of the surplus soil material.

5.1.3 Soil material logistics management

This study revealed that logistics plays a significant role in the success of soil recycling. The project manager of street project 2 said that well-designed logistics is essential for

soil recycling, as considerable cost savings are achieved by shortening and optimizing transport distances.

The general operating model for soil logistics management is that the project has one subcontractor that provides soil logistics services. Project construction managers typically direct and manage transportations, but transportation and on-site material handling are outsourced to subcontractors.

In soil logistics, transportation is not systematically optimized, but transportation is done when necessary. However, construction managers always aim to use the largest possible fleet of vehicles to reduce transportation costs. Light railway construction project 2 and street project 1 revealed that they are trying to use return transportation as often as possible. For example, when the clay is taken away from a construction site, crushed stone is brought back with the same truck. The optimization of the transport route and other driving is the responsibility of the subcontractor, as the transport company is typically invited to tender at a fixed price.

Many interviews revealed that coordinating the schedule of different projects is a considerable challenge for soil logistics. Rarely projects work together on the level that when a project excavates surplus soil, another project needs it for filling. The most optimal situation would be for the material to flow directly from excavation to backfill, but in reality, storage is needed to recycle the soil between different projects. In this study, two storage operating models have been observed: on-site or off-site soil material storing.

In the case of on-site storage, the surplus material was stored on the site before it was placed at the recovery site. Site storage was mainly used for soil excavated from the site, which was later utilized at the same site for filling. For example, the parking facility foundation project, subway station construction project, and apartment building construction project used on-site storage for its surplus material, which is used later in the fillings. Also, projects used on-site storage for storing sourced material. For example, street project 2 stored non-cohesive soil materials on the construction site area that had been acquired from the apartment building foundation project 2 before used the material in fillings. Light railway construction project 1 stored the crushed stone that it processed in the project area, from where they were distributed around the project sections. The biggest challenge of site storage is the lack of space. Not all projects had the opportunity to store soil materials on site. The handling and storage of soil materials require a lot of space, which should be taken into account when designing the site's structure. In one project, unpolluted non-cohesive soil had to be disposed of to landfill site because the material did not have storage facilities and had to be disposed of quickly from the site.

Another soil material storage model identified in the study is off-site storage. In that model, the project uses an external storage area to store or handle soil materials. An apartment building foundation project 1 operates in minimal space so that the project couldn't store any soil material at the site. The project had access to use outside storage areas for soil material, which was rented from the client. Project storage all excavated material that is needed in the fillings. Light railway project 2 used centralized soil material storage for soil material. The project had rented an area capable of processing blasted rock into mineral aggregates and storing soil material. Project sections delivered surplus non-cohesive soil material to the storage area and delivered crusher run and other materials back to project sections. The project highlighted that the key factor of the soil material handling success was the storage area. The light railway construction project 1 had gained access to use snow landfill sites owned by the client. The project has got access to sites from spring to the end of November, which is why it has not been possible to use the area in long-term and large-scale storing. Most projects thought that the lack of storage and treatment areas is a big challenge for soil recycling. Interviewees believed that the use of external storage areas could enhance soil recycling.

5.2 Challenges in soil material recycling

One of this study's aims was to identify the biggest challenges in the circular economy of surplus soils and how to overcome them. The interviews revealed that there are many challenges associated with the recycling of soil material. The study mapped out the biggest challenges for soil recycling from the construction site perspective. In the interview, there was a question, what are the biggest challenges in soil material recycling from a construction site perspective. The results are shown in Figure 14.

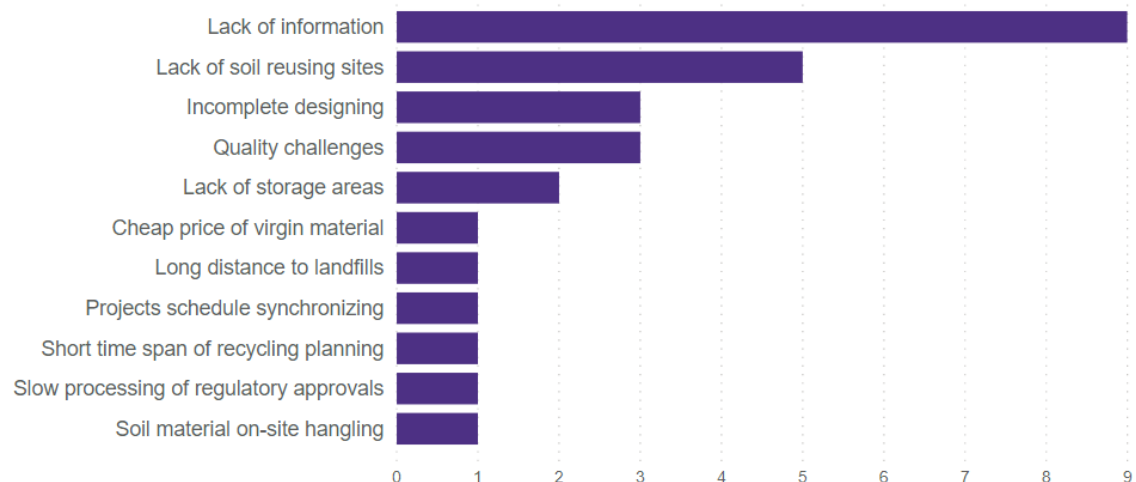


Figure 14 Soil material recycling challenges in site's perspective.

In the study, all projects thought that lack of information is the biggest problem in soil material recycling. Other challenges related to material handling, utilization, and storage were also seen as significant. The challenges identified in the study can be classified into four categories, that are:

1. Lack of information sharing and co-operation.
2. Logistics challenge
3. Legislation and quality challenges
4. The environmental challenges in soil material recycling.

This section reviews the challenges of soil management that have emerged in the study. This section also examines the site interviewees' thoughts on how to overcome these challenges.

5.2.1 Lack of information sharing and co-operation

Lack of information was identified as the most significant challenge in soil recycling. Several projects revealed that they do not know what other projects YIT has ongoing, and they are not aware of who is working on which project. In the workshop attendant N said:

"When visiting sites, I have seen that YIT has three sites in the 20-hectare area that don't talk to each other. There is no communication of project's needs and surplus materials. The projects are independent and operate as small companies, even though we are a big company. We do not take advantage of our large size in order to optimize material flows. On this basis, coordination between projects is needed."

It was clear from the interviews that the problem had been identified years ago and that various solutions had been developed over time. Interviewee G described the former solution as follows:

"Fifteen years ago, a list of the company's other projects and people who work there always was visible on the sites. Now even such a list would make it much easier for the sites to operate. Now the soils are recycled just according to how people know each other."

The interviews revealed that most of the projects would like to have a soil material coordinator of some operation model, which would help project personnel in soil material recycling. Currently, soil recycling generates extra work for project personnel, and due

to a rush at projects, it may not be done. In the Street Project 1, interviewee D described soil recycling as follows:

"Because working on a site is hectic, no one had time to identify potential sites for surplus soil recovery. The sites do not have time to plan for soil material recycling on a larger scale, but projects should have some ready-made solution."

In the interviews, it emerged that the projects would prefer an information system where they could look at the soil material needs of other projects themselves and report their surpluses or a coordinator who would do the work for them. However, some interviewees believed that the projects already have a lot of information systems in use at the moment, so new information systems would no longer be needed. As a solution, it was suggested that existing information systems could be utilized or that a coordinator coordinates the recycling of soil. The interviews highlighted that the coordinator could also be tasked with communicating soil needs and surpluses to other companies and cities. In a situation where the competitor's site is right next to our site, and another YIT site would be a long-distance away, it would be more profitable for YIT to transport the material to the competitor's site. Interviews revealed that soil material logistics optimization generates the most considerable cost savings due to cheap material value compared to the cost of transportation. Coordinating such situations and calculating different scenarios could be the task of the soil coordinator.

Soil coordination would be particularly important in environmental construction, where projects are in deficit for soils. The head of environmental construction described the current situation as follows:

"Because there is no knowledge of the soil material surpluses of other projects when creating a tender, the contracts must be accounted at a high price, in which case the materials have to be procured from suppliers. As a result, the contract price is not competitive, and the contract will be lost."

In the interviews, it emerged that the coordinator should have an overall image of the surplus materials and the shortage or deficit of materials on YIT's projects when the information could be utilized already in the tendering process.

In alliance projects where the city is involved in the alliance as a project client, co-operation with the city has been successful. Light railway construction project 2 told that critical success factor of soil material circulation has been sympathy of the client. Also, in the light railway construction project 1, they have done co-operation with the project client, but despite the co-operation, the project has disposed of soil material to landfill.

This research identified that usually in public contracting construction; contractors and clients do quite a little cooperation to recycle soil materials. The study found that the project personnel would like to have more cooperation with the clients, especially to recycle low-quality materials. Today, soil materials are delivered around 50 kilometers from sites to landfill sites, because all clients don't have facilities to receive surplus soil materials. In street project 2 interview interviewee E said as follows:

"It would be good if the cities as a client could organize the reception of soil for its projects in its area. They could also process the material and sell it back to contractors. The operation's profitability gets lost if the material is driven 30-40 km to be processed and driven back, and the current operating model makes no sense."

In a street project 2, interviewee F said that in his experience, cities are reluctant to use recycled soil in their projects. He described the current situation as follows:

"The client often assumes that the contractor will build with virgin materials. Then, when there is re-used material, it is often questioned. It can be difficult to form a common understanding of the use of recycled soils."

Currently, clients and contractors do not have a standard view of soil recycling. Many interviewees had the opinion that cooperation with cities should be developed, as the contractor's ability to recycle soil materials is limited.

Currently organization within YIT is built up in a way that there is a low level of cooperation between YIT segments. IT was identified in the workshop that great potential left untapped when infrastructure projects and Housing segment do not work together. Attendant N in the workshop described the current situation as follows.

"In many cases, housing production does not even ask YIT's infrastructure for foundation work but outsources it directly to subcontractors. Small contracts for residential construction form large volumes. When combined with the schedule, it is likely to be found that there are huge volumes of soil in housing production that are not under YIT."

It was identified in the workshop and interviews that the foundation construction work for small apartment building projects are competitive, so it is not always most profitable for YIT to carry out the construction work itself. In the workshop, participant Q pointed out that the Housing segment is continuously acquiring plots that could potentially be used for soil storage before construction on the plot begins. Attendant Q said:

"When making an investment decision on a plot, it would be essential to map the needs and opportunities of the plot for soil material recycling. The possibility of storing

soils, the need to import soils, or the volume of surplus soils should be mapped. We should also map the preload needs so that we could use the site for the temporary storage of non-cohesive soil.”

It was highlighted in the workshop that the coordinator’s role could be to map the pre-construction needs and storage possibilities of the land plots with the housing segment. In general, the interviews revealed that co-operation and communication with the YIT infrastructure projects segment, YIT group, competitors, and cities could reduce the amount of useful material ending up to a landfill site.

5.2.2 Soil material recycling logistics challenges

The study revealed that logistics problems play an essential role in improving the efficiency of soil logistics. In the interviews and workshops of this research, three logistics challenges related to soil recycling were identified. The same challenges arise from interviews with all projects. None of the challenges was perceived by just one project. In table 13 is presented soil material logistics challenges raised in this research.

Table 13 *Three challenges, causes and requested solutions of soil logistics in YIT’s internal soil recycling that arise in interviews and the workshop.*

Challenge	The cause of the challenge	Requested solution
1. The high cost of transportation compared to material price.	Due to the challenge, if the material cannot be stored or handled in the near the site, it is more profitable to dispose of the surplus soil in a landfill. It is not profitable to transport the extra soil to a storage area dozens of kilometers away from the site.	Optimizing of transportation distances and developing a process to utilize the material as near the place where it is excavated. Also, use as large vehicles as possible and take advantage of return transportations.
2. Logistics scheduling between the projects	When project’s tasks are not synchronized, the material will have to be disposed of in a landfill if there is no interim storage capability on-site.	Improve project scheduling to make projects work more synchronized.
3. Lack of temporary and permanent storage areas	It has to dispose of the material to a landfill because based on challenges 1 and 2, the storage area should be located close to the construction site.	Utilize the YIT housing segment’s plots for storage and communication with cities and possible storage area renting. The storage areas should locate near areas where construction takes place.

First, there is a challenge of optimizing transportation distances, because soil material value density is relatively low, and the share of transportation cost in the material price is relatively high. Attendant N said in the workshop that:

“The price of the material is equal to the cost of transportation. In soil management, it is essential to minimize transport distances so that processing can take place where surpluses are generated and where surpluses are utilized.”

That describes well that the biggest goal of soil logistics is to optimize transportation distances. Interviews revealed that today, especially transportation distance from sites to landfill sites is very long. The interviews revealed that if soils could be recycled close to where they are originated, there would be significant cost savings from reduced logistics costs. Other ways of reducing logistics costs that have emerged from the interviews are to use the largest possible vehicle size and to utilize return transportation. In the street project 1 interviewee D told that using as large vehicles cannot always be used due to the narrow layout of the construction site. He demanded that when designing site layout, it would be essential to design layout so that it would be possible to use large vehicles because using small vehicles causes unnecessary back and forth driving, which increases transportation costs.

The second challenge under the logistics challenge is scheduling challenges. Scheduling different construction sites and transports so that the soil would flow in just in time deliveries is challenging. In the street project 1 interview interviewee D said as follows:

“At the beginning of the project, it is known when the soil material should leave the site, but scheduling the fillings is more challenging.”

There are a lot of changing things on a construction site, so punctual timing of work steps is challenging. Apartment building foundation project 2 told that they recycled non-cohesive soil material to another YIT project, in a way that the work on the other YIT project schedule had to be stretched a bit so that the transports worked just in time. This was possible because there was the same project manager on both projects. Interviews and workshops did not provide clear solutions on how the scheduling challenge should be addressed. Not all YIT's construction sites can be made to operate at the level that the material would flow smoothly from one construction site to another. For this reason, storage areas must be used to recycle the soil.

The third logistics challenge is related to storage. Storages are an integral part of soil recycling, but there are many challenges associated with storage. As said earlier in section 5.2.1, the good location of storage is essential. In interviews with several projects,

it emerged that soil recycling could be made more efficient if YIT had centralized storage areas. The most necessary storage would be in the Helsinki metropolitan area, where the project sites are becoming increasingly tight. Interviews revealed that in the Helsinki metropolitan area, storage should be located along the highway and not far from the Kehä 3 road, to keep transportation distances from sites short. Workshop attendant N said as follows:

“Project schedules never coincide, but storage locations are always needed. Owning storage areas is a very important thing, and they must be in a good location and not far away from the cities.”

In the Helsinki metropolitan area, where the problems of soil recycling are greatest, obtaining and licensing storage areas is challenging due to dense settlements. In the workshop attendant N proposed a solution to storage problem:

“Soil storage sites must be planned from the perspective of the whole YIT Group not only at the level of individual projects. As YIT's plots, for example, building plots could well be utilized for soil storage. For example, in a situation where the plot has already been purchased, but there is no building permit for it, one could apply for a permit to use it as a short-term soil storage area.”

The utilization of YIT's own plots as a storage area also came up in several interviews. The workshop participants and interviewees believed that developing cooperation with the Housing segment could be a good development direction. It was generally recognized that there is a lot of untapped potential in the use of the Housing segment's plots. Besides, the interviews and the workshop revealed, for example, the determination of the pre-construction needs of YIT's plots, in which case loading berm could be built on the plot for 1-2 years. Attendant O of the workshop reminded that if YIT's plots are systematically utilized for storage, there must be certainty about the circulation of the material as if not the operation is considered as a waste handling area or landfill activity requiring environmental permit.

Light railway project 2 operates soil material storage successfully in their project. Interviewee C told in the interview that there is a fulltime wheel loader and driver who operates the storage. In the street project 2, interviewee E said that in his experience from another company, there is a requirement for the storage area that there are a full-time wheel loader and some responsible person for maintaining the storage.

5.2.3 Legislation and quality challenges

The interviews and literature review in section 2.4 raised the same issue, that there is strict legislation for soil recycling. As mentioned earlier, soil recycling requires material storage. In the workshop, participant O pointed out that obtaining the necessary permits from the environmental authority for the storage and handling of surplus soil can be challenging, especially in the Helsinki metropolitan area, where there are many neighborhoods in the vicinity of construction sites. In addition, the workshop discussed the utilization of YIT's plots in soil storage, in which case participant O pointed out that it is necessary to demonstrate the circulation of soils in storage areas systematical. She said the soil should have a maximum storage period of one year and known and planned reuse purpose in order to avoid permitting. In a longer storage period, the activity would be considered as a waste handling or landfilling. It was highlighted in the workshop that it would be essential to stay in close contact with the authorities when storing surplus soils.

In addition, long handling times for soil material processing and stone crushing permits causes challenges for soil recycling. For example, light railway project 2 was applying environmental permission for blasted rock crushing. The permitting process lasted more than a year, so these permissions need to be applied very much ahead. Street project 2 interviewee E told as his experience as follows:

“Often in the tendering phase, it is assumed that the soil can be handled on the site, but when the project starts, it is far too late to apply for permits. In this case, it is often assumed in the calculation that it is possible to process the soils on site, so this results in high costs for the project when the soil material has to be transported somewhere else to be processed.”

To avoid such situations, YIT must apply for permits well in advance, or correspondingly, YIT must have some soil handling areas, according to which contracts can be calculated. The limitation of on-site treatment is usually that the treated soil can only be used for the project in question. The environmental permits issued for both light railway projects prohibit the use of the material outside the certain project, which limits the possibilities for recycling surplus the material. In addition, projects can crush blasted rock only from the same project from which the rock is originated.

Other factors independent of YIT may also affect the recycling of soil material. For example, the decision concerning temporary activity causing noise and vibration granted to apartment building foundation project 2 could not be exploited on the construction site due to the flying squirrels found from the site area. For this reason, the plan for crushing

and reusing soil material needed to be canceled. The interviews revealed that other YIT projects had had similar problems in recent years.

There are also many quality challenges in soil recycling. For example, in a street construction project 2 excavations reached 15 meters below the ground level, so it wasn't easy to forecast what material is that deep below the ground surface. Test drilling was carried out in the project, but it was not possible to obtain a certain quality of the soil material. The same challenge arose in other projects that the exact properties of the soil can only be ascertained during excavation. This poses challenges to soil recycling design because there is no certainty about material quality properties.

In addition, in the parking facility foundation project interviewee I raised that when doing soil material recycling with competitors, quality monitoring is essential. YIT's projects may be required to report the exact quality characteristics of the materials, but when purchasing recycled soil from another company, there is no certainty about the quality of the material without separate quality assurance. The workshop highlighted that if a coordinator manages the soils, its essential role would be to ensure the quality of the material procured from outside of YIT.

5.2.4 Environmental challenges in soil material recycling

This study found that the environmental impacts of soil recycling are not widely assessed by projects. As part of the operational management, the aim is to minimize soil material transports, which reduces emissions. The people interviewed in the study clearly recognized that there is a significant potential for reducing carbon emissions by improving soil recycling. It was discussed in several interviews that in soil material logistics and emissions and cost go hand in hand. When transportation costs are cut, emissions are cut as well. Every project aims to reduce transportation costs, so simultaneously, they try to minimize transportation emissions.

However, the smaller carbon footprint of recycled material in the projects under study was not very much considered. In some cases, recycled material transportation distance is much longer than a distance of virgin material delivery straight from the supplier to site. In this case the cost of recycled material may be the same that even higher than recycled material. In one interview, the interviewee said:

"If the soil material is transported a few kilometers to interim storage and then transported back to site, the profitability of recycled material is lost because the aggregate supplier delivers the material so cheap that it is worth disposing of the material some-

where and buy the aggregate from the supplier. Yes, this is a pretty much Euro perspective from YIT's point of view. Of course, we understand the environmental aspects and investing in them, but things are largely viewed from the Euro point of view."

To increase the use of recycled soil material, some incentive system should be created for contractors that recycled material would seem more attractive. In addition, soil material logistics, especially the scheduling of recycled soil material logistics, should be improved that the price of recycled soil material would be attractive for projects. Besides, currently, the coordination of the utilization of recycled soils requires a lot of work from the projects. This makes it much easier to buy virgin material from the mineral aggregate supplier. To increase the use of recycled soil material, material procurement and disposal should be much easier for project personnel.

A few interviews identified that more environmentally friendly construction will be common in the future. Means to reduce the carbon footprint of construction materials and improve resource efficiency should be continuously developed. Interviewee C told that he is already involved in project tendering where the project needs to report carbon footprint.

5.3 Economic value capture potential of soil material recycling

It was revealed from the interviews that in infrastructure construction, especially traffic and foundation construction, soil management accounts for a really significant part of project costs. Interviews and workshop revealed that successful soil material management is a source of competitive advantage. In this research, projects in which soil management has been particularly effective has led to significant improvements in project performance. Improvements in project performance have been directly related to the better economic performance of the project. Two case projects were able to report calculated the cost savings from soil recycling. Thanks to soil recycling, the total cost of the projects had decreased by about 2 percent, which is a significant cost saving for an individual project. Other projects that couldn't report accurate numbers told that soil material recycling had generated significant cost savings for the project.

It was identified in the interviews and in the workshop that soil recycling can generate direct cost savings that affect the performance of an individual project, as well as indirect cost benefits that result indirectly from the recycling of soil. The effect of these cost savings creates economic value capture potential in soil material circular economy. The research finding for the formulation of economic value capture potential in soil material recycling is presented in table 14.

Table 14 Formulation of economic value capture potential in soil material recycling.

Directs cost savings

-
- Reduces logistics costs
 - Reduces landfilling fees
 - Reduces usage of virgin material

Indirect

-
- Company image benefit
 - Improved competitiveness in tenders
-

ECONOMIC VALUE CAPTURE POTENTIAL

In table 14, direct cost savings are generated in the short term by developing operations efficiency, but indirect cost savings are related to improving a company's competitiveness in the longer term. The workshop showed that construction projects clients are increasingly interested in sustainable construction, so a centralized circular economy operating model can contribute to gaining new business. Also, due to improved cost efficiency, the company's position in the bidding areas is better, which contributes to making the company more competitive.

In order to exploit the economic potential for value capture, it was discussed in the interviews it would be necessary to invest in a centralized soil material recycling process. The following opinion emerged in several interviews:

“If someone started to centrally maintain the material needs and surpluses of all the projects, then he/she would certainly earn her salary with cost savings based on his/her operation.”

Thus, it can be said that the projects' operational management believes that there is a remarkable economic value capture potential in soil material recycling. Interviews revealed that the potential for cost savings from centralized soil recycling had been identified more than a decade ago, but no action had been taken to implement it.

Interviews and workshop revealed that currently winning competitive bidding-based infrastructure projects is mostly based on the lowest price. In the workshop attendant N said as follows:

“From a competitiveness standpoint, the city's soil treatment areas are for everyone's use, and the business is done by them who manage the soil material more agilely than others. Thanks to our recycling projects, we have won many small infrastructure projects because recycling opportunities have brought us competitiveness. We should

develop action so that we can manage surplus soil more cost-effectively than competitors and the city.”

Earlier in this section, it was suggested that the projects wish to develop co-operation with the city, but it is more important to develop the company's own operations to be more agile.

The workshop and interviews highlighted the essential issue of addressing the challenges of soil recycling outlined in section 5.2 to capture the value of soils as well as possible within the organization. In the interviews and the workshop, suggestions were made on how YIT's operations should be organized in order to capture the value within the organization. The results are discussed in the next section 5.5.

5.4 Organizing soil material circular economy in YIT

In the interviews of this study, two different directions emerged about how soil management should be organized at YIT. Interviews and the workshop highlighted that the organization's goal is to reduce the disposal of usable soil in landfill sites. First, there is an option that a solution where projects could individually report their need and surpluses of soil material. The minimum viable product of solution would be a list where ongoing projects, their soil material situation, and contact person are presented.

Another solution option would be a systematic process where soil materials are managed from the tendering phase to project execution. There would be a coordinator or even team whose responsibility would be to keep in contact with projects and maintain information of surplus and deficit soil materials for projects.

5.4.1 Simple solution

Some of the people interviewed in the study were not enthusiastic about the development of an information system for soil management. These parties considered that the use of existing communication channels could be sufficient to increase soil material recycling. Attendant Q said in the workshop:

“It is simplest, the solution could be a list with a contact person, amount of surplus or needed soil material and schedule when it needs to be disposed of or filled.”

The simple solution was that the implementation of the solution would be driven by the needs of the individuals and not be ordered by the organization, which could improve the implementation of soil material recycling. Some interviewees agreed that projects currently have a lot of reporting responsibilities, and no more responsibilities are needed.

5.4.2 Systematic soil material management

As said in the earlier section, projects have many reporting responsibilities, and no more responsibilities are needed. Some interviewees and workshop attendants told that the solution should be made easy for the projects. So, a centralized function should be organized for soil management, which would be responsible for collecting, maintaining, and delivering soil management information to projects. The interviews revealed that there would be four tasks in soil coordination. First, supporting projects in operational soil management and recycling. Second, gathering information about soil needs and surplus from the tendering phase to create a snapshot of soil material balance. Third, Mapping and maintenance of temporary storage areas. Fourth, utilization of soil information when co-operating competitors and both external and internal reporting.

Today, soil coordination is the responsibility of construction sites, but it is widely recognized that this operating model is not working. Workshop attendant N said as follows:

“Right now, the projects are coordinating soils, and it won’t become anything at all. Coordination must take place long before the projects are implemented.”

Soil material coordinator should have an understanding of other projects' soil material needs so that soil material circulation would be planned before project execution starts. However, soil recycling plans may change due to unexpected features, so it is important that the soil coordinator can implement the operational management of soil material logistics.

In the interviews and the workshop, it emerged that coordination should be done with all YIT projects, and not only with Infrastructure projects. Attendant P said as follows:

“There would definitely be a need for some function to circulate soil material inside whole YIT.”

in addition, in the interviews, it emerged that the soil volumes of housing and business premises construction should be taken over by YIT. Interviewees believed that, for example, a systematic mapping of landfill needs for housing plots could avoid material disposing to a landfill.

In addition to the operational soil management of the project’s coordinator should be seeking opportunities to utilize clay and silt materials, because today reception fees for clay and silt are high and transportation distances to landfill sites are very long. Hence, attendant Q said in the workshop as follows:

“Replacing clay and silt soils somewhere else than landfill is one of the most essential things in soil material recycling.”

The soil material coordinator should look for possible reusing locations for soil material within YIT's projects, competitors, or clients' other projects. Stakeholder cooperation with cities and competitors would be an integral part of the role of the soil coordinator.

An essential part of soil coordination is the collection and communication of information to projects. In the study, the interviewee hoped that information would be passed on to the projects through some information system, but the interviews also hoped that the coordinator could be called and inquired about possible surplus soils or reusing locations. Several interviews raised the following wish for a soil management information system:

“In the beginning, the management information system should be as simple as possible so that all complexity can be minimized.”

The interviews revealed that if, for example, existing reporting systems could be used to gather soil information from projects. In addition, a few projects interviewed in this study wished that the soil coordinator should be regional, because for the coordination of soil materials together with cities and authorities requires regional personal knowledge. Interviewee C wished that Southern Finland coordinator wouldn't cut in projects soil material recycling that locate somewhere else in Finland.

As mentioned earlier, soil information should be systematically collected from the tendering phase. Workshop attendant Q said as follows:

“ If someone starts planning the coordination of the soil material in the middle of the construction project, it will be too late.”

In the workshop, attendant Q pointed out that in soil management, it would be essential to integrate the management of tender accounting and project opportunities into soil management information systems, so that filling information to soil material systems could be minimized.

In the workshop attendant, N pointed out that it would be a great opportunity to utilize soil material information of lost projects. If there is a soil deficit in the lost project, then YIT can use this information, as the company who has won the contract will, in any case, need soil for the project. In this situation, YIT could offer surplus materials to the competitor. This would be possible with the help of systematic soil material information gathering from the tendering phase.

In the interview, attendant O pointed out that it is likely that in the future, the disposal and recycling of soil materials will have to be reported to the authorities. This is essential to keep in mind when developing systems. However, it is necessary that the development work is not done with the systems and reporting above, but that the system must facilitate operational soil recycling. Recycling and disposing reporting should be systems by-products.

5.4.3 Potential of UAV photogrammetry in soil material management

In the workshop attendant N pointed out that today YIT utilizes UAV photogrammetry in creating digital models and snapshots of sites. UAV photogrammetry is defined by (Eisenbeiß, 2009) as follows:

“UAV Photogrammetry describes photogrammetric measurement platforms, which operate as either remotely controlled, semi-autonomously, or autonomously, all without a pilot sitting in the platform, and the photogrammetric processing of UAV images. The broad definition covers balloons, kites, gliders, airships, rotary and fixed wing UAVs with the capability for photogrammetric data acquisition in manual, semi-automated and automated flight mode.”

Today at YIT photogrammetry is done by drones and processing system. In the workshop attendant N said that with the help of the system used by YIT, it is possible to measure the volumes of different soil piles accurately. For example, the volume of aggregate stored on a pile during mining can be determined quickly using drones. However, the volumes of different soil piles are not systematically measured using a drone. Volumes of soil piles are measured only occasionally when projects so request.

In the workshop attendant N said that nearly all YIT infra projects sites are mapped regularly, so the information of soil material storages are very easily shared to projects. By systematically utilizing UAV photography, YIT has the opportunity to generate really accurate information about the volumes being processed. It was generally discussed in the workshop that the role of the soil coordination support function could be to systematically analyze and share soil material volume information to projects. Potential soil material coordinator could work closely with the team which is in responsible of UAV photogrammetry. Workshop attendant N said that additional flights are not needed because all sites are photographed regularly, so no major additional resources are needed.

6. DISCUSSION

The study highlighted that there is considerable potential for improving soil recycling within YIT. This section presents an analysis of the results. First, the research findings are compared to previous literature. Second, framework for soil material recycling operations planning and management is presented. Third, the results of this study are discussed, and fourth, future development opportunities for YIT within soil material recycling is presented.

6.1 Comparison current status of soil material circular economy in YIT with previous academic literature

Table 2 in the second section of the study presented sustainable business models that are:

1. Minimize material and energy usage (Ellen MacArthur Foundation, 2015; Bocken, et al., 2014)
2. Maximize value through the value chain (Ellen MacArthur Foundation, 2015; Bocken, et al., 2014; Stahel, 2016)
3. Substitute with renewables and natural processes (Bocken, et al., 2014)
4. Shaping products design to support the circular economy (Ellen MacArthur Foundation, 2015; Antikainen & Valokari, 2016; Stahel, 2016)
5. Collaboration between different players (Witjes & Lozano, 2016).

This study explored how soil material's circular economy should be promoted, so four of the business models presented above emerged in the interviews. First, it is clear that to improve soil recycling, soil material usage should be minimized. In street construction project 2, the material efficiency of the project could have been improved from the achieved level by more detailed planning of the soil material usage because purchased surplus material had to be disposed of on a landfill site. To avoid material overuse, project design should be done more accurately. Second, interviews highlighted that more recycled materials could be utilized in construction. In order to significantly increase the efficiency of soil recycling, recycling should already be taken into account in construction project design and tendering. In addition, the interviews highlighted that increased collaboration with competitors and clients is essential to improve soil material recycling because one company's capabilities are limited.

Table 3 in section 2.3 shows the different recycled materials that could be utilized in infrastructure construction. The study revealed that today these materials are not widely used in infrastructure construction at YIT.

Tiehallinto (2007) and Tornainen & Sikiö (2018) suggested that ash from coal and organic material combustion can be used to stabilize clay and silt soils. However, workshop attendant P said that mixing the ash with moist soil is not profitable because the operation is expensive. The Landfill Closure project had mixed ash from ash burning, but the process was expensive. According to interviewee P, in the current situation, operations are almost entirely controlled from a cost perspective, so it is more profitable to dig the clays out of the ground, dispose of them somewhere else, and fill the dig with other materials.

In addition, no projects had utilized sludge generated as industrial by-products, which, according to Tornainen & Sikiö (2018), could be utilized in load-bearing road structures. In addition, stone products from the mining industry were not utilized in any of the projects. The only projects being recycled were asphalt and crushed concrete.

Adams et al. (2017) present in the framework that circular economy design in construction project is essential during the project whole life cycle. The framework is presented in figure 2 in section 2.3. Adams et al. (2017) present that material circulation should be designed in each part of the construction project during project life cycle. According to Adams et al. (2017) different parts in project life cycle are:

1. Design
2. Manufacture and supply
3. Construction
4. In use and refurbishment
5. End of life

Today at YIT, the design of soil circulation starts generally not until in construction phase. Some projects interviewed in this study have done soil material recycling planning in design phase. Each project interviewed in this study pointed out that the circulation design should be started in the project design phase, but today it is not done at YIT. Also, the supply of soil materials is not centrally managed due to a fragmented supply chain. All deliveries are happening on demand, and only a few projects interviewed in this study were able to use reverse transportations. Today at the end of projects life, the materials are selectively excavated. However, they are not systematically utilized in construction because there is not a connection from the demolition to designs on new construction

projects. It was clear from the interviews that the projects would like more coordinated recycling of soil materials throughout the projects' life cycle.

In section 2.3, there were presented ten challenges of circular economy in the construction industry. In this research, the same challenges pointed out, but not all of them weren't pointed out as an issue in YIT. Table 15 comprises ten circular economy challenges in the construction industry and this research findings.

Table 15 *Circular economy challenges in construction industry (Adams, et al., 2017) compared to the research findings of this study.*

Challenge	The research findings of this study
1. Lack of interest	Lack of interest was not found as a problem in this study. The persons interviewed in the study had an interest in soil recycling, but the lack of operating models made soil recycling challenging.
2. Limited awareness across the supply chain	The lack of knowledge between the different stakeholders in the construction project could be improved. For example, in a contract-based business, the client and the contractor often have different perceptions of soil recycling that contractor tries to recycle as much soil as possible and client wants as good quality and cheap price as possible.
3. Lack of circular economy knowledge	The study found that the circular economy of soils was a topic familiar to all interviewees, lack of circular economy knowledge was not the reason for the low level of recycling.
4. Lack of incentive to design for end of life (products)	The study revealed that there is currently no incentive system other than contractor's cost savings from improved recycling.
5. Lack of consideration for end-of-life issues (buildings)	This was not relevant for this study because soil materials are always reusable in the end of buildings life cycle, in case they are un-polluted.
6. Lack of market mechanisms for recovery	Lack of market mechanisms was pointed out as one main challenge in soil material recycling. There is not any market mechanism how supplier and project in need would meet their needs.
7. Unclear financial case	The study revealed that cost savings from soil recycling or soil disposal costs are closely monitored by projects not centrally in the company level. For this reason, on a larger scale, there has been no awakening to the cost of inefficient soil management or value capture potential for effective soil management.

8. A low value of material/products at the end of life	Recyclable soil is valuable, but this study found that a greater challenge is the low cost of virgin materials.
9. Fragmented supply chain	A fragmented supply chain is a big challenge in soil recycling as managing logistics is a significant cost in soil recycling. The study highlighted that efficient recycling of soils requires coordination of supply chain.
10. The complexity of buildings.	The complexity of the structures is not a problem for soil recycling, as modern methods succeed in excavating the soil in a sorting manner.

In the table 15 circular economy challenges in construction industry presented by Adams et al. (2017) are more concept level than the challenges found in this research. This study mainly interviewed the operational management of projects, so the challenges identified were widely related to the operational activities of projects. However, the study revealed that all challenges presented by Adams et al. (2017) are not challenges at YIT. In this study, the lack of circular economy motivation and knowledge presented by Adams et al. (2017) were not observed. The study found that project personnel has a high interest in developing soil recycling and project personnel has a lot of ideas on how soil recycling should be improved. However, the findings of this study are in line with Adams et al. (2017) with the findings that the unclear financial case and lack of market mechanisms complicate soil material circular economy.

In section 2.4, it is presented that there may be more incentives to improve soil material recycling and sanction for reusable soil material disposing of to landfill sites (Adams, et al., 2017). Also, workshop attendant O pointed out that she will believe that soil material recycling will be more regulated in the future.

Also, section 2.4.3 identified that the price of virgin raw materials and the lack of treatment areas in densely populated areas pose a challenge to soil recycling. (Härmä, et al., 2010) The same findings came to the fore in several interviews. Besides, the literature and interviews identified that the definition of systematic soil recovery posed challenges to soil recycling, as soils cannot be stored without a certain recovery location. (Finnish Ministry of the Environment, 2015; Härmä, et al., 2010).

Section 2.2.3 identified that following the circular economy business model provides value within the organization (Korhonen, et al., 2018). The same was identified in the interviews, as today, the circular economy of soils is driven by the potential to capture value within individual projects. As presented in section 5.3, there is a significant potential to capture value in soil material circular economy.

De Lima et al. (2013) present that in earthwork construction logistics generate a significant share of cost due to large volume transported and large vehicle fleets. Optimizing soil material logistics can create significant cost savings. (De Lima, et al., 2013; Choudhari & Tindwani, 2017; Sobotka, et al., 2012) The same was clearly detected in this research that the cost savings from soil recycling are mainly due to the transport costs saved when the material can be procured closer. The literature and this research find out that the price on soil material is relatively low compared to logistics cost. (De Lima, et al., 2013)

It was presented in the literature that temporary organizations mainly conduct construction projects, and they are using temporary supply chains. For that reason, construction supply chains are difficult to control and designed a case-by-case basis. (Behera, et al., 2015; Vidalakis, et al., 2011) This research finds out the same result, that supply chains are rarely optimized due to logistics planning horizon is relatively short. It was detected from interviews that project with long lead time and the logistics chains were more optimized than shorter projects. This research finds that there is a lot of untapped potential in improving earthwork construction logistics due to a lack of optimization and usage of return transports. From the construction contractor's point of view, optimizing supply chains is difficult, as all the projects interviewed in this study are operated soil material logistics by subcontractor company.

Vrijhoef and Koskela (2000) argue that logistical challenges and the organization's complexity are one of the main reasons why the construction industry is suffering from both low productivity and rising production costs. In this study, it was found that by improving soil logistics' efficiency, significant cost savings can be created, so inefficiently organized logistics has a clear link to the un-productivity of a construction project.

The contract-based business has traditionally focused on reducing costs by cutting procurement and resource cost, leaving process development secondary positions. It is suggested that contractors should change their operations from project-centric to more process-oriented. It is argued that logistics costs could be a better measure than resource purchase price. (Wegelius-Lehtonen, 2000) The same was strongly highlighted in the study that cost savings in earthwork construction is due to improvements in logistics processes. For other materials, it might be useful to identify logistics costs and compare them to the purchase price.

It was presented in the literature that construction logistics' role in construction operations is neglected because traditionally, logistics is not involved in construction projects value creation. (Barima & Rowlinson, 2010; Hjelmbrekke, et al., 2016;

Kadangwe & Emuze, 2017) Based on the results of this study, this view can be shown to be wrong. In this study, it was found that project staff was clearly aware of logistics' role in project value creation and cost. However, the reason why logistics was inefficient was the lack of common operating models and tools. The interviews clearly highlighted the project staff's wish that YIT would introduce an operating model that would make soil logistics more centralized and thus more efficient.

It was presented in the literature that construction logistics should be planned during each phase of the project's life cycle, from design to execution (Serra & Oliveira, 2003). The study found that today logistics planning is largely implemented only at the project execution stage of the project. In the planning phase, for example, the aim is to design the site in such a way that interim storage is possible, but for many projects, logistics planning proceeds at the same pace as the execution of the project.

Table 4 in section 3.3.2 presented tools to improve construction logistics. There were the same improvement topics discussed in the interviews. Some of the development proposals are too futuristic compared to the current situation. Today, logistics is not managed through information system and information is delivered mostly by phone, for example, BIM solutions are not relevant, as much development must happen before BIM technology can be utilized in logistics improvement. Table 16 discusses logistics improvement topics to their suitability to YIT's soil material logistics.

Table 16 Logistics improvement tools and their feasibility to YIT soil material logistics.

Tool	Feasibility to YIT	Discussion
Centralized logistics	Feasible	A centralized function would be needed for logistics management to make the soil needs and surpluses of other construction projects visible. This could be used to make logistics more efficient, for example, by maximizing return transport.
Just-in-time deliveries	Feasible	By synchronizing schedules for different projects, just-in-time deliveries to construction sites could be increased to avoid interim storage.
Improved scheduling	Feasible	The biggest challenge in soil recycling is scheduling. By improving scheduling, soils could be made to flow more efficiently between construction sites.
Safety stocks	Feasible	By increasing the storage of soils, the dispose of unpolluted soils and the purchase of virgin material

		on structures for which recycled soils would have been suitable could be avoided.
BIM-based solutions	Not feasible	The current logistics operating model does not allow the use of BIM technology in logistics optimization. In turn, the amounts of soil calculated with UAV technology can be utilized in maintaining the amounts of soil.
Simulation-based solutions	Not feasible	Simulation-based solutions are not currently in use at YIT so it would not be feasible to use them in logistics optimization.
Pre-assembly	Not relevant	Pre-assembly is not relevant in earthwork construction.
Web-based logistics software	Feasible	This research finds that the people responsible for soil material management would like to have some program that would help manage soil logistics.
Third party logistics service provider	Not feasible	Today all logistics are operated by subcontractors, but it is managed by YIT. All project wished that YIT would have more control in soil material logistics, not less so third-party logistics service provider is not feasible solution

It is justified in the literature, and in this research, planning of earthwork construction logistics has a significant effect on project economic performance. Sobotka et al. (2012) argue that even a small improvement in material flow management and logistics optimization is bound to bring substantial economic benefits. The same was detected in this research. Two projects in this study said that they were able to gain from 1 to 2 percentage cost saving with improved soil material logistics management. Due to massive soil volumes, the cost-saving was significant. Nevertheless, Sobotka et al. (2012), Choudhari & Tindwani (2017), and De Lima, et al. (2013) argue that soil material logistics cannot be designed by a rational manner. It was suggested in the literature that some technical solutions like linear programming, computer simulation, and genetic algorithm should be utilized in soil material logistics design. However, today these kinds of solutions are not feasible at YIT because digital information management models should be developed at the first place. Today there is centralized information of projects soil materials so that technical solutions could not be utilized. In the workshop attendant, Q said that a small improvement in soil material logistics management would create a significant benefit in soil material coordination operation in YIT, and IT systems should not drive the development of soil material management. The study revealed that the success of soil management was mainly due to the project staff's inspiration so that cost

savings can be achieved in a rational manner. It was discussed in the workshop that the development of information systems is potentially a future development.

6.2 Framework for designing soil material systematic recycling

This study clearly showed that the development of centralized soil management operating model could solve a part of soil recycling challenges. The third research question in this study was, “how can YIT organize construction operations in a way that it can reuse relevant surplus soil material at YIT’s projects.” This study will answer that question by developing a framework for soil material recycling planning for contract-based and self-developed projects.

According to Wegelius-Lehtonen (2000), construction companies should turn their mindset from project-oriented business to a process-orientated approach. The purpose of the framework is to form an operating model so that, in project-based construction, soils can be managed process-basis. This research has shown that there is practically a continuous flow of soil material in the Helsinki Metropolitan area, so the development of a process-based management system could be feasible.

In section 3.3.3, there were presented factors that need to evaluate when designing earthwork operations. The factors and their role in the framework are presented in table 17.

Table 17 Soil material logistics design and their feasibility to YIT (Moselhi & Alshibani, 2009) (Peurifoy, et al., 2018).

Factor	Feasibility in the framework
Availability of resources	The management of transport resources is not the responsibility of YIT, as all logistics is subcontracted.
Time constrains	Time constraints are an integral part of soil material logistics.
Quantity of soil to be moved	Quantity of soil to be moved is essential in soil material operations planning.
Hauling distance between cut and fill	Distance between excavation and fill is an integral part in soil material logistics optimizing.
Construction site conditions	Construction site conditions are not relevant. In practice, all construction sites can be operated with large vehicles.

Soil type	Soil type is an essential part of soil material recycling design.
Equipment characteristics and constraints	Equipment characteristics are not relevant because equipment usage is in subcontractors responsible.

Based on the literature and interviews, it can be said that four variables need to be coordinated in soil recycling between projects. The variables are as follows:

1. Quantity of soil to be moved
2. Quality of soil to be moved
3. Soil material logistics synchronizing to projects schedule
4. Transportation distance between projects.

Information on soil quantities should be obtained from the tendering and design phase of the project, and the accuracy of the quantities should be defined as accurately as possible. The soil quality classification scale is the same as that currently used by YIT. The different soil categories are sludge, clay, silt, non-cohesive soil, gravel, crushed rock, and blasted rock. The scheduling aims to make the projects work so that the soil materials can be recycled as efficiently as possible between construction sites without needing temporary storage. The goal of transport distance management is to deliver soil materials over the shortest possible distances. Both literature and research have shown that the cost of transportation is really high compared to the cost of the material.

The study identified that YIT would need some function to coordinate soil recycling. Some interviewees believed that information on ongoing projects would be enough to increase the efficiency of soil recycling. However, this study revealed that soil recovery's most significant potential would not be exploited if the coordination of soil recycling was left to projects. Therefore, in this study, I propose that a function should be established for YIT, which would be responsible for the coordination of soil materials between construction sites.

It is clear from the interviews that soil recycling should be organized as an integral part of the project process. Adams et al. (2017) present that there are a different tasks in soil material recycling for each part of the project. Adams et al. (2017) present that different parts are designing, manufacturing and supply, construction, use, and end of life. In turn, Serra and Oliveira (2003) present that different parts of the construction project in terms of logistics are design, planning, procurement, and execution. Relevant in this research's scope are activities that happen from design to construction project execution. Besides,

it became clear from the interview that planning for soil reclamation should start as early as possible. Therefore, I suggest that the examination of soils begin with a market study. Thus, I formed a framework that presents soil management tasks in different parts of the organization at different stages of the project.

The study identified that currently, the project manages the soils independently on a case-by-case basis. Wegelius-Lehtonen (2000) recognized that making construction more efficient requires a shift to a more process-minded approach. This research also finds out that the most significant factor in soil material recycling success is a personal resource, so I think it is justified to develop a management framework that shifts soil material management towards the process approach. The framework follows the circular economy framework in construction project presented by Adams et al., (2017) and the construction logistics design framework presented by Serra and Oliveira (2003) according to which soil recycling should be planned for each project throughout the project life cycle.

Roughly divided, YIT implements two types of projects, contracting-based and self-developed projects. The two types of projects differ significantly from each other, so the soil material recycling framework must be drawn up separately for each of them. In addition to contract based and self-developed projects YIT is a partner in alliance projects. For alliance projects it is not feasible to present a framework for soil management, as alliance projects are always really large and unique entities. The frameworks for contract-based and self-developed projects are presented in the next two subsections.

6.2.1 Contract-based projects

The contracting business is an activity where the client orders a contractor to carry out a pre-defined construction project. In a contract-based business, four organizational functions play a role in soil management. The functions are calculation, production, procurement, and support function I proposed earlier. The project's life cycle in the contract-based business can be divided into five milestones. Milestones are:

1. Decision to participate in the tender
2. Submission of the tender
3. Winning the contract
4. Starting the construction
5. Finishing the project.

Thus, the role of each function involved in soil management can be specified in each part of the project life cycle. By standardizing the tasks of each function, the methods of soil management can be harmonized. The framework for soil material recycling is presented in figure 15.

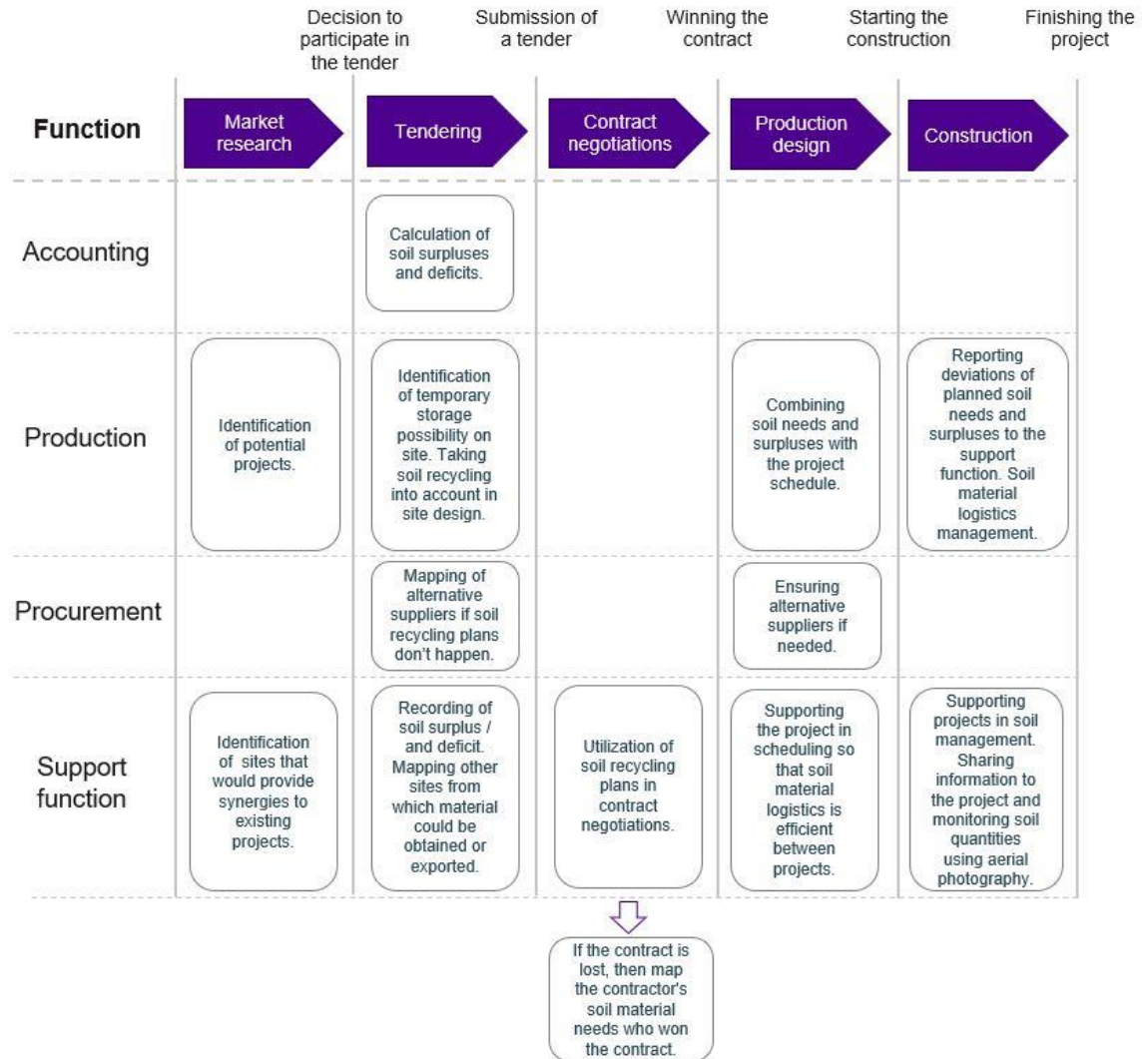


Figure 15 The framework for soil material recycling in contract-based business.

In the market research phase, the production function is responsible for finding potential projects. The support function's role is to support the production function and identify potential projects that could benefit from synergies with other existing projects. For example, if YIT had a multi-year contract in progress that handles a lot of soil material, then the goal of the support function would be to identify projects close to an existing project that deals with soil materials.

At the tendering stage, the purpose of the accounting function would be to determine the soil needs and surpluses of the project. The task for production function would be to determine temporary storage possibilities on site. In the workshop, participant O said

that construction sites might be used for temporary storage if the material can be assigned a precise recovery site. Besides, the function of the production function would be to take into account the recycling of soil materials in the design of the site layout. At the tendering stage, the procurement function would be tasked with identifying potential suppliers if, for some reason, the planned soil recycling would not be successful. In the tendering phase, the support function role would be to record soil material needs and surpluses and map other projects where extra soil material could be sourced and where overheard soil material could be reused primarily internally but also externally.

At the negotiation stage, soil recycling plans could try to gain a competitive advantage and be used as a bargaining by presenting how the contractor will promote circular economy in construction business by recycling. However, if the contract would be lost, the task of the support function would be to map the soil needs of the competitor who won the contract. In a situation where YIT had a surplus next to that project, it would be profitable for everyone to deliver the surplus soils to a site nearby.

In the production design stage, production functions task would be to combine soil material needs and surpluses to project schedule, so a schedule can be formed when soil material logistics should be operated. The support function's task would be supporting the production function in scheduling that soil material would be more efficient between projects. In the production design phase procurement function role would be to ensure alternative suppliers for soil material.

In the construction phase, production functions role would be reporting deviations of planned soil needs and surpluses to the support function. Also, the production functions task would be to coordinate soil material logistics in co-operation with support function. In construction phase support function's task would be supporting projects, sharing soil information to the project, and monitoring soil quantities using an UAV photography drone. Today YIT sites are photographed regularly using drone and drone flights can be used to produce a snapshot and information on the amounts of soil in the project.

6.2.2 Self-developed projects

Self-developed projects are projects in which the YIT acquires a plot and develops, plans, and implements construction projects. In self-developed projects, project development, accounting, production, procurement, and support function participates in soil management. Self-developed projects can be divided into five milestones that are:

1. investment decision to the plot
2. the start of design

3. decision to start the construction
4. starting the construction
5. finishing the project.

Each function is tasked with different parts of the project. The framework for soil material recycling in self-developed projects is presented in figure 16.

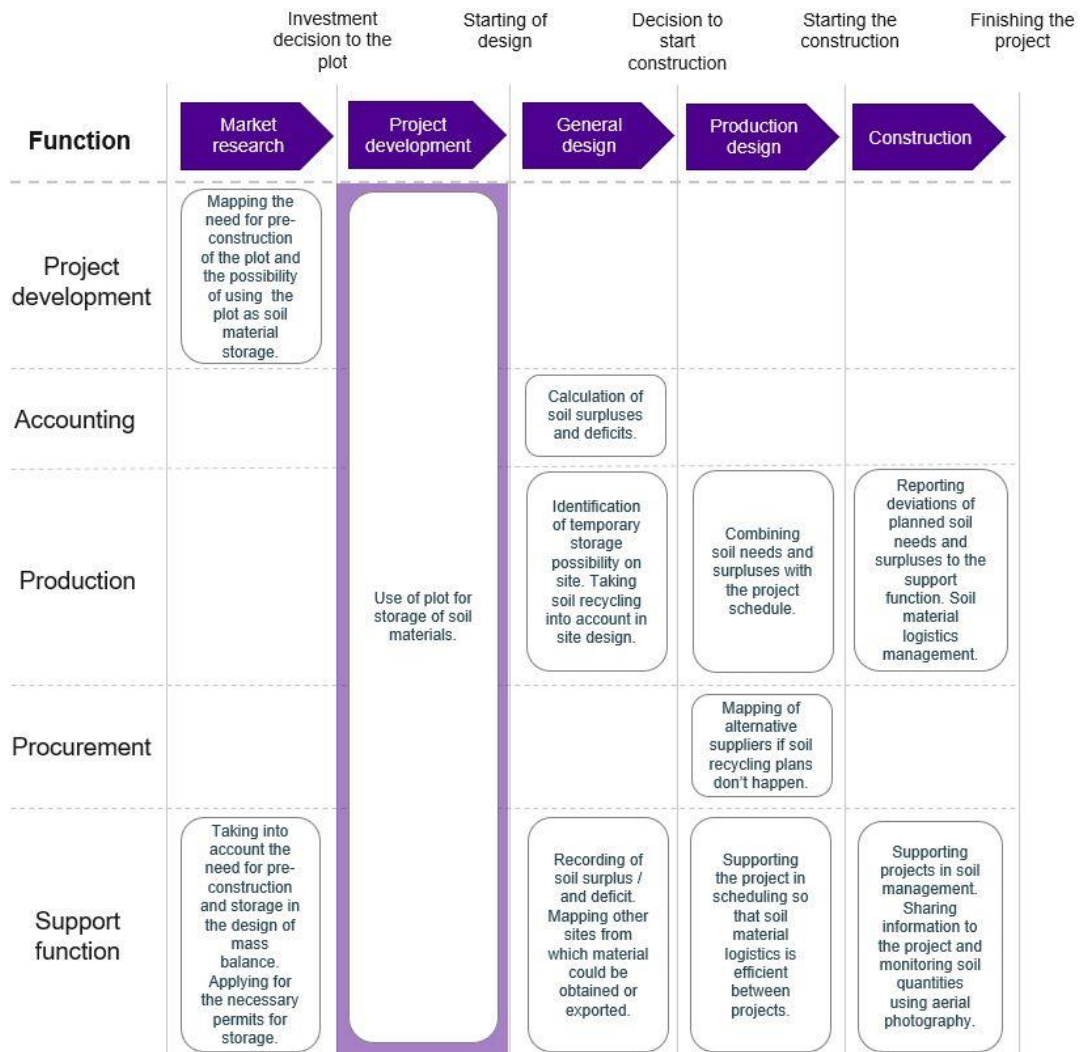


Figure 16 The framework for soil material recycling in self-developed projects.

Before the investment decision to the plot, market research needs to be conducted. In the market research phase, project development function's role would be mapping the needs for pre-construction of the plot and the possibility of using the plot as soil material storage. It would be essential to recognize plots that would be able to use as a soil material storage as early as possible. Then support function could apply for necessary environmental permits for soil storage. Also, the support function task would be considering the need for pre-construction and storage in the design of soil material

moving operations. In the project development phase, when it is considered what is going to be constructed on the plot, the plot would be used as a storage for soil material.

In the general designing phase, the accounting function's task would be to calculate soil surpluses and deficits. In the same phase, production functions task would be to identify temporary storage possibilities on-site and take soil recycling into account in site design. In the general design phase, the support function's task would be to record soil surpluses or deficits and map other sites from which material could be obtained or exported primarily internally but also externally.

In the production design phase, production functions task would be combining soil needs and surpluses with the project schedule. The procurement function's task would be to map alternative suppliers if soil recycling plans do not happen, and support functions task would be supporting the production organization in scheduling so that soil material logistics is efficient between projects.

During the construction phase, production function tasks are the same as in contract-based business, so reporting deviations to plans and managing soil material logistics in cooperation with support function. Also, the support function's tasks are the same as in contract-based business, so they support the project in soil material management and provide information to the project.

6.2.3 Requirements for proposed operations model

Currently, soils are coordinated by project staff at YIT. Based on the interviews, it is necessary to set up a support function for soil coordination. Thus, in the framework I propose, it is recommended for YIT to invest in a soil coordination function, which would be responsible for supporting projects in soil management.

In order to implement the proposed soil management operating model, it is recommended for YIT to develop and implement a soil management information system. The purpose of the system would be to collect information on the needs and surpluses of project soils from the planning stage to the project implementation and maintain the information re real time. In addition, the information system should have a function for the project to report deviations from soil recycling plans and enable material recycling outside of YIT if it is not possible internally. This study does not take a position on the requirements of the required information system in more detail.

In addition to the information system, the proposed operating model requires the systematic utilization of storage areas, which considers legislation. In other words, YIT

must establish an operating model for systematical consideration for environmental permits applications for temporary soil recycling areas.

6.3 Overcoming soil material circular economy challenges

Based on the research and interview, it would be recommended for YIT to move to more coordinated soil management. Without effective management of material flows and logistics, the value capture potential of the circular economy of soils cannot be exploited. Some of the interviewees argued that a function is not needed for soil coordination, but based on the analysis of the results, I say that the function responsible for soil coordination improves significantly value capture potential in soil material circular economy.

The inefficiency of construction logistics has been identified for more than 20 years (Wegelius-Lehtonen, 2000), but this study showed that problems are still commonplace in the construction industry. Also, soil recycling's cost-saving potential has been presented in the literature as early as 30 years ago (Mayer & Stark, 1981). The same issue came up in the interviews when the interviewee D said that this issue had been thought about for at least 20 years and nothing has been done about it yet. This study did not provide an understanding of why the problem is still unsolved, even though it was realized tens of years ago. In the workshop attendant, N presented that the root cause for the issue is that construction companies' organizations are formed in a way that projects are responsible for individual performance. Project staff has been rewarded for personal performance, not for the performance of the entire project portfolio. Workshop participant N thought that this is an essential reason why soil recycling has not been developed in the past, as the staff has not had the will to do so.

Therefore, in order to fully exploit the potential of soil management, the whole organization need to be committed to operation. In order to get the organization committed to the activities, I suggest that a model should be developed, which would share the cost savings from soil recycling to the projects in a transparent way. Interviewee D ja N highlighted that everyone is interested in achieving cost savings for their projects, so the organization should be able to implement activities through the cost savings generated by projects. Workshop attendant N viewed that soil material recycling challenges would not be fixed until projects are not rewarded based on their own results. In his view, this issue has been raised years ago.

When considering how the value of soil material in the circular economy can be utilized, the challenges raised in the interviews must be overcome. The framework presented in

this study will help to overcome every challenge identified in the study. Table 18 presents the soil material circular economy challenges that raised in this study and the solution proposed by the framework presented in this study.

Table 18 Research solution to soil material circulation issues.

Challenge	A solution to the challenge
Lack of information	With the help of the systematic process and the soil management support function, soil information can be collected from the projects, and respectively, soil information can be distributed to the projects.
Lack of soil reusing sites	As a systematic process, all sites that can receive additional soil materials can be identified. In addition, the task of the support function would be to map construction sites outside YIT that could receive additional soil materials.
Incomplete designing	By raising the issue of incomplete design already at the tender calculation stage, incomplete design can be identified and discussed with the client. Thus, the design's possible poor quality will not be clarified during the production of the project.
Quality challenges	The framework does not provide a direct solution to the quality challenges of recyclable soils. However, it would be good for the person working in the soil support function to be aware of the soil quality requirements so that he/she could support projects in recyclable soil quality challenges.
Lack of storage areas	Systematic licensing and utilization of YIT's own plots could significantly increase soil storage capacity.
Cheap price of virgin material	The framework does not provide a solution for the low cost of recycled materials, but through the systematic recycling of soils, it is possible to keep the price of recycled soils competitive.
Long distance to landfill sites	By systematically recycling of soil material, the amount of soil transported to the landfill can be minimized.
Projects schedule synchronizing	When soil recycling planning is incorporated into the project life cycle, a snapshot of soil needs and surpluses at the level of the project portfolio at a given time can be formed. This information would be shared by the support function to the production organization so that they could schedule projects to run synchronously.
Short time span of recycling planning	When soil recycling is taken into account at the market research phase, the recycling planning timeframe is significantly extended.
Slow processing of regulatory approvals	When YIT's own plots are licensed systematically, and as early as possible, the schedule delay caused by the slow permitting procedure can be minimized.

Soil material on-site handling	When the handling of soils is taken into account in the production planning phase, the site can be designed so that there is sufficient space for the handling of the soils.
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The study clearly revealed that pure clay soils, moist clay, and silt soils are disposed of the most in landfill sites. It had been suggested in the literature that ash from energy production could be used to stabilize moist soils. Thanks to stabilization, wetlands could be left in the structure and not have to be disposed of in landfill sites. (Torniainen & Sikiö, 2018) (Tiehallinto, 2007) However, in the workshop attendant P said that stabilizing moist soils with ash is very complicated and expensive. Today it is nearly more profitable to dispose of moist soils to landfill sites than stabilize them with different binders. I suggest that the primary aim is to reuse moist soils in ways other than stabilization. However, technological developments need to be closely monitored, as methods of stabilizing moist soils may become more cost-effective in the future.

Integrating systematic soil coordination into the tendering process is essential. The study revealed that there is significant cost savings potential in soil material coordination. When potential cost savings can be included in the contract price, the probabilities of winning the contract are higher. Systematic soil material coordination can make earthmoving construction more resource-efficient so that the price of construction remains more competitive. In a situation where no investment is made in soil coordination, there is a risk that YIT's competitiveness will weaken due to inefficient soil management if other companies are able to develop their soil material recycling operations.

In order to make the soil material circular economy more efficient, the challenges presented in table 18 need to be clarified and systematic soil material management provides solution to the issue. Based on this research, project personnel are motivated to get involved in improving soil recycling. Also. the challenges of soil recycling have been on the agenda for years, but now the general atmosphere is favorable for development projects that promote sustainable development, so there is potential to find a broader commitment to the issue than before. Based on this research, the operating model is not yet fully implementable in the organization, so I suggest that a person be resourced for further development initially.

6.4 Future development for the YIT

This study identified several areas for further development for YIT. First, there should be investigated what kind of information system should be developed or purchased. It is sure that there will be a huge amount of information, so maintaining it manually in Excel sheets would not be feasible in the long run.

In addition, YIT should consider how the cost savings from soil recycling can be shared equally between projects. On a few occasions, the study found that creating a transparent system for allocating savings to projects is a prerequisite for soil recycling. I suggest that the system should also focus on monitoring other indicators and cost savings, such as reduced quantities of soil landfilled, or tonne-kilometers saved in logistics. Besides, YIT must plan how a new soil reclamation operating model would be implanted in the organization.

Also, the study revealed by the interviewees that the circular economy of other construction materials should also be promoted. For example, it might be useful to sequence how the current state of utilization of concrete crushed at YIT and how its utilization could be developed. Besides, interviewee D arose that it should be developed recycling opportunities for the waste generating from soilcrete construction. Interviewee D said that waste from soilcrete construction is weak concrete in nature. Today the reception fees in landfill sites for soilcrete construction waste are high.

7. CONCLUSION

The pressure to reduce the carbon footprint of construction and increase the circular economy's efficiency has increased in recent years. In its strategy, YIT has shown that it intends to invest especially in the development of responsible construction. Responsibility measures focus in particular on reducing CO₂ emissions. It was identified in the research that soil material recycling is an effective mean to reduce CO₂ emissions.

Significant theoretical findings were made in the study. A significant theoretical finding was that construction should be thought of as a systematic process in which certain tasks are taken into account in every stage of project in order to improve recycling of materials. By combining circular economy planning with efficient logistics planning and operational management, it is possible to achieve an operating model that maximizes soil recycling from project design to execution. Also, a significant theoretical finding was that there are legal limiting factors in the operating environment that requires applying for permits, so an environmental permitting professional must be involved in the soil recycling operations.

In addition to theoretical findings, significant practical findings were made in the study. The most significant pragmatical findings of this research was that there is significant potential to improve company's performance by improving the circular economy of soils. Also, the soil material circular economy can significantly cut down construction emissions, due to reduced use of virgin material transportation distances. Equally, by improving the efficiency of the soil material circular economy, it is possible to achieve cost savings and thus improve the competitiveness of a company's operations. Also, the study found that soil has already been successfully recycled at the project level, but with systematic soil recycling, it is possible to multiply the amount of recyclable soil. An essential finding of the study was that project personnel have a broad interest in the development of soil recycling, so attitude training on the topic is not needed.

Three research questions were defined for this study. The first research question was to define what the current status of soil material circular economy in YIT is. The study revealed that today YIT conducts soil recycling on a case-by-case basis, and there is no standardized operating model for soil recycling. In some of the projects studied in this research, soil materials have been successfully recycled, but there are several challenges associated with soil material recycling. The significant challenges in YIT are lack of information, lack of soil reusing sites, incomplete designing, quality challenges,

and lack of storage areas. The success of soil material recycling is mainly dependent on project personnel because there is no standardized process for soil material recycling.

The second research question was what is possible economic capture potential that can be reclaimed by improving soil material circular economy. This study was unable to provide a clear answer to the economic value capture potential that could be achieved by improving soil materials' circular economy. The research question could not be answered, as most of the projects studied did not have an accurate calculation of soil quantities and their costs so that the estimates obtained were so inaccurate that no conclusions could be drawn from them. Also, there is not any synchronized cost allocation model that researchers could have estimated potential savings. However, two of the projects studied had been used to calculate cost savings from soil reclamation. Two projects that have done allocations of cost generated cost savings that were reached by soil recycling, estimated that the cost-saving was approximately 1-2 percent of the total budgeted costs. It can be assumed that similar cost savings would be obtained in other projects as well. In addition, several interviews revealed that, according to their experience, there is a huge value capture potential in improving soil material recycling. In general, the study found that soil recycling's profitability arises when logistics can be optimized, and landfilling of soil materials can be reduced.

The third research question was, how can YIT organize construction operations in a way that it can reuse relevant surplus soil material at YIT's projects? To this question, the study presented a framework of an operating model that makes soil recycling and its design an integral part of the project life cycle. The framework was able to meet all the challenges of soil management that arise in this study.

Based on the study, two tasks can be identified for the further development of the soil material circular economy. As a first step, I propose that YIT be resourced to a soil coordinator, whose task is initially to act as a developer of the circular economy of soils. His/her task would be to develop soil recycling on the basis of the framework presented in chapter 6.2. According to the research, the lack of soil material and reusing information is a significant challenge for projects, so another task for YIT should be to invest in an information system to manage soil information. In addition, the lack of treatment sites and uses was highlighted as a significant challenge in the study, so the potential soil coordinator should set out to explore the possibilities of acquiring soil recycling and storage areas and develop a process to systematically identifying soil reusing areas. The change towards centralized soil recycling applies to all the organization's projects, so the organization's management must be widely involved in the change if the project is decided to be developed further.

This study expanded the academic literature because the academic literature had not previously studied how a construction firm could develop soil material circular economy between multiple projects. Researches related to soil and rock material recycling has been discussing recycling material within an individual project. This research addressed how recycling between several projects should be organized.

This study provided a new connection to how the circular economy and logistics academic literature relate to each other in enhancing soil recycling. The previously published circular economy academic literature focuses on a higher level on the conceptualization and design of soil recycling operating models. While the logistics literature has taken a more detailed position on the planning of operational logistics of soil recycling. This study found that large-scale development of soil recycling requires both the adoption of a circular economy business model and more efficient and well-planned logistics.

This study corrected the previously presented theory that there is a need for motivational education in the construction industry towards a circular economy. Based on this study, people in the construction industry are highly motivated to develop a circular economy, but the most significant obstacle to development is the lack of operating models and methods.

This study focused only on the development of soil recycling from the perspective of the infrastructure contractor. Potential subjects for further academic research would be to map the views of other actors in the soil material circular economy ecosystem. I would suggest that the challenges of the soil material circular economy and the state of the future should be studied from the perspective of cities, project clients, designers, and authorities. This study found that different actors in the ecosystem may have conflicting views on the development of soil recycling, so it would be justified to conduct research on how the views and interests of different actors in the ecosystem could be aligned.

This study was a single case study from the perspective of a construction company, so the research has left out the viewpoints of other stakeholders involved in soil recycling. The most significant recycling challenges identified by the study could have been very different if construction projects clients and designers had been included in the research. However, this study served as a description of what are the challenges of soil recycling in a large Finnish construction company and how a construction company should organize soil recycling.

This study was carried out in Finland's largest construction company so if the research had been carried out in a smaller construction company, the results identified could have

been different. Also, this study was conducted in Finland, focusing on projects operating in the Helsinki metropolitan area. The study raised Finnish environmental legislation and various permit procedures for soil recycling as a challenge and a limiting factor for the proposed operating model. The results of the study could be significantly different in an area where there are no challenges due to the lack of soil treatment areas or equally as restrictive legislation on soil recycling as Finland has. The results of studies conducted in other countries could differ significantly from the results of this study.

Thus, the challenges of soil recycling rising from the study cannot be generalized globally. However, the cost savings obtained in the circular economy of soils are realized by the same logic in other operating environments, and the framework for organizing the soil material recycling can be utilized in other operating areas and in other construction companies.

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ATTACHMENT A

The interview structure

Soil material sourcing

1. How did you procure the soil for the project? Did you source via procurement function or independently?

Soil material disposing

2. How do you dispose surplus soils to landfill sites?
3. What soil material do you dispose of to landfill sites?
4. How much you have disposed of unpolluted soil material to landfill sites?
5. How do you see that the disposing of usable soil material to landfill could be reduced?

Soil material recycling?

6. Have you recycled soil materials inside the project?
7. Have you recycled soil materials outside of the project?
8. Have you had challenges with authorities in soil material recycling?
9. Do you have had some challenges or issues in soil material recycling?
10. How has soil management been taken into account in the project's tender calculation? Have synergies been sought between the projects?
11. At what stage of the project should soil recycling be considered?
12. How do you see the opportunities / challenges of developing sorting excavation / working methods to improve the sorting and recycling of soils / different types of soil? Or is this already being done enough?
13. Where and how should low-quality soils be / could be utilized? What should be done to them to make recycling more efficient? How much, for example, are the possibilities for utilizing these discussed with the client in advance, or are the solutions left only to the contractor?
14. Have aspects of the recycling of surplus materials emerged in customers' demands or is it a source of competitive advantage?

15. Is the surplus material necessarily always even in its contractors' control, or does it belong to the client?

Soil material recycling organizing

16. Do you feel that the project has enough information related to soil procurement / recycling?
17. Do you feel that project would have needed help from support function?
18. Is there a need to discuss soil recycling with other stakeholders?
19. How was the project soil material logistics managed?
20. Has the project had a need for external storage and handling areas or have its own areas been sufficient?
21. Has the project analyzed the environmental impact of soil recycling?

Soil material recycling lessons learned

22. Which factors did the project succeed in / failed in soil material management and recycling?
23. What are the biggest challenges in soil material recycling and management?
24. What impact has successful soil material management had on the economic performance of the project?

Soil material management in the future

25. How should soil management be organized? Do you feel that an information system would work as a solution to the problem, or do you need more coordinated soil management?
26. How would you like to get information about the available soil materials? (SMS, e-mail, IT system, coordinator)
27. Do you feel that it would be good for YIT to co-operate with other actors (municipalities, cities, other companies) with the recycling of unpolluted soil materials?

Ending the interview

28. Is there anything there you didn't mention?

ATTACHMENT B

Volume questionnaire

1. How much soil has been procured for the project?
2. How much clean usable soil has been disposed of to a landfill?
3. How much clean, poor quality soil has been disposed of in the project that could not have been exploited due to its characteristics?
4. How much unpolluted soil and rock has been successfully recycled within the project?
5. How much unpolluted soil and quarry has been successfully recycled outside the project?
6. How much money have you managed to save by recycling the soil?