Increasing coordination of excavated material between infrastructure projects

Creation of a digital platform for the coordination of excavated material at the Swedish Transport Administration

Master's thesis in the Master's Programme Infrastructure and Environmental Engineering

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ABSTRACT

Efficient management of excavated material is a crucial part of the work towards reaching future climate goals. Through coordination of excavated material between different infrastructure projects, both the cost and environmental impact can be lowered, as well as minimizing the demand for new material. The overall aim of this thesis is to develop a digital platform for the coordination of excavated material between the Swedish Transport Administration's infrastructure projects to achieve an efficient use of resources. Good examples of coordination as well as challenges and opportunities related to coordination have been identified through an interview study and an experience exchange meeting. The insights gained from this served as a foundation for the creation of Mass-Portal, which is a platform based on ArcGIS online. An automatic data entry has been created by the use of FME to minimize manual labor when updating Mass-Portal. This platform works by incorporating all relevant infrastructure projects owned by the Swedish Transport Administration, to be able to find nearby projects to coordinate with. To integrate this platform into the Swedish Transport Administration's organizational structure, several implementation recommendations are provided, along with a suggested methodology for the use of Mass-Portal that involves roles at the Swedish Transport Administration and consultants. Mass-Portal is exclusive to the Swedish Transport Administration but would need to be scaled up and include all relevant actors to achieve its full potential.

Key words: management of excavated material, excavated material, coordination, resource efficiency, Swedish Transport Administration, Mass-Portal, digital tool.

Ökad samordning av schaktmassor mellan infrastrukturprojekt

Skapandet av en digital plattform för samordning av schaktmassor på Trafikverket

Examensarbete inom masterprogrammet infrastruktur och miljöteknik

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SAMMANFATTNING

Effektiv hantering av schaktmassor är en avgörande del i arbetet mot att nå framtida klimatmål. Genom samordning av schaktmassor mellan olika infrastrukturprojekt kan både kostnad och klimatpåverkan minimeras, samt begränsa efterfrågan på jungfruligt material. Det övergripande syftet med detta examensarbete är att utveckla en digital plattform för samordning av överskottsmassor mellan Trafikverkets infrastrukturprojekt för att uppnå en effektiv resurshantering. Genom en intervjustudie och ett erfarenhetsåterföringsmöte har goda exempel på samordning samt utmaningar och möjligheter relaterade till samordning identifierats. Insikterna från detta fungerade som en grund för skapandet av Mass-Portal, som är en AcrGIS online baserad plattform. En automatisk datainmatning har skapats genom programvaran FME för att minimera manuellt arbete vid uppdatering av Mass-Portal. Denna plattform fungerar genom att integrera alla relevanta infrastrukturprojekt inom Trafikverkets verksamhet, för att kunna hitta närliggande projekt att samordna med. För att integrera denna plattform i Trafikverkets organisationsstruktur ges flera implementationsrekommendationer, tillsammans med förslag på metodik för användningen av Mass-Portal, som involverar roller på både Trafikverket och hos konsult. Mass-Portal är exklusivt för Trafikverket men skulle behöva skalas upp och omfatta alla relevanta aktörer för att nå sin fulla potential.

Nyckelord: masshantering, schaktmassor, samordning, resurseffektivitet, Trafikverket, Mass-Portal, digitalt verktyg

Contents

Preface

This thesis was completed at the Department of Architecture and Civil Engineering in the autumn of 2023 and spring of 2024 as the final assignment for a five-year program in civil engineering at Chalmers. The thesis is valued as 60 hp.

We would like to express our deepest gratitude to our supervisor Jenny Norrman and examiner Lars Rosén at Chalmers for guidance throughout this process and valuable inputs to the thesis. We would also like to thank our supervisor Joakim Claesson at the Swedish Transport Administration for initiating this project and for supporting us with knowledge, inputs, and contacts in the industry. Other important people to express our gratitude to are those working with GIS and FME at the Swedish Transport Administration, Svante Tegeland, Zeljko Simunovic, and Mikael Nettby.

Lastly, we want to express our gratitude to the people who pa6rticipated in the interview study, experience exchange meeting, and the evaluation of the platform, for sharing their experience and thoughts regarding coordination of excavated material. Together, we have created a platform for coordination of excavated material which has the potential to improve the resource efficiency of excavated material, contributing to a more sustainable and circular industry.

Robin Andersson and Carolina Borre, Gothenburg, May 2024

Glossary

Actual applied volume *Verklig anbringad volym (va)*	Volume in the placed state, measured according to the actual filled section. The unit is m^3.
Bill of quantity *Mängdförteckning*	Detailed list of the planned construction works, presented with corresponding construction codes from AMA Construction 23, as well as the quantities of material, either as surplus or demand.
Construction contract *Utförandeentreprenad*	Contract that includes construction where the Swedish Transport Administration is responsible for the technical solution.
Construction stage *Byggskede*	The construction stage is the stage of the project where the contractor and sub-contractors execute the construction plan.
Design and build contract *Totalentreprenad*	Contract that includes design and construction where the contractor is responsible for the technical solution.
Design PM mass management *ProjekteringsPM Masshantering*	Design PM mass management is a summary of different subject areas related to planned mass management, e.g., environment, geology, and geotechnics. This document is ordered by TrV.
Design stage *Detaljprojektering*	The design stage, also known as the pre-construction stage, is the stage of a project where comprehensive plans for the structures final design are created.
Environmental properties *Miljöparametrar*	Environmental properties are based on the waste framework directive and guidelines from Swedish EPA.
Excavated material *Schaktmassor*	Excavated material is the quantity of soil and rock that is excavated from its original location.
General material- and work description *Allmän material och arbetsbeskrivning (AMA)*	Swedish reference work used to establish technical descriptions for construction and installation works.
Internal order *Beställning*	Decision on investment at the Swedish Transport Administration.

Investigation stage *Utredningsskede*	In the investigation stage, an analysis is made together with external actors regarding the identified deficiencies and requirements, resulting in suggestions for possible solutions.
Mass handling *Masshantering inom projektet*	Management of material, most commonly soil and rock, within a project.
Mass management *Masshantering*	Management of material, most commonly soil and rock, on a larger scale.
Material demand *Behov av material*	Material demand is the quantity of soil or rock a project need during the construction stage. The quantity is described in *actual applied volume*.
Plan stage *Planskede*	Early design and planning that aims to ensure that the project is well integrated with existing infrastructure and that environmental laws are taken into consideration. Approving of the plan is a legal process.
Planning stage *Planeringsskedet*	During the planning stage, the scope and extent of the project is defined, and viable conditions for the project are secured.
Regulatory authority *Tillsynsmyndighet*	A regulatory authority is a government body tasked with independent control over specific areas of human activity in a licensing and regulating capacity.
Request for proposal (RFP) *Förfrågningsunderlag*	A document that announces a project, describes it, and solicits bids form qualified contractors to complete it.
Road administrator *Väghållare*	The road administrator is the owner of the road and is responsible for its function and maintenance.
Strategic planning stage Strategisk planering	During the strategic planning stage, deficiencies in the transport system, and future needs are identified.
Surplus material *Överskottsmassor*	Surplus material is the quantity of soil and rock which emerges during construction stage and cannot be used within the project. The quantity is described in *undisturbed volume in theory*.
Technical properties *Tekniska parametrar*	Technical properties are based on classifications from AMA construction 23.

Undisturbed volume in theory *Teoretiskt fast volym (tf)*	Volume in the natural state, measured or calculated according to the theoretical section on a drawing. The unit is m^3.
Waste *Avfall*	Waste includes any object, matter, or substance belonging to a specific waste category that the holder disposes of, intends to dispose of, or is required to dispose of. Defined in 15 kap. §1 (SFS 1998:808).
Waste prevention measures *Avfallsförebyggande åtgärder*	These are actions taken before a substance or an object becomes waste, and which aim to reduce the amount of waste, decrease the content of hazardous substances in materials and products, or minimize the negative effects on human health and the environment that substance or object may cause. Defined in 15 kap. §2 (SFS 1998:808).

1 Introduction

The construction of infrastructure is highly resource-intensive, demanding large volumes of construction materials, transportation, and overall logistics. A large aspect of infrastructure construction is material management, where the majority of the materials being handled are excavated soil and rock (Gammelsæter & Larsson, 2023). The construction sector is one of the largest consumers of natural resources, while also contributing to a large part of the global CO_2 emissions. In 2019, the use of aggregates in Europe was 4.2 billion tonnes, or the equivalent of covering the entire surface area of Denmark to a depth of 33 centimeter. This thesis will focus on the management of excavated material and increasing resource efficiency through coordination.

1.1 Background

With a growing consensus on the need to be more resource-efficient, new requirements are continuously being placed on the management of construction materials to reduce the need for new materials and dispose of existing ones (Gammelsæter & Larsson, 2023). A more resource-efficient use of soil and rock leads to reduced climate impact, economic savings, and savings of natural resources. Previous studies indicate that the coordination of excavated material between different infrastructure projects is a crucial factor in increasing resource efficiency, allowing for the use of materials that would have otherwise been disposed of (Eras et al., 2013; Gammelsæter & Larsson, 2023).

Both global and domestic sustainability agendas work towards reduced emissions and more effective use of resources to manage future climate and socioeconomic challenges. The United Nations has 17 sustainable development goals (SDGs) as part of the 2030 agenda for sustainable development (United Nations, 2023). To achieve these goals, certain targets are set for each goal. The United Nations (2023), target 12.2 states: “By 2030, achieve the sustainable management and efficient use of natural resources.”, this applies directly to the management of excavated material.

The Swedish Environmental Protection Agency (Swedish EPA) describes sustainable mass management as:

> “In sustainable management of excavated materials, health- and environmentally suitable materials are circulated expediently. Evaluation of suitability is based on what risks the material poses to human health and the environment in the short- and long-term, based on the content of the material, and the site where the material will be used.
>
> Thereby, circular and resource-efficient management of excavated material is achieved with reduced extraction of geological natural resources, reduced transportation, and emissions of greenhouse gasses, as well as positive conditions for healthy habitats and functioning ecosystems that are not threatened by the occurrence of toxic substances in the environment.”(Swedish EPA, 2022a).

The current waste legislation in Sweden leaves room for interpretation in the context of what is to be considered waste (Magnusson et al., 2022). This results in different practices depending on which local authorities and government agencies are involved in the decision-making process. Which leads to uncertainties for the contractors regarding the use of excavated material, depending on whether or not the material is to be classified as waste. This results in larger volumes being disposed of, and therefore lowering the overall resource efficiency of the projects.

The management of excavated material has since several years back received a larger focus in Swedish infrastructure projects due to its financial impact, environmental consequences, and changed legislation and guidelines (Gammelsæter & Larsson, 2023). Achieving sustainable management of excavated material is complex and requires extensive planning (Swedish EPA, 2023a). The material needs to be evaluated if it is suitable to use within the project or in a nearby project, and if treatment is required to achieve satisfactory environmental and technical properties. It is of utmost importance to not increase the contamination of the soil as it may negatively impact the environment and/or human health. Natural habitats should not be changed to a large extent, as it affects the biodiversity and if needed, compensatory measures should be made.

The Swedish Transport Administration (in Swedish: Trafikverket), hereby referred to as TrV, is one of the largest actors in the construction sector in Sweden, with a yearly turnover of 57 billion SEK(Swedish Transport Administration, 2023). As one of the largest actors, TrV is also one of the biggest producers of construction waste. From a socio-economic point of view, it is important to plan for a sustainable mass management process, since the cost of mass management is often a large part of the total budget for a project. In projects owned by TrV, the majority of the budget is taxpayer-funded, which entails a larger responsibility to ensure that the funds are used wisely.

In 2022, an internal audit regarding TrV’s work with the management of excavated soil and rock was published (Swedish Transport Administration, 2022c). The audit aimed to review if TrV had implemented the legal framework regarding the management of excavated material in their projects, to obtain a practically applicable, efficient, and safe mass management process. One of the main findings of the audit was that coordination of excavated material between different projects and disciplines is necessary to ensure circular and resource-efficient mass management. In the audit, the lack of coordination is classified as a “high risk” observation, meaning that it has considerable consequences and frequently occurs, and should therefore be of priority to solve.

TrV does not currently have a defined process for coordinating excavated material. There is however an ongoing project internally at TrV currently investigating how this process should be structured and implemented (Jansson et al., 2023). The work is based on several interviews and workshops with people at TrV and the results are set to be published in 2024.

1.2 Aim

The overall aim of this thesis is to develop a digital platform (Mass-Portal) for the coordination of excavated material between the Swedish Transport Administration's infrastructure projects to achieve an efficient use of resources.

To reach the overall aim, the following objectives were formulated:

- Investigate existing digital tools for coordination of excavated material.
- Conduct a current situation analysis and identify stakeholder needs.
- Develop Mass-Portal through an iterative process.
- Evaluate how Mass-Portal should be used in different stages of the planning- and design process and how it should be implemented at TrV.

1.3 Scope and limitations

The following scope and limitations are applied to this thesis:

- In this thesis, TrV is defined as the road administrator and therefore carries responsibility for the excavated material. Municipalities are responsible for their own infrastructure projects, but their role in this thesis is that of a local regulatory authority.
- This thesis exclusively deals with soil and rock materials, excluding other materials such as asphalt and concrete.
- Only actors that are directly involved in the design- and decision-making process, i.e., TrV, contractors, consultants, and regulatory authorities are involved in the interview study.
- Only TrV's projects in the western region of Sweden will be included in the platform.
- The implementation strategy will be tailored for projects in the investment operations at TrV, i.e., for projects with a budget between 5 million and 1 billion SEK.
- In this thesis, the quantity of the surplus is defined as undisturbed volume in theory, and the quantity of the demand is described as actual applied volume. The conversion factor between the two volumetric units is material dependent and are left out of the scope of this thesis, but are important to consider.

2 Theory

This chapter will present an in-depth theoretical background on sustainable management of excavated material and existing digital tools for coordination to understand the result and discussion of this report.

2.1 Legislation and guidelines

2.1.1 Legislation and guidelines in EU countries

The Soil Strategy for 2050 was published by the EU Commission in 2023 to reduce the negative impact on the soil (European Commission, 2023). The directive would entail more comprehensive reporting and investigation of Swedish soils if implemented, but also more collaborations between authorities to protect the soils. Sustainable use of soils and management of contaminated sites are some of the main subjects in the directive.

The Waste Framework Directive (WFD) was implemented in 2008 within the European Union (European Commission, 2024c). The purpose of this directive is to define basic concepts and definitions related to waste management. The waste hierarchy was defined in this directive and presents the order of management and disposal of waste, see Figure 1. Illustration of the waste hierarchy from WFD (European Commission, 2024c).Figure 1. According to the waste hierarchy, waste production should be minimized by taking preventive measures, such as utilizing the material as a resource within the project to minimize the amount of surplus material. If there is a production of waste, it should be managed according to the waste hierarchy. If possible, the waste should be prepared for re-use, and if not possible be recycled as a construction material, thereby ceasing to be waste. If the previous steps are not possible, or unsuitable for any reason, the material should be recycled by using it for construction work. Disposal is at the bottom of the waste hierarchy, i.e., transporting the material to a landfill.

Figure 1. Illustration of the waste hierarchy from WFD (European Commission, 2024c).

The order of measures in the waste hierarchy does not always need to be applied, as prioritized measures do not always result in a better outcome (Swedish EPA, 2024). The most important aspect is to protect the environment and human health, which is the basis for choosing the most suitable measure in each case.

There is also a Landfill Directive issued by the European Commission to protect both human health and the environment from different types of contamination from waste (European Commission, 2024b). There are criteria for inert-, non-hazardous- and hazardous waste. Waste in this case is Construction and Demolition waste (CDW), which is a term defined in the Waste Framework directive (European Commission, 2024a). CDW covers a wide range of materials such as concrete, wood, glass, and excavated soil. The fact that soil is classified as CDW has made it problematic as the soil characteristics differ from the other materials, mainly as it is a naturally occurring material (Coussy et al., 2019).

The legal framework of managing excavated soil and rock in other developed countries differs slightly from that in Sweden. Denmark has similar legislation regarding the management of excavated soil and rock, regarding how it is classified as waste upon excavation, but lacks clear criteria for it to seize to be waste (Swedish EPA, 2022a). In Finland, non-contaminated excavated soil and rock can be regarded as non-waste upon excavation, given that the material is used again at the site, or a different site (Swedish EPA, 2022a).

The legislation and guidelines regarding excavated soil in France differ from other EU nations (Hale et al., 2021). If excavated material is considered clean and does not originate from a contaminated site, the soil is defined as a natural material and can therefore be reused outside the excavation site. If the soil is contaminated, however, it falls under the national policy for contaminated sites and may not be reused outside the excavation site. The use of excavated soil for construction purposes usually requires a permit from the environmental authority, even if the material is considered clean. The purpose is to ensure that the environment and human health are not compromised as a result of the planned action. There is however a lack of guidelines on the permit procedure where it is unclear what documents and investigations need to be included, which often results in a reluctance to apply, and instead send the soil to a landfill. Another obstacle that makes reusing excavated material challenging is the responsibility and ownership associated with it. If a contractor uses excavated material at a site, that actor is solely responsible for any future impact of the environment or human health caused by their actions. If they however dispose of the material in a landfill, they also relieve themselves of the responsibility for the material and future implications.

The Soil Quality Decree is a policy in The Netherlands, which was set up to achieve sustainable soil management (Gadella, 2023). According to the decree, soil, and sediment are reusable if there is a useful application, and it complies with reuse standards based upon stand-still and fit-for-use principles, and if there are tolerable risks to humans and ecosystems. An environmental declaration of Soil Quality, also known as a Soil passport, needs to be performed to be able to reuse the soil. A notification of the application needs to be sent to the competent authority. The Netherlands classifies soil using threshold values for different categories. These threshold values dictate what sort of land use is permitted on the premises. The threshold values are divided into three different categories: 1) Background value, 2) Residential value, and 3) Industrial value/Intervention value.

2.1.2 Legislation and guidelines in non-EU countries

Regarding the management of excavated material, England, Wales and Canada follow the same procedure. Contaminated Land: Applications in Real Environments Scheme (CL: AIRE Scheme), is an organization in England that provides guidelines and a Code of Practice for more sustainable remediation and redevelopment of land, based on British legislation (CL:AIRE, 2011). Four factors are defined regarding the use of material as non-waste. 1) Protection of human health and protection of the environment, 2) Suitability of use, without further treatment, 3) Certainty of use, and 4) Quantity of material. A material management plan, a tracking system, and a verification plan need to be produced. The four factors also need to be ensured to be able to proceed with the excavation work where the material is classified as non-waste. One important part of this procedure is that a qualified person needs to be involved to ensure that the contract is adequate. Lastly, a final verification report of the excavation work needs to be handed to the environmental agency and kept for two years.

The British legislation can be applied for three reuse scenarios 1) Site of origin, 2) Direct transfer, and 3) Cluster project. Scenario 1 would entail the use of the material in the same project, either directly or with on-site treatment. Direct transfer reuse implies the direct use of the excavated material at another site, without any treatment and, therefore no contaminated soils can be included. A Cluster project is a more complex arrangement with several sites included. This approach facilitates the remediation and/or development of several sites in the proximity of a decontamination/treatment facility. Canada, Ontario, is using the same system as England and Wales. They have a Code of Practice issued by the Residential and Civil Construction Alliance of Ontario (RCCAO) (2012).

There are two classifications of soil and rock in New South Wales (NSW) in Australia, Virgin Excavated Natural Material (VENM) and Excavated Natural Material (ENM) (NSW EPA, 2014). Materials classified as VENM do not pose any risk for contamination and have not been affected by human activities. Materials classified as ENM are defined as naturally occurring rock and soil that has been excavated, contain at least 98 % (by weight) of natural material and do not meet the definition of VENM. ENM are classified as general solid waste (Transport for NSW, 2022). When ENM is transported to another site, the receiver must legally accept it and can then reuse or reprocess it. Several requirements need to be fulfilled to reuse the material, as defined in the Excavated Natural Material Order 2014 (NSW EPA, 2014). Sampling, both chemical and other material concentrations, test methods, and record-keeping for transportation and reports need to be included. NSW´s target is to reuse 100 % of the ENM produced.

The use of excavated soil in Switzerland is restricted based on the threshold values (Hale et al., 2021). In addition to the threshold values of the excavated soil itself, the content of pollutants of the site where it is to be reused must also be investigated, if reuse is to be possible. The concentration of pollutants in the soil places it in one of three “impact categories”: 1) uncontaminated excavated soil, 2) slightly contaminated soil, and 3) heavily contaminated soil. If the excavated soil is placed in category 1, the soil can be reused freely, whereas soil in category 2 can only be used on-site or nearby, and soil in category 3 cannot be reused at all.

2.1.3 Legislation and Guidelines in Sweden

The Swedish EPA has published guidelines regarding how the waste legislation can be implemented for excavated soil (Swedish EPA, 2023a). These guidelines are based on the Swedish Environmental Code, Miljöbalk (SFS 1998:808), which is the main legal framework for regulating and promoting the sustainable management of waste in Sweden, and defines important waste concepts. An illustration has been produced by the Swedish EPA to clarify these guidelines, presented in Figure 2 below.

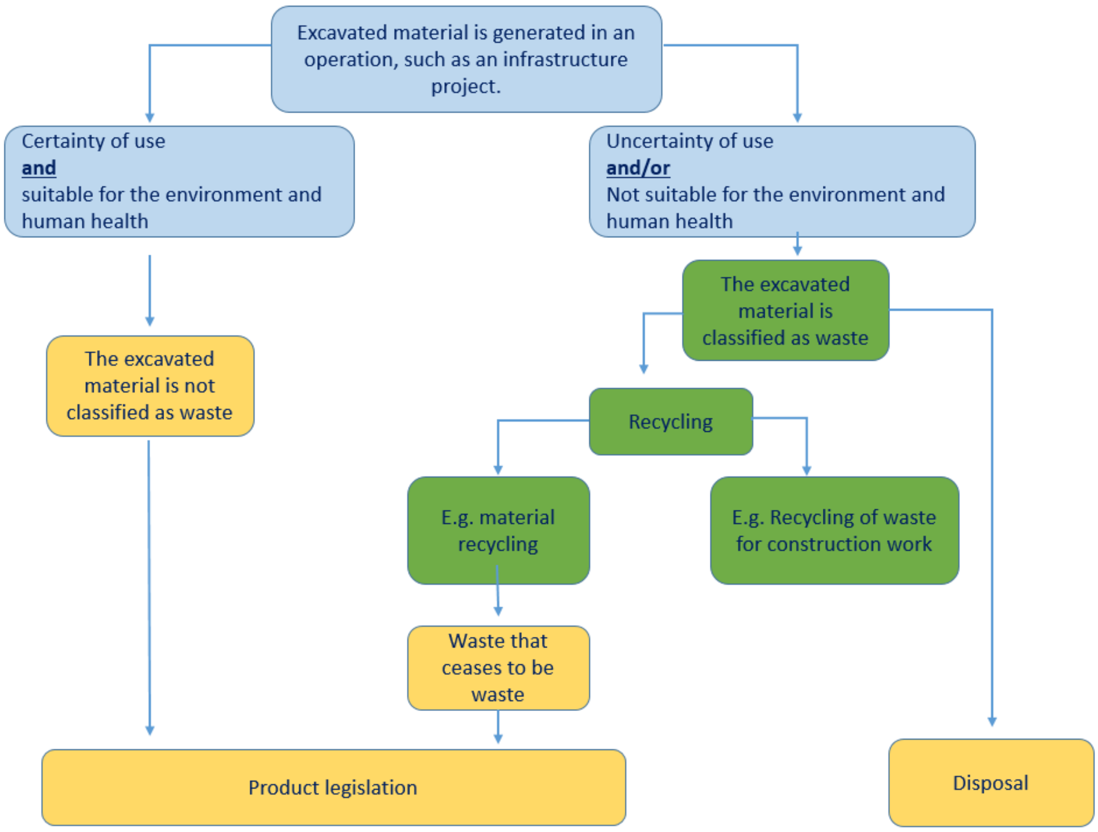

Figure 2. The Swedish EPA's suggestion on how the waste legislation should be interpreted for excavated material (Swedish EPA, 2023a). Translated by the authors.

There are two important factors to consider, according to the Swedish EPA, when evaluating whether the excavated material is to be considered waste or not (Swedish EPA, 2022a). The factors are:

- The material is suitable for the environment and human health.
- There is certainty of use for the material.

Contaminants in the material can be naturally occurring or a result of human activities, and can harm the environment and human health (Swedish EPA, 2022a). To ensure that the excavated material is suitable for the intended purpose, the technical and environmental properties of the material need to be known. There are guidelines from the Swedish EPA regarding how sampling, analysis, evaluation, and documentation should be conducted regarding the investigation of waste (Swedish EPA, 2023b). The owner of the material should be able to prove that the quality of the material is technically and environmentally suitable for the intended purpose at the specific location. The actor receiving the material has the final responsibility regarding whether the material is suitable to use at the defined location or not.

The owner of the excavated material must ensure that the material is suitable to be used in another project within a reasonable timeframe (Swedish EPA, 2022a). This is fulfilled if the technical and environmental quality of the material is such that it can be sold on the current market, the waste producer can prove that there is a demand for the excavated material on the current market, and the timeframe is defined.

There is no need to have a written contract to verify that the material has the certainty of use, as long as the demand is in some way visualized or quantified, such as in a regional plan for the excavated material or similar (Swedish EPA, 2022a).

If the excavated material poses no threat to the environment and human health, as well as having certainty of use, the material is not classified as waste but as a resource, see Figure 2 (Swedish EPA, 2022a). The material can then be used as a product at the defined place according to the Swedish product legislation.

If the excavated material is not suitable for the environment and human health, and/or does not have certainty of use, the material is classified as waste, see Figure 2 (Swedish EPA, 2022a). For waste to cease to be classified as waste, recycling the material or using it for construction purposes are two possibilities to use the material effectively. Recycling usually entails a permit when used in construction purposes. If the other options are not suitable or optional, disposal of the waste in a landfill is required.

2.2 Material properties in Sweden

To be able to reuse excavated soil and rock in a project, the technical properties of the material, and the environmental properties are important aspects to consider (Magnusson et al., 2015). The technical properties include parameters such as particle size, deformation properties, and bearing capacity. Environmental properties refer to the presence of pollutants, both total- and leachate concentrations, and the maximum allowable value for the specific project, which differs depending on location and purpose.

2.2.1 Technical properties of the material according to AMA

General material- and work descriptions (AMA), is a Swedish reference work used to establish technical descriptions for construction and installation works (Svensk Byggtjänst, 2023). There is a specific reference work for construction work called AMA Construction 23, which is used to classify the technical properties of material and descriptions regarding how the execution of the work is to be carried out.

The structure of AMA Construction 23 is based on a system where the important information is presented first, followed by a hierarchical structure with codes and headlines. If it is possible to reuse or recycle material from the excavation in the construction work, the material needs to be classified according to table AMA CE/1. The classes of material types are 1, 2, 3A, 3B, 4A, 4B, 5A, 5B, 6A, and 6B and are presented in Table 1. If the filling material is to be used for areas with vegetation, the classes of material type are 11, 12a, 12b, 13a, 13b, 14a, 14b, and 15 according to table CE/2 in AMA Construction 2023 (Svensk Byggtjänst, 2023). Identical tables, CB/1 and CB/2, are presented for excavation work and contain the same material classifications. This thesis only focuses on the classifications in Table 1, as they are the most commonly used.

Table 1. Classification of different materials, soil, and rock, for construction work. Material type, name of the soil and rock material, content (weight-%), descriptions of the material and frost susceptibility class is presented. Compiled and translated by the authors (Svensk Byggtjänst, 2023).

Material type	Name of soil and rock material	Content (weight - %) X/Y			Example	Frost suscepti-bility class
		Fine 0,063/ 63 mm	Clay 0,002/ 0,063 mm	Organic soil %/63 mm		
1	Rock type A	<10		≤2	Mica-poor granite or gneiss and other hard and strong rocks such as quartzite, dolerite, porphyry and leptite	1
	Rock type B	<10		≤2	Mica-rich granite or gneiss and other rocks with moderate strength and poor wear resistance.	1
2	Boulder and stony soils Coarse-grained soils	≤15		≤2	Boulder, rock, gravel, sand, sandy gravel, gravely sand, gravel till, sand till	1
3A	Rock type C	≤15		≤2	Rocks with high mica levels, clay shale, some coarse-grained granites and some porous sedimentary rocks, very strong transformed rocks	2
3B	Mixed-grain soils	16-30		≤2	Clayey or silty sand, clayey or silty gravel, clayey or silty sandy till, clayey or silty gravel till, clayey or silty till	2
	Rock type D			≤2	Rocks with high mica levels, clay shale, chalk limestone, clay-converted rock, not classified rock material	3
4A	Mixed-grain soils	31-40		≤2	Rocks with high mica levels, clay shale, chalk limestone, clay-converted rock, not classified rock material	3
4B	Fine-grained soils	>40	>40	≤2	Clay, clay till	3
5A	Fine-grained soils	>40	>40	≤2	Silt, muddy silt, silty clay, silt till, silty clay till	4
5B	Mineral soils with organic content			2-6	Muddy clay, muddy silt	4
6A	Organic, mineral soils			6-20	Clayey mud, silty mud, sandy humus soil	3
6B	Organic soils			>20	Mud, peat, humus soil	1

2.2.2 Environmental properties of the material

The environmental quality of excavated material is usually measured by the total content of certain metals and pollutants, as well as the leachability of the material (Swedish EPA, 2022b). The guideline values for the total content exist for risk assessment at contaminated sites, but are often used to classify material for disposal purposes, and when reusing excavated material for construction purposes. Different areas have different thresholds for acceptable contamination levels in the soil, depending on the land use. For example, the soil at a playground should not exceed the soil guideline values for sensitive land use (KM), but the soil at an industrial site could reach levels up to less sensitive land use (MKM). The occurrence of higher levels of pollutants than what is set in the target values does not necessarily mean that it has generated negative consequences, but rather poses a potential threat to human health, the environment, or natural resources. If the contamination level in the soil does not pose any risk for human health or the environment, the material is classified as less than negligible risk (MRR) (Swedish EPA, 2010). This assessment needs to be done for each specific location as the condition varies.

During construction projects, if excavated material is to be used as a resource, the local regulatory authority or the regional regulatory authority, depending on the size and environmental impact of the project, will decide what level of pollutants are allowed in the material according to the law (Swedish EPA, 2022a).

Another way to classify contaminated soil is through leaching tests, to determine the possible threat of spreading contaminants (Elert et al., 2006). These tests are common to classify excavated soil for waste disposal, and construction purposes. The classifications are inert-, non-hazardous- and hazardous waste (European Commission, 2024b).

2.3 Temporary storage for excavated material

If it is not possible to transport the excavated material directly to the other project, temporary storage may be required. These locations can be located within the project area and are then known as area with temporary right of use (Swedish Transport Administration, 2014). The areas must be specified and motivated in the plan process and approved to use the land temporarily during construction. These areas are used to fulfill temporary needs during the construction of the projects, e.g., transshipment points for material and vehicles, or temporary roads for efficient transportation in and out of the projects, and need to be restored at the end of the project.

The location of temporary storage can also be external and be located outside of the project area. In these cases, the regulatory authority has to be notified of the activity and approve of it (Brinkhoff et al., 2020). There are other designations for transshipment locations in Sweden, such as NÖT-area, mass logistic center, and temporary storage space. The definition of a NÖT-area is a Near, Open, and Temporary area, for example close to buildings, open for several projects, and used temporarily as long as there is a need for coordination of excavated material and later on used for other purposes (Lundberg et al., 2017).

It can be challenging to construct large infrastructure in highly urbanized areas as the space for unloading/reloading and storage can be limited (Sobotka & Blajer, 2017). To solve this logistical challenge, it is important to properly plan the management of excavated material in advance and use transshipment areas near the project to improve the possibility of resource utilization. An example of this is the mass logistic center (MLC) Norra Djurgårdsstaden, run by the municipality of Stockholm (City of Stockholm, 2023). It is a logistics center for excavated soil and rock which has been built to store and process material to reuse it in other projects in the future. The facility has a permit to sort material up to 400,000 tonnes at the same time. Up until the year 2019, the material was sorted through a dry sieve which led to a 30 - 40 % recycling rate, but since 2023 the recycling rate is up to 80 % as they have invested in a wet sieve. In the wet sieve are the finest material, under 0,2 mm, removed which contains the majority of the contaminants.

In Helsinki, Finland, a development program for coordination of excavated material has been established and from 2014-2017, eight temporary land mass storage areas were established in urban areas to manage excavated material (City of Helsinki, 2024). To implement these storage places, they were added to the City of Helsinki Master Plan process, where the locations were based on future planned projects in the city.

2.4 Processes at the Swedish Transport Administration

2.4.1 Stages of the process

The different stages of the process, from start to finish, for an infrastructure project at TrV are presented in Figure 3.

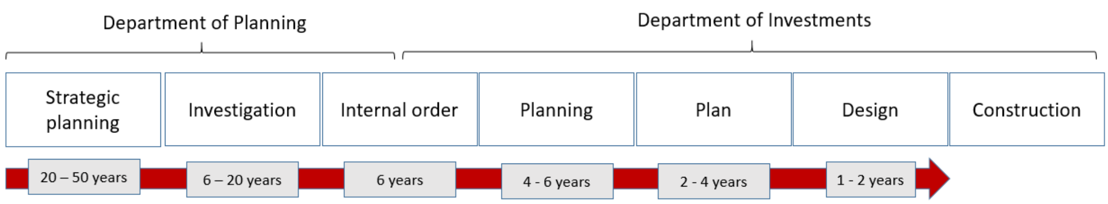

Figure 3. Overview of the process of a project at TrV (Jansson et al., 2023). Translated by the authors.

In the first stage of the process, strategic planning, deficiencies in the transport system, and future needs are identified by the department of Planning at TrV (Jansson et al., 2023). This process is based on analysis and dialogues with external actors, such as municipalities and regional administration boards.

In the second stage, investigation, an analysis is made together with external actors regarding the identified deficiencies and requirements, resulting in suggestions for possible solutions (Jansson et al., 2023). For these solutions to contribute to sustainable development, they must guarantee effective resource management. (Swedish Transport Administration, 2021). This analysis is called an option analysis study and is based on the four-step model which is 1) Rethink, 2) Optimize the existing infrastructure, 3) Renovate, and 4) Build new.

When the options analysis has been conducted, the suggested solution undergoes quality checks regarding time, cost, and content to ensure its feasibility (Swedish Transport Administration, 2022a). If approved, an internal order is then sent by the department of Planning to the department of Investments for projects with a budget ranging from 5 million to 1 billion SEK.

During the planning stage, the scope and extent of the project is defined, and viable conditions for the project are secured (Jansson et al., 2023). It is important to include the management of material in the project definition, as it has a large impact on the overall time, cost, and feasibility.

The plan process is described in the laws (SFS 1971:954) and (SFS 1995:1649), and is established to ensure that the project is well integrated with existing infrastructure and that environmental laws are taken into consideration (Swedish Transport Administration, 2014). The plan for the road or railway must be discussed with relevant stakeholders, e.g., municipalities and affected citizens, to create transparency and allow for feedback. The location and design of the road or railway area are analyzed, described, and ultimately established. The plan process is described in Figure 4.

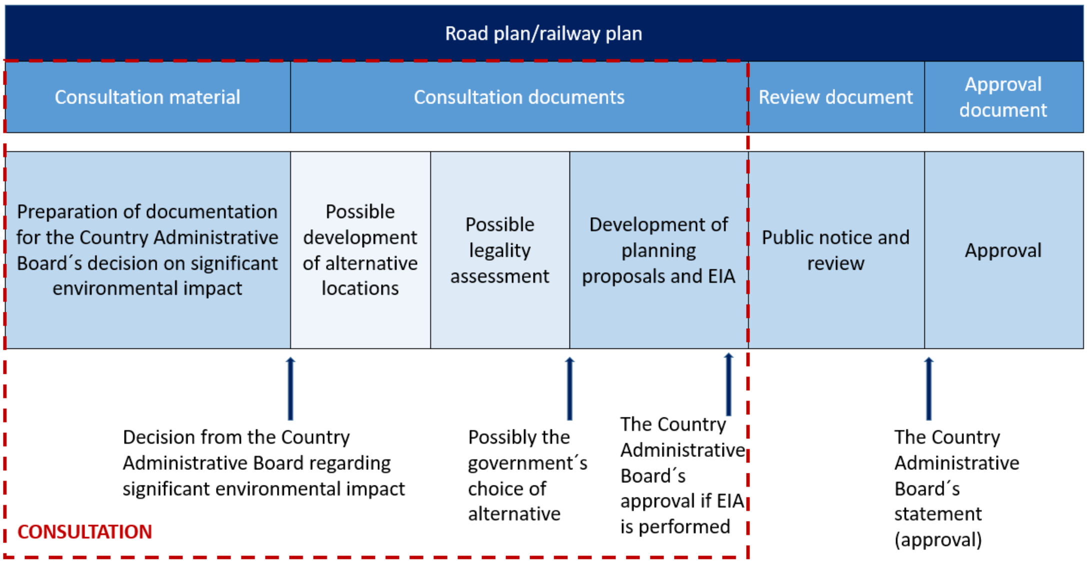

Figure 4. The process for road plan and railway plan at TrV. The illustration is translated from Swedish Transport Administration (2014).

The plan process can vary depending on the size of the project´s impact on the environment (Swedish Transport Administration, 2014). A larger impact on the environment leads to an extended plan process due to more involvement from other actors and decisions taken at a higher level.

The design stage of the project is usually conducted by consultants, producing documents and blueprints, based on investigations and subgrade material handed over to them from the client (Höök, 2008). The material produced by the consultant need to be approved by TrV, before moving forward to the next stage of the project, but the consultant is still responsible for the results from their material, even after the material has been approved by TrV.

The construction stage usually starts when the procurement documents have been approved by TrV, a viable contractor has been sourced, and a contract has been signed (Révai, 2012). This part of the process may differ depending on the contract form, whether it is a construction contract or a design and build contract.

2.4.2 Operational processes at the Swedish Transport Administration

The operational processes that are in place at TrV are to ensure that the organization works interdisciplinary, and not in separate compartments. The processes also exist to ensure that key components are regarded, such as environmental impact and technical solutions. The operational processes relevant to the department of Investments are presented in this chapter and are illustrated in Figure 5.

There are two main processes during the stages from order to construction, which are planning actions on roads and railways (PA) and implementing actions on roads and railways (IA) (Swedish Transport Administration, 2024b). PA and IA span over multiple stages of the process, as seen in Figure 5. The main purpose of the process PA is to coordinate planned actions and to make sure that the information regarding the action is transferred to relevant departments within TrV. Its purpose during these stages is also to evaluate the economic aspect of the project.

The purpose of the process IA is to oversee the implementation of the action to ensure that actions for roads and railways have the correct function and quality and are done accordingly to laws and regulations (Swedish Transport Administration, 2024b). The main process has sub-processes with different focus areas. One sub-process is called environmental assurance, and it covers mass management among other things. In this sub-process are important activities described regarding the subject of environmental assurance.

The different stages of a project also have tollgates (TG) and milestones (MS) that need to be accomplished before moving on to the next stage (Swedish Transport Administration, 2024b). Milestones aim to ensure that critical activities are implemented before a tollgate decision. Tollgates are used to ensure that the project is ready to start the next phase of the work process. The project manager can choose to exclude parts of the checklists for the milestones, if deemed not necessary for the specific project.

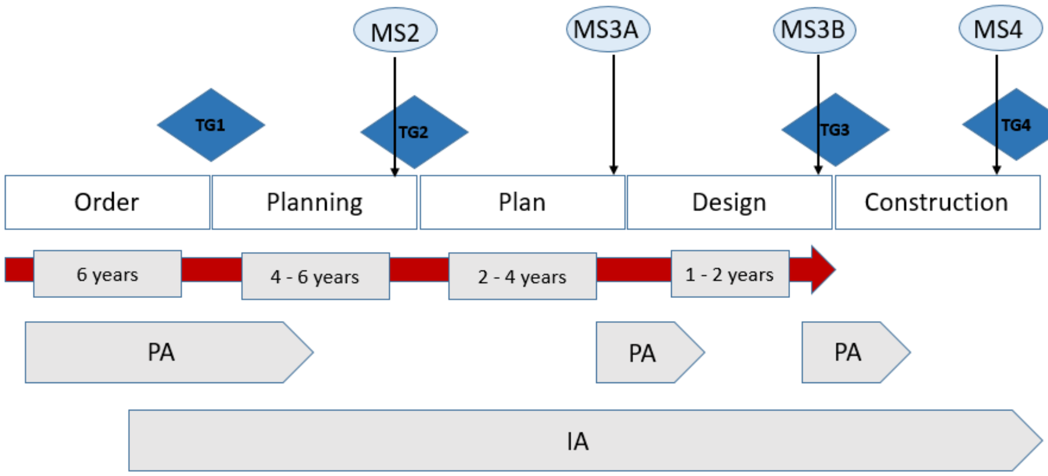

Figure 5 Overview of the operational process from order to construction stage and identified tollgates and milestones during each stage. The illustration is adapted and translated from TrV (2024b).

2.4.3 Different contracts and requirements for mass management

TrV is a government authority and is therefore bound by law to follow the principle of public procurement (The National Agency for Public Procuerement, 2023). Depending on the type of contract, construction, or design and build, the ownership of the material differs and thereby also the responsibility to manage them. To ensure that decisions regarding the management of excavated material are made uniformly and correctly in the organization, TrV has published a report to define how they, as an owner of the excavated soil, should interpret the legislation (Cullhed et al., 2023).

In a construction contract, the contractor get access to the planned mass management when the contract is signed. (The National Agency for Public Procuerement, 2023). The contractor then needs to construct according to the plan, detailed in the construction contract. TrV is then responsible for the excavated material and ensuring that the material is properly managed according to law.

In a design and build contract, the contractor who wins the tender is responsible for planning the management of excavated material in detail for the project and then getting it approved by TrV (The National Agency for Public Procuerement, 2023). The contractor then needs to apply their plan during the construction stage. The contractor is responsible for the excavated material, but TrV still has a responsibility to ensure that the material is properly managed according to law.

When a consulting company is assigned to plan the management of excavated material, they must meet the requirements described in the requirements document, known as Design PM mass management, Projekterings PM masshantering in Swedish (Swedish Transport Administration, 2022b). There are three types of documents depending on the stage of the project and the type of request for proposal (RFP) which depends on the contract form that is assigned:

- plan stage/system act
- RFP for construction contract
- RFP for design and build contract.

The stages of the process where these documents are delivered over from consultants to TrV for each contract type are presented in Figure 6 below.

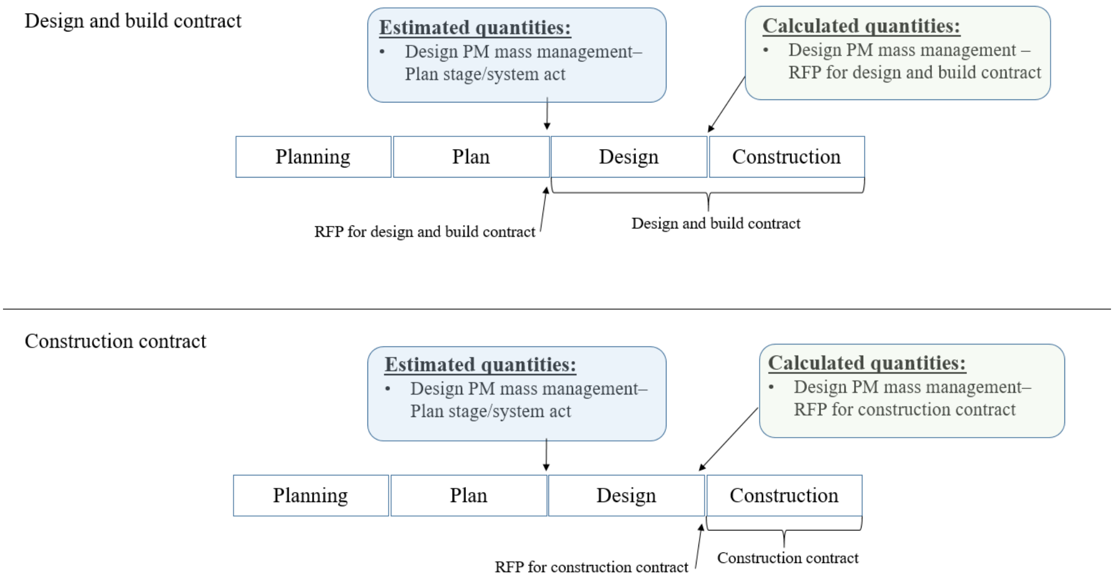

Figure 6. Where in the process Design PM mass management is delivered, depending on the type of contract.

The requirements differ between the different documents, but the largest difference is that Design PM mass management – plan stage/system act is based on estimated quantities. This is because the basis for decisions is inadequate, as there has not been enough sampling. In Design PM mass management – RFP for construction- and design and build contract, the quantity should be calculated as there has been more sampling and therefore more reliable data to base the decision on.

2.5 Digital tools for coordination of excavated materials

There is a wide range of existing digital tools for coordinating excavated material, used in varies stages of the process, spanning from early planning to construction. These tools are often owned and operated by authorities in their respective country, but some examples of privately owned ones exist as well. Some examples of existing, discontinued, or yet-to-be-launched tools are presented in Table 2.

Table 2. Summary of digital tools for coordination of excavated material, the stage of use, the purpose of the tool, and domain.

Digital Tool	Stage	Purpose	Domain
Loop Rocks	Construction	Marketplace for excavated material	Private
Pinpointer	Construction	Facilitate the coordination of excavated material	Private

Optimass	Early planning	Long term planning for the management of material within a larger area (Municipality/Region)	Private
Porfyr	Construction	Marketplace for excavated material	Public
TERASS	Construction	Marketplace for excavated material	Public

Loop Rocks

Loop Rocks was launched in the spring of 2017 and was in use for two years until the owner, NCC, decommissioned the digital tool (Brinkhoff et al., 2020). Projects could through a digital app connect with other projects to share surplus material or receive material. Transportation companies could also register if they could transport the material. When the app was in operation, 18,000 users used the tool and saved around 3.5 million tonnes of material per year. Loop Rocks was mainly used for projects in urban areas and conjunction with larger infrastructure projects. The business was not profitable and it was not possible to bring in capital externally, which lead to its decommission (Siljevall, 2019).

Pinpointer

Pinpointer, a Swedish-owned digital tool, which through its network of projects and facilities can assist projects with the disposal or receiving of excavated material (Pinpointer, 2023). The matching of the sender and the receiver is done automatically through their in-house developed software, and then manually verified. The company has a third part, impartial, environmental consultation to ensure that the material is correctly classified. Pinpointer proceeds from the waste hierarchy when proposing solutions for the projects and is responsible for the affair with both the sender and recipient (Magnusson et al., 2022). The digital tool also offers services as documentation from production and transportation according to the industry standard, for increased traceability and monitoring (Pinpointer, 2023).

Optimass

Another relevant existing digital tool in Sweden is Optimass, used in early-stage analysis to investigate the surplus and demand of soil and rock over time in a larger area, such as for municipal exploitation purposes (Lundberg, 2024). The tool is based on self-produced standard values for the quantity of emerged excavated material for different types of projects. These calculations are then used to suggest where optimal locations of temporary storage should be located to minimize transportation, reduce costs, and use the material effectively.

Porfyr

Porfyr is an upcoming digital marketplace platform for the exchange of excavated soil and rock in Norway (Gulli, 2023). It will be launched in 2024 and will be used nationwide. The platform is owned and managed by a public actor, the municipal of Bearum, to minimize problems connected to privately owned platforms such as competitors refusing to use them. The users of the platform are contractors, developers, recycling facilities, etc. The municipality of Bærum is also planning on providing temporary storage locations for the users of Porfyr, to create opportunities that allow for an easier coordination of excavated material.

When the surplus or demand arises, the user needs to log in to the website and create a listing (Municipal of Bærum, 2024). The user then needs to answer several multiple-choice questions regarding the type of material, quality, quantity (tonnes), and timeframe when the surplus arises or when the project needs the material. Information regarding the location of the material as well as further description of the material is also possible to report. Attachments, such as documents regarding material properties, are possible to include as well.

TERASS

TERASS is a digital tool to exchange excavated soil in France, with tractability functions included (Coussy, 2023). It is free of charge and was launched in 2012 by The French Geological Survey (BRGM), where all actors that plan to have a surplus/demand of material or have a physical surplus can use the platform to plan mass management or to make a deal with another actor. When a deal is made, a traceability document is created and sent to another system (RNDTS) to collect data regarding the excavated soil. BRGM does not provide any temporary storage locations to enable coordination but is instead the exclusive owner and manager of the platform.

3 Method

The method for this thesis is presented in Figure 7. Initially, a literature review was conducted to enhance the understanding of sustainable management and existing digital tools. The insights gained from this review served as a foundation for formulating the research problem, used for the current situation analysis and identification of stakeholder needs. Building upon these findings, Mass-Portal was subsequently developed

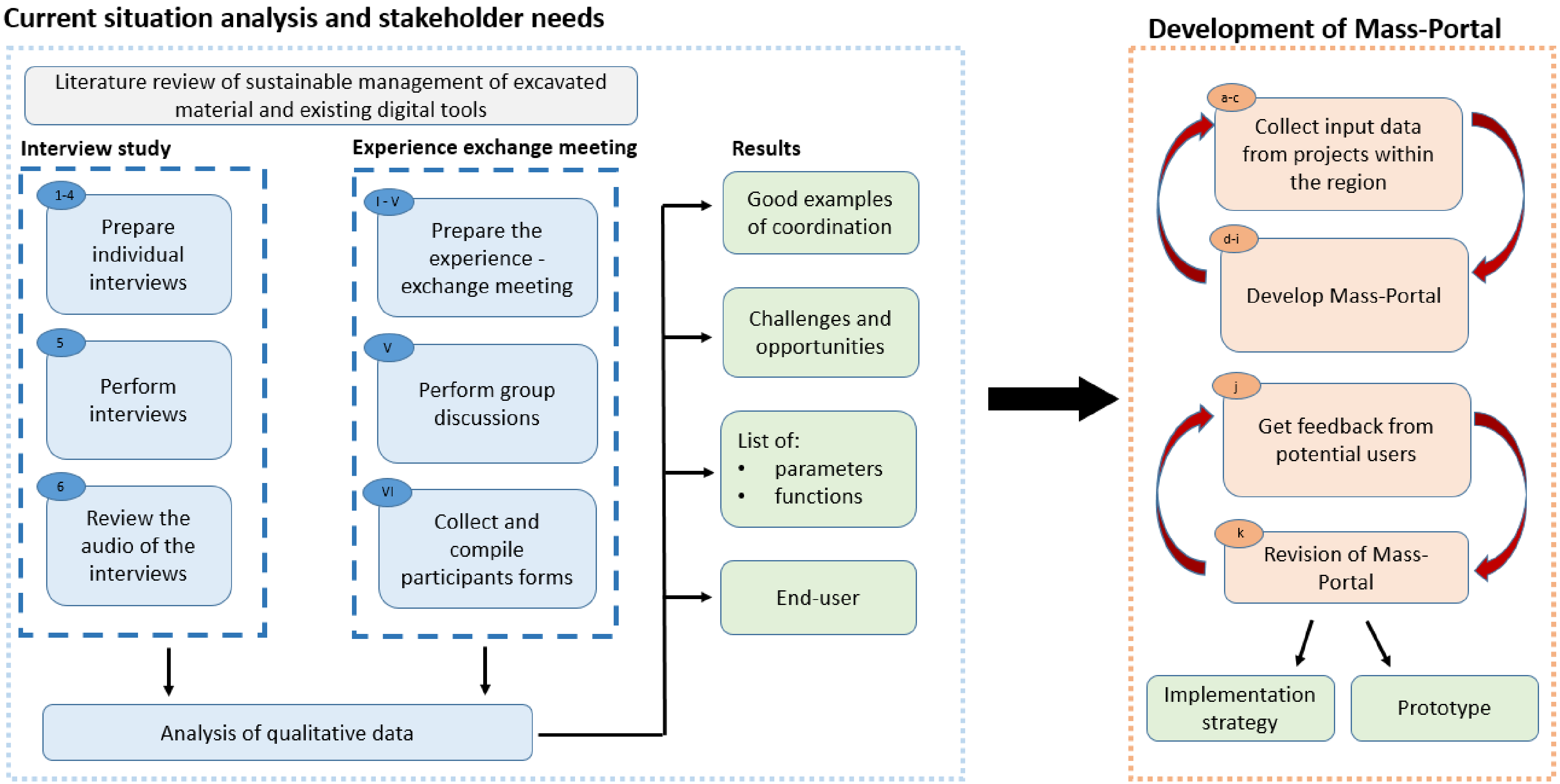

Figure 7. Schematic picture of the methodology for this thesis.

3.1 Current situation analysis and stakeholder needs

Several problem formulations related to the coordination of excavated material needed investigation. This was necessary not only for constructing a user-friendly platform for the coordination of excavated material but also to create a deeper understanding of challenges and opportunities in the field. The following problem formulations were established as a basis for the information collection.

Challenges and opportunities:

- What is essential for a successful coordination of excavated material?
- What are the largest obstacles when coordinating excavated material?

Platform design and contents:

- At which stage in the planning process can the platform be of use?
- Which parameters should be included in the coordination platform?
- What filters and functions should the platform have?

End-user and implementation strategy:

- Who is the end-user of the platform?
- How would the division of responsibility be structured to enable continued use and maintenance of the platform?
- To what extent will external actors get access to the platform?

3.1.1 Individual interviews

The interviews were conducted in a semi-structured manner, where the questions were formulated to create discussions on the topic of coordinating excavated material. The interviews were aimed to map previous experiences in the field to get a clear understanding of what needs to be included in Mass-Portal. The method for performing the interview study is presented below.

1. Interview questions were identified, based on the problem formulations.
2. Actors and specific roles to interview were identified, to get different perspectives. Descriptions of the interviewees are presented in Appendix A.
3. Specific interview questions were formulated for each actor/role. Some questions were general and asked all interviewees and others were more specific questions depending on the role of the interviewee. See Appendix B.
4. Interviewees were contacted, time and date were booked. Interview questions were sent in advance to interviewees.
5. Interviews were performed. The interviewees were asked several interview questions and the interviews were recorded. Notes were taken during the interviews.
6. Interviews were reviewed and notes were expanded. The interviews were not transcribed.

The semi-structured approach is an effective way to gather data in qualitative research, as it allows for in-depth information and evidence, as well as keeping flexibility and adaptability during the interview (Mashuri et al., 2022). The aspect of confirmation bias needs to be considered throughout the interviews since it is easy to find data that supports one's own beliefs and ignore what contradicts them.

An important aspect to consider when conducting an interview study of this magnitude is the anonymity and personal information of the people being interviewed. Individuals included in the study are exclusively referred to by their professional role as well as what type of company/agency they work for. The interviewees were informed of the aim, goals, structure, and purpose of the interview before it began, to ensure transparency during the interview.

3.1.2 Experience exchange meeting

Beyond gathering information from the interview study, results from a large experience exchange meeting for environmental specialists within TrV were also included. The meeting focused on sharing past experiences within the subject of management of excavated soil, with a particular focus on efficient use and coordination of material. The results from the meeting were gathered through a survey, which the participants were asked to fill in. The method for the experience exchange meeting and survey are presented below.

I. Questions and instructions for the meeting were formulated, see Appendix C.
II. A PowerPoint presentation with instructions and questions was created.
III. A survey was created, with the same questions as in the presentation.
IV. The presentation was sent out by e-mail to participants.
V. The experience exchange meeting was held through Skype. Participants got instructions in large groups and were then divided into smaller groups of around 6-8 people with one person leading the discussion.
VI. Participants were given the survey by e-mail after the meeting and were asked to compile their answers and thoughts from the meeting.

3.1.3 Analysis of qualitative data

When analyzing the findings from the interview study, it was important to distinguish between articulated data and attributional data. Participants are likely to limit their conversation to content that exposes them to the least controversy and might therefore avoid important subjects that are uncomfortable to talk about (Massey, 2011). The results focus on articulated data from the participants while attributional data is discussed. The results from the interview study and experience exchange survey were divided into four different categories:

1. Good examples of coordination
2. Challenges and opportunities for coordinating excavated material
3. List of parameters and functions
4. End–user.

Good examples of coordination are based on experiences from the interviewees where the coordination of excavated material was successful, as well as insights from foreign actors and their work with coordination. The challenges and opportunities presented are from a broader perspective with some specific insights and examples, both from within TrV's organization and also from private actors. The list of parameters and functions directly relate to the creation and use of the coordination platform. The result regarding the end-user is focused on which role/actor should be responsible for what part of the usage of Mass-Portal

3.2 Development of Mass-Portal

The following method was applied to create Mass-Portal:

a. Relevant projects were selected to be included in the platform and project data was gathered. Project data was gathered from geotechnical and environmental documents, Design PM mass management and bill of quantities.
b. A table in an Excel sheet with the list of parameters was created.
c. The table was filled in with project information.
d. The attribute list in ArcGIS (a Geographic Information System software) was structured with the relevant format for the data, based on the Excel table.
e. Project data was imported to ArcGIS as a feature layer. The project area was defined by the authors according to publicly available and internal documents.
f. The feature layer was uploaded as a web layer to TrV's ArcGIS online portal.
g. The uploaded feature layer was imported to a web map. Mass-Portal was constructed using WebApp Builder.
h. Filters and functions were added to Mass-Portal in the WebApp Builder.
i. A back-end process in Feature Manipulation Engine (FME) workbench was created to allow for automatic updates in Mass-Portal and a more efficient process when adding new data.
j. People at TrV tested Mass-Portal and evaluated its functions.
k. Mass-Portal was revised.

This resulted in the creation of a prototype of Mass-Portal and an implementation strategy. The result from the current situation analysis and stakeholder needs served as the foundation for the implementation strategy and prototype, which were developed iteratively with suggestions and contributions from the authors.

FME Workbench, which was used for data automation, is a licensed software used to translate data between different formats (Safe Software, 2024). This software, as well as ArcGIS Pro is licensed through TrV and was therefore chosen over other similar software solutions.

While creating Mass-Portal, ethical aspects was considered in the same way as the interview study. These ethical aspects are largely the same as for the interview study, except for the sharing of project-specific data. The data shared on Mass-Portal are based on internal, and publicly available documents, and not classified information. It is intended that the projects themselves upload their data, which would mitigate the risk of sharing unwanted information. Mass-Portal will be based out of TrV servers, which means that it is not cloud based, and therefore not as susceptible to cybersecurity issues.

4 Results from the interview study and experience exchange meeting

In the interview study, a total of 31 people were interviewed, 21 from TrV and 10 from consultancy companies, construction companies, municipal authorities, and foreign actors. The people included in the interview study had diverse backgrounds, ranging from environmental specialists and rock engineers, to project managers and purchasing managers. The specific roles and actors interviewed are presented in Appendix A. The experience exchange meeting consisted of around 100 environmental specialists at TrV, and 46 of the participants responded to the survey. The questions they were asked are presented in Appendix C.

4.1 Good examples of coordination

4.1.1 Cases of successful coordination

The majority of cases mentioned during the interview study and experience exchange meeting related to the contractor and their ability to coordinate excavated material within their operation. Since mass management usually entails a large share of the total cost for a project, contractors can usually use this to their advantage when they have nearby solutions to deal with the excavated material (e.g., other projects, quarries, recycling facilities, etc.). Some examples that arose as well as their key factors for success are presented in Table 3, followed by detailed descriptions of each example.

Table 3. Summary of good examples of coordination. The type of project and key factors to success are presented for each case.

Type of project	Key factors
Highway expansion divided into smaller projects, coordinating material between the different projects.	• Access to temporary storage • Common vision for coordination within the program • The material was accessible when the demand for it arose
Railroad maintenance where surplus excavated material could be used for the construction of a nearby intermodal terminal.	• Extensive sampling and analysis of the material • High disposal costs which led to other options being investigated • Clear and continuous dialog with the environmental authority • Matching timeframe of the two projects
Demolition of a bridge where the concrete could be reused as filling material for the construction of a nearby cut-and-cover tunnel project.	• Close proximity between the projects • Ability to store the material at the site of origin • Suitable quality for the intended purpose • Financially beneficial for both involved projects

Pedestrian- and bicycle path receiving construction material from a nearby railroad construction.	• Positive stance from the local environmental agency • The material did not have to undergo any treatment before use • Relatively small volumes which minimized the logistical complications
Wildlife passage receiving material from a nearby project that had a surplus of excavated rock.	• The same contractor for both projects • Ability to delay one of the projects to match the timeframe of the other one

A project that was mentioned by several project managers and specialists was the expansion of the highway E20 in Västra Götaland county. This was a large project divided into several sub-projects where there had been successful coordination of excavated material amongst them. In this particular case, one of the sub-projects had a surplus of about 250,000 m^3 of rock after construction, which they crushed down to smaller fractions and stored on a temporary surface within the project's borders. The other sub-projects could then go to the site and collect the material they needed.

A railroad maintenance project produced a surplus of highly polluted material (>MKM), and since the disposal cost was high and the distance to the nearest disposal site was long, other solutions were investigated. They discovered that an intermodal terminal was going to be constructed nearby and therefore decided to test the material further and discovered that parts of it were less polluted (KM) than previously thought. Because of this, the material could be used in the construction of the intermodal terminal, which resulted in shorter transportation distances, lower disposal costs, and more resource-effective mass management. The keys to success, in this case, were a clear and continuous dialog with the local environmental authority, that the projects were in the construction stage in the same timeframe, and a willingness to achieve a resource-effective and environmentally friendly management of excavated material.

The demolition of a major bridge (Götaälvbron) in Gothenburg was also brought up during the experience exchange meeting, as well as during a few interviews. The demolition of the bridge resulted in a large amount of crushed concrete. This material could then be used to fill various sections of the West Link project, which is an 8 km railroad project in Gothenburg consisting of mostly cut-and-cover tunnel sections. In this case, the municipality of Gothenburg was the owner of the bridge and TrV is the owner of the West Link project. This collaboration led to considerable savings for both TrV and the municipality, as TrV did not have to buy as much filling material, and the municipality could avoid large costs related to the disposal and transportation of the material.

Several examples of coordination of excavated material were also brought up during the internal experience exchange meeting at TrV. Multiple environmental specialists mentioned a pedestrian- and bike path project that could use excavated material from the construction of a new railroad in their project. This was possible since the railroad project had had a surplus of excavated material that held the required standard for the construction of the pedestrian- and bike path, as well as the local environmental agency having a positive attitude towards the solution.

An example of a case where the contractor managed to coordinate excavated material within their operation was when TrV was building a wildlife passage and the contractor had another project nearby, where there was a surplus of excavated rock. These two projects could then be coordinated in time to construct the wildlife passage using the rock that was excavated in the nearby project.

The examples of successful coordination that was mentioned during the interviews and experience exchange meeting had different conditions and were between different types of projects. However, common key factors can be identified for the majority of the cases.

The common key factors are:

- Close proximity of the projects
- Matching timeframe or access to temporary storage locations
- The material properties of the surplus were fit for the purpose
- Financially beneficial to coordinate material
- The possibility to coordinate material was identified early enough to do the necessary preparatory work

4.1.2 Insights from foreign actors

Interviews were conducted with representatives from both France and Norway to get a more in-depth understanding of how other European countries work with the subject of coordinating excavated material. The interviewee from France was a project manager for contaminated sites and soils from the French Geological Survey (BRGM) and the interviewee from Norway was a project director from Bærum municipality.

Through the interviews, it became apparent that both France and Norway have come a long way with their work with excavated material, with slightly similar strategies. They both have publicly owned marketplaces where excavated material can be reused and recycled in different projects. BRGM has a national platform where all excavated soil and rock (over 500 m^3) needs to be registered, to be able to track the material and make sure that it is handled correctly. Connected to this platform is also a marketplace for the exchange of excavated material, where users can buy and sell from each other, with a certain degree of security since the material has been quality controlled.

Norway was also in the process of implementing a nationwide platform for the reuse of excavated material. Their work originated in Bærum municipality but has since been scaled up to a nationwide level on the order of the government. The key aspect of their success has been the introduction of publicly owned areas to store excavated material for the duration between excavation and reuse. These areas are so far only used for the municipality's projects, but they plan on allowing all actors to use them, given that the material has been quality controlled with regards to the technical and environmental properties.

4.2 Challenges and opportunities for coordinating excavated material

Several notable insights arose during the interviews and the experience exchange meeting related to the management of excavated material, specifically regarding challenges and opportunities from a broad and sector-wide perspective. A summary of challenges and opportunities is presented in Table 4.

Table 4. Summary of challenges and opportunities related to coordination of excavated material.

Challenges	Opportunities
Inadequate knowledge regarding coordination	Reduced cost for the management of excavated material
Lack of formal process or routine for coordination	Reduction in transports, which reduces the costs and environmental impact
Risks/Uncertainties with coordination	Increase resource efficiency on both a project and organizational scale
Risk of dependency between projects, due to delays	Contribute to a circular economy and reaching the climate goals
Unclear waste legislation and guidelines	
Contractual issues with regard to public procurement	

When discussing the coordination of excavated material between projects, the majority of employees at TrV mentioned that they have little to no experience with it and that it rarely occurs within TrV. A project manager within TrV mentioned that this is due to the lack of formal processes and routines for coordinating material, as well as unclear responsibilities regarding who should be in charge of the question in a project. The project manager also mentioned that in their role, they have a lot of requirements to fulfil for each project, which leaves little to no time to work on the coordination of excavated material with other projects, suggesting additional resources in the projects to deal with the question.

On the topic of the feasibility of coordinating excavated material between projects, certain risks and uncertainties were brought up by several interviewees, most notably, the time aspect. If one project were to be delayed for any number of reasons, it would directly affect the other project's time plan. This brings up the issue of dependency between projects, and how to minimize the liability that coordinating excavated material between projects brings. A project manager from TrV mentioned that for the coordination of material to work, it needs to be as easy and reliable as simply ordering material from a quarry.

A few of the interviewees, including a subject supervisor for mass handling at TrV, suggested the inclusion of quarries and landfills in Mass-Portal. This is because even though coordinating material between projects is possible, it might not always be the best solution, both from a financial and environmental perspective. The benefit would have to be assessed on a project-to-project basis, where the distance between projects and quarries/landfills greatly influences the potential benefit. If the distance between the projects is far greater than the distance to the closest quarry, it is most likely more beneficial to get new raw material and dispose of the excavated material.

The subject supervisor for mass management also mentioned that when assessing the benefit of coordinating material between projects, it would have to be viewed from a broader perspective. Instead of measuring the benefit in each particular project, it should be measured as a net benefit for TrV, meaning in a certain case, it might not be beneficial for one of the projects involved, but the overall results would be positive for the organization.

A person within TrV, working mainly with contracts towards contractors and consultants mentioned a potential pitfall related to the Public Procurement Act. Coordinating excavated material between TrV's projects could be considered an "illegal direct procurement" when the work is not advertised and bid on. This is because as a public actor, TrV must do business through public procurement to enable a fair and transparent business model.

During an interview with an environmental officer for a municipality in the vicinity of Gothenburg, it was mentioned that it made little to no difference to them whether TrV classified excavated material as waste or a resource, stating they still would need the same documentation and insurances. The municipality was positive towards the direction in which the industry is heading, with a more sustainable approach towards excavated materials, but mentioned that an increased rate of re-use of excavated material may bring an increased risk to the environment.

Several of the interviewees said that the waste legislation is difficult to interpret and that it often results in different interpretations. This is especially problematic when case officers from the regulatory authority that decides on the reuse of material have different opinions on the matter. This results in material that could be reused as a resource is sent to a landfill, because of how the waste legislation is interpreted in that specific case. However, the coordination of excavated material has not been done to any greater extent and the transition to a more resource-efficient way of thinking in the area may take time. This is why it is important to highlight successful instances of coordination and what the key factors were. The projects need to start working more on the coordination of excavated material and increase the dialog with the local environmental authority.

4.3 List of parameters and functions

All interviewees were asked which parameters they consider important to present when coordinating with excavated material. The majority of interviewees mentioned the same parameters, timeframe, quantity, and quality of the material (environmental and technical). Depending on who the user of the platform is, different parameters might be of varying importance. If the purpose is to communicate with the local regulatory authority to prove suitability for coordination, in-depth lab analysis of the contents of the material might be important. However, a project manager might only want to know that the contamination of the material is below threshold levels and that there is a degree of certainty regarding the timeframe, quantity, and quality. As a result of this, the total content of contaminants for projects in Mass-Portal will be presented according to the following range, MRR-KM, KM-MKM, >MKM. Attachments with test results will be provided for the option of further analysis of the material.

Relevant project information that will enable a first contact is the name of the project and assignment number. It was also mentioned by several project managers that uncertainties or risks should be described in the platform for easier assessment. It could for example be if the project has a political decision ahead which may cause delays. Information regarding when the data was last updated should be included for the end-user to assess how relevant the information is. As a result of these discussions, the most frequently mentioned parameters were selected for inclusion, see Table 5. Additionally, a column labelled “Other” was added to capture important information that did not fit into the predefined categories, such as risk factors.

Table 5. Descriptions of parameters presented in Mass-Portal.

Parameter	Description
Name of the project	Official name of the project
Surplus/Demand	If the quantity is a surplus or a demand
Quantity	Volumetric quantity (m^3)
Material type according to AMA	Material classification according to table (CE/1) in AMA Construction 23
Total content of contaminants	According to the Swedish soil guideline values. Options: MRR-KM, KM-MKM, >MKM
Presence of invasive species	Specify which invasive specie
Start of construction	The date for the planned start of construction
End of construction	The date for when the construction is planned to be finished
Assignment number	Assignment number from TrV
Type of project	Specify if it is a road or railway project. The type of planned action, can be specific or more general
Stage	Options: Planning/Plan/Design
Funding	Regional or National funding
Other	Here can information that is necessary to know be specified, e.g., risk factors, uncertainties or other.
Last updated	Year-month-day

For Mass-Portal to be a viable tool and easy to use, several functions need to be implemented, presented in Table 6. Several interviewees mentioned that it is important to evaluate if it is financially and environmentally justifiable to coordinate excavated material between projects. The difference between the transportation distances to the nearest quarry or disposal site in comparison to a suitable project to coordinate with needs to be evaluated. To be able to assess this, interviewees mentioned that geographical information regarding the location of quarries and disposal sites should be included in Mass-Portal. Other geographical information, such as water protection areas, Natura 2000 areas, road networks, and groundwater reservoirs were also mentioned as being beneficial information to include.

Table 6. Descriptions of the functions in Mass-Portal.

Function:	Description
Filter	Surplus/Demand Material types according to AMA Construction 23 Total content of contaminants Search radius
Background layers	Water protection area Natura 2000 Groundwater reservoir Road network Quarries Disposal sites

4.4 End-user

Through the interviews, it became apparent that all involved actors are in agreement with the transition towards a more resource-efficient mass management process, but also that TrV holds the key to accelerating this process. A few different suggestions of end-users were brought up in the interviews, with the most prevalent being a new central function at TrV, a regional coordinator of excavated material. The main focus for this function would be to coordinate material within a region and use Mass-Portal as a tool in this work. It was also suggested that Mass-Portal would be used as a tool for the consultants during the design phase of projects, to be able to investigate possible use of surplus material in nearby projects.

A project manager within TrV suggested that this proposed new central function would be working with separate funding from the projects, which would allow coordination of material between projects, without any of the specific projects being liable for the cost/risk that would be associated with it. The project manager described the proposed process as projects would upload data regarding surplus and demand of material to the platform. The coordinator would then use this information and Mass-Portal to investigate nearby projects that are suitable receivers for the material and then set up the necessary logistics with transports and temporary storage areas close to the projects. The function of a regional coordinator of excavated material was suggested to be funded using a small percentage of the budget of all projects within each region.

Similar suggestions for a central role/function to coordinate excavated material between projects were also brought up during the experience exchange meeting. It was mentioned that the consultants and contractors lack a general overview of TrV's operations, and therefore, TrV should bear the coordination responsibility. Mass-Portal would be a useful tool to investigate possibilities and initiate contact between projects, but it would need a person or group managing it to allow coordination of material to happen, similar to what the project manager mentioned regarding how the use of Mass-Portal should be configured. Worth noting is that almost everyone interviewed at TrV, as well as the participants in the experience exchange meeting were very adamant that the responsibility of using and updating the platform should not fall on the project managers or specialists involved in the projects, as it would be a too large task to take on.

On the topic of implementation of Mass-Portal, several project managers, specialists, and people working with procurement at TrV mentioned that it would be beneficial to include the use of Mass-Portal in the task description for the consultants. The consultant would then use Mass-Portal to investigate nearby projects to coordinate material between, as well as upload their project data to Mass-Portal. The consultants were asked if they thought this would be feasible to include in their work. Their position was positive, as long as the task description also clearly describe the work needed for Mass-Portal. The consultants also mentioned that they currently have no way of knowing if other nearby projects have a demand or a surplus of material, and that the platform would be a great way of accessing that information.

5 Mass-Portal – A Coordination Platform

Mass-Portal aims to create conditions for coordination of excavated material between projects at TrV, and not to be a market platform for excavated material. Users should be able to evaluate if there are possibilities for coordination between projects and then contact the other project for further discussions and evaluations.

Mass-Portal is constructed using Web App Builder in ArcGIS Pro's online environment. The web app is based on an underlying web map, where all the data is imported and stored. Adding new data to the web app is done by adding it to the underlying database table, which contains the information for all projects, and where the data is then automatically updated in the web app.

5.1 Usage and maintenance of Mass-Portal

Using Mass-Portal does not require any software licenses in ArcGIS Pro, but the user needs to be granted viewer access by the owner of the web app. It is possible to make Mass-Portal available for the entirety of TrV, as well as granting viewer access to consultants in specific projects.

The input data for the projects are imported from an Excel sheet that includes the parameters in Table 5, see Appendix D. The data should be separated based on whether it is a surplus or demand, what type of material it is according to AMA and the total content of contaminants in the material. This results in each row of the attribute table of the layer file for a project containing a single type of material (both material types according to AMA and total content of contaminants) as well as the same purpose (surplus or demand).

Adding a new project or updating the information of an existing one is done through FME Flow, which is a web-based interface to import data and run an underlying FME Workbench script, see Figure 8. The user provides the mentioned Excel sheet as well as any attachments and selects if it is a new project or an existing one. If it is a new project, the user is presented with a map and is asked to draw a polygon representing their project. This geometry is only for visual purposes and it is therefore not crucial for it to be exactly within the project bounds. When the user hits run, the table in the spatial database that Mass-Portal is based on is automatically updated with the new information, thereby updating Mass-Portal.

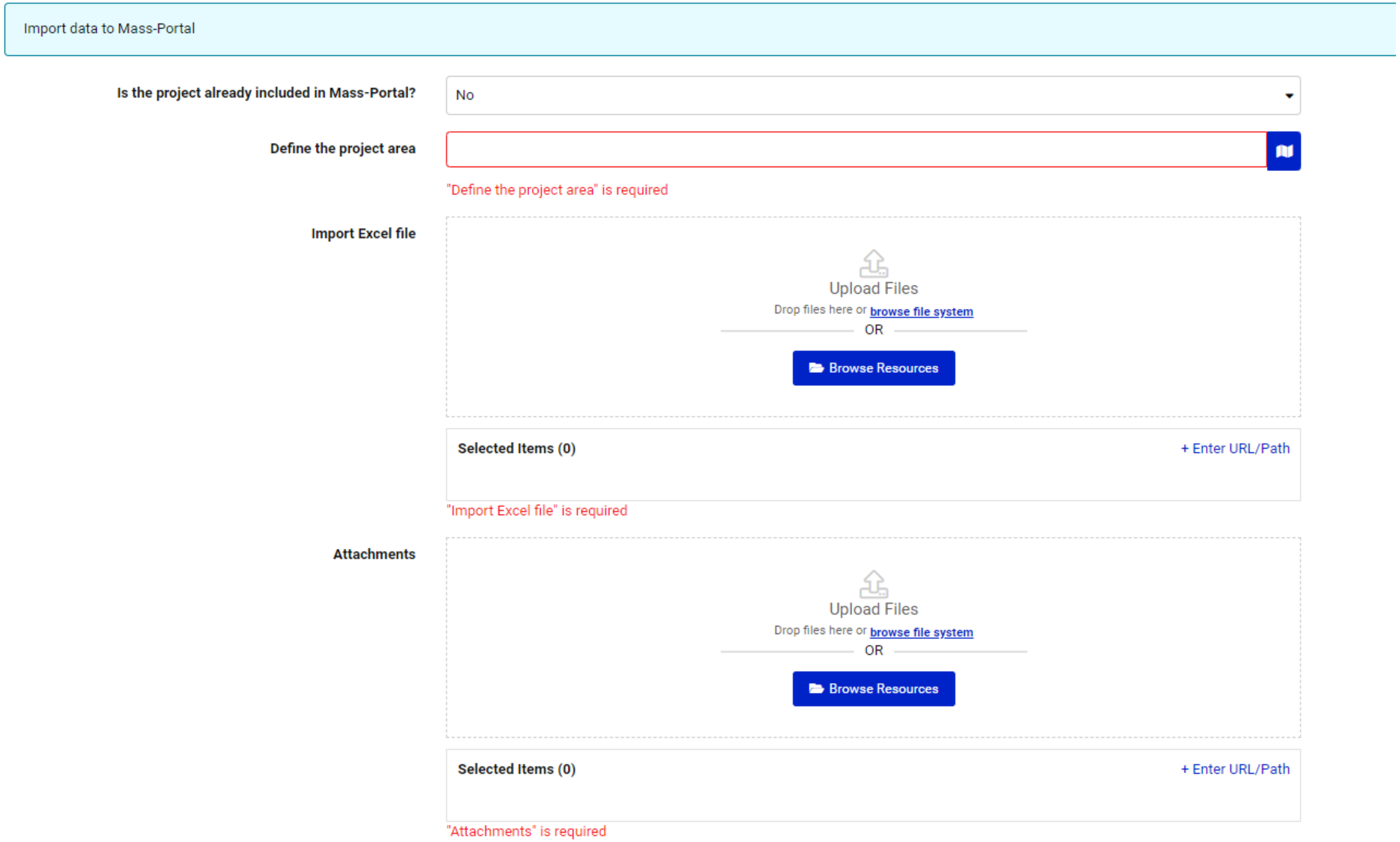

Figure 8. User interface for importing data to Mass-Portal through FME flow. The user can define the project area, import the Excel file and any attachments.

The process of adding new information is based on a script produced in FME Workbench, which has been uploaded to FME Flow, see Appendix E. This script merges an Excel table (the input data table) with a designated table in the spatial database. The script works by deleting the rows in the spatial database table that have the same assignment number as the one in the Excel table and replacing the rows in the spatial database table with the rows from the Excel table. When a new project is added, the assignment number in the Excel table does not exist in the spatial database table, and the script merges the Excel table with the spatial database table and updates it. The ability to provide attachments and draw a polygon in FME Flow is also done through the FME script.

5.2 Functions

Mass-Portal is designed with a simple structure, with the intentions of enabling user-friendliness and ease of use. The information should be easy to read, and the functions intuitively used. The platform was tested by project managers and specialists at TrV, and the purpose was to evaluate how intuitive the use of the platform was, and if the instructions were sufficient enough. After the testing, minor user-interface changes were revised as well as clarifications in the instructions for Mass-Portal.

The functions in Mass-Portal are based on the results that arose from the interview study and presented in Table 6 in chapter 4.3 .

5.2.1 Filters

For the platform to be user-friendly and efficiently used, various filters have been implemented to facilitate the matching of projects. When the user is searching for projects to coordinate with, they have four main filter functions to work with, three are parameter-dependent, and one is location.

The user selects what technical properties (material type) and environmental properties (total content of contaminants) they are interested in, and whether they are in demand or have a surplus of material. Worth noting is that the surplus is presented as undisturbed volume in theory, whereas the demand is presented in actual applied volume. This means that a conversion between the two needs to be performed in order to get the actual quantities to match.

For example, the user has a railroad project that allows for threshold levels of MKM, and needs material with the material type 3A, they would select the material type as 3A, the total content as MRR-KM and KM-MKM, and then search for projects that have a surplus of that type of material. The user can then use the "Near me" tool to select on the map where their project is located and then set the radius of which they are interested in searching. The filter functions are presented in Figure 9 and the search radius in Figure 10.

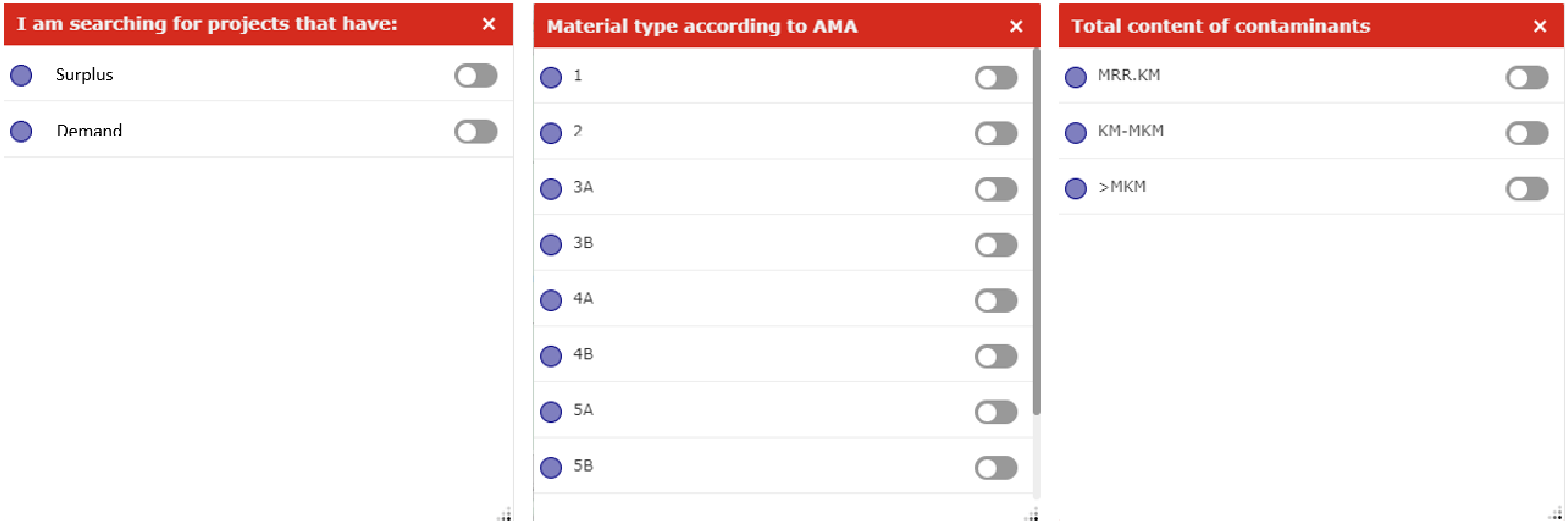

Figure 9. Filter functions within Mass-Portal. The user selects either surplus or demand, as well as technical and environmental properties of the material.

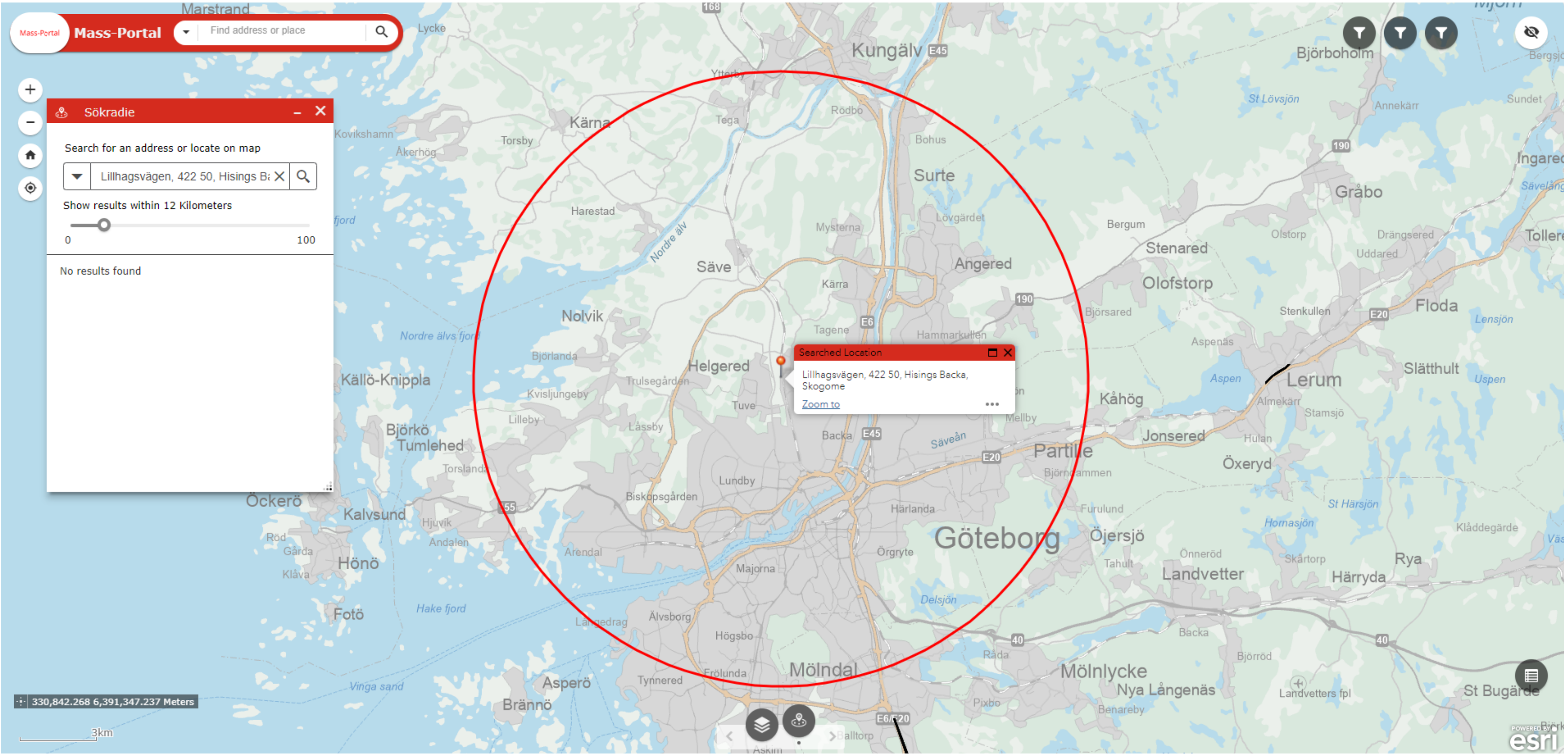

Figure 10. Search radius function within Mass-Portal. The red circle represents the search area defined by the user.

5.2.2 Background layers

Several background layers have been added to the platform to support the assessment of whether or not it is suitable and/or feasible to coordinate excavated material between two projects. Background layers that have been added for assessment of environmental aspects are water protection area, Natura 2000 area, and groundwater reservoirs. These layers can indicate the allowed level of contamination at the site and if more tests need to be done to evaluate the suitability of reusing excavated material.

It is important to assess the distance between the two projects in comparison to buying new material from quarries and disposing the surplus at a disposal site. Background layers with the location of quarries and disposal sites are therefore included in the platform.

5.2.3 Other functions

Mass-Portal is supported by user instructions, as well as a document containing general information regarding the coordination of excavated material. This document describes important aspects that need to be taken into account when coordinating material between projects, and what needs to be done (for example filing a report to the local environmental agency). These documents are in Swedish and are accessible in Mass-Portal through a link in the menu bar.

5.3 Implementation strategy

In the current task description issued by TrV to consultants, a requirement is to tabulate the total quantity of surplus material that is not suitable for reuse within the project. This quantity must then be categorized depending on the possibility of using the material as a resource in another TrV project or not. The surplus needs to be suitable for use in another project concerning technical feasibility and allowed contamination levels at the other location to be able to classify it as a resource. To be able to tabulate this amount, the consultant will need to evaluate if there are any TrV projects nearby that are suitable receivers of the surplus, which would be possible through the use of Mass-Portal. It is also a requirement to tabulate the demand of external material. In this case, Mass-Portal can be used to evaluate the possibility of receiving material from nearby projects. The important information necessary for coordination is already required in Design PM mass management. To get the information needed for Mass-Portal, an Excel sheet with a given structure has been created.

A suggestion is to include a requirement in the document such as “Complete the provided Excel sheet and include it in the delivery of Design PM mass management”. This requirement should be included in all three types of Design PM mass management: Plan/system act, RFP for construction contract, and RFP for design and build contract. The structure of the table is presented in Table 5. As several combinations of material types according to AMA and contamination levels can arise, the table can contain several rows of surplus and demand. The filter functions can be used to sort out the information that is not of interest. The table will be handed over to TrV at the delivery of the consulting assignment and a resource at TrV will then import the data from the Excel sheet to Mass-Portal. To ensure that this step is completed, a task to investigate the feasibility of coordination through Mass-Portal will be added to the following milestones: MS2A. MS3A, and MS3B. It was mentioned during an interview with a project manager at TrV that the project manager of the project is responsible for ensuring that all tasks in the milestones are completed, before moving on to the next stage.

A process for the coordination of excavated material at TrV, with the use of Mass-Portal, has been created with a focus on which actors bears the responsibility for different tasks. There are two slightly different processes depending on the type of contract (construction or design- and build). The process for construction contracts is presented in Figure 11 and for design and build contracts in Figure 12.

Red boxes represent tasks to be performed by people at TrV and grey boxes represent tasks performed by consultants. The processes contain the same steps, but the declaration of intent or orientation decision is placed in the plan process for the design and build contract instead of in the design stage as it is for the construction contract. The process has been designed this way, as several interviewees mentioned that it is important to include information regarding the coordination of excavated material between projects in the RFP. This is for the contractors to be able to count on the scenario and not have unexpected changes during construction.

An important aspect of the process is that as the consultant’s work continues, they are asked to have a continuous dialog with TrV. During these regular meetings, the potential coordination with other projects should be brought forward and discussed between the consultants and TrV. The resource at TrV should be responsible for the contact with another project as the consultant does not have the same ability to contact relevant people within TrV, as someone at TrV. The resource at Trv can be a project manager, a specialist within mass management, or a coordinator of excavated material. The result from the discussions should be presented in the Design PM mass management as well as including the Excel sheet in the delivery of the document for each stage.

The timeline of a project can change during the different stages due to e.g., political decisions, appeals, or funding. The decision to coordinate material between projects therefore needs to be made by TrV during the design phase, as the risk and uncertainties are minimized. It has been clear during the interview study that it is of great importance to start the planning of coordinating excavated material in the early stages of the project. It is not common for two projects to have the same schedule and a just-in-time solution is therefore difficult to coordinate. Temporary storage locations or temporary use of land needs to be investigated in the early stages as it requires a registration or permit. To spend resources and money on costly investigations and planning for the coordination of excavated material, beneficial conditions need to be identified early on, in which Mass-Portal will assist.

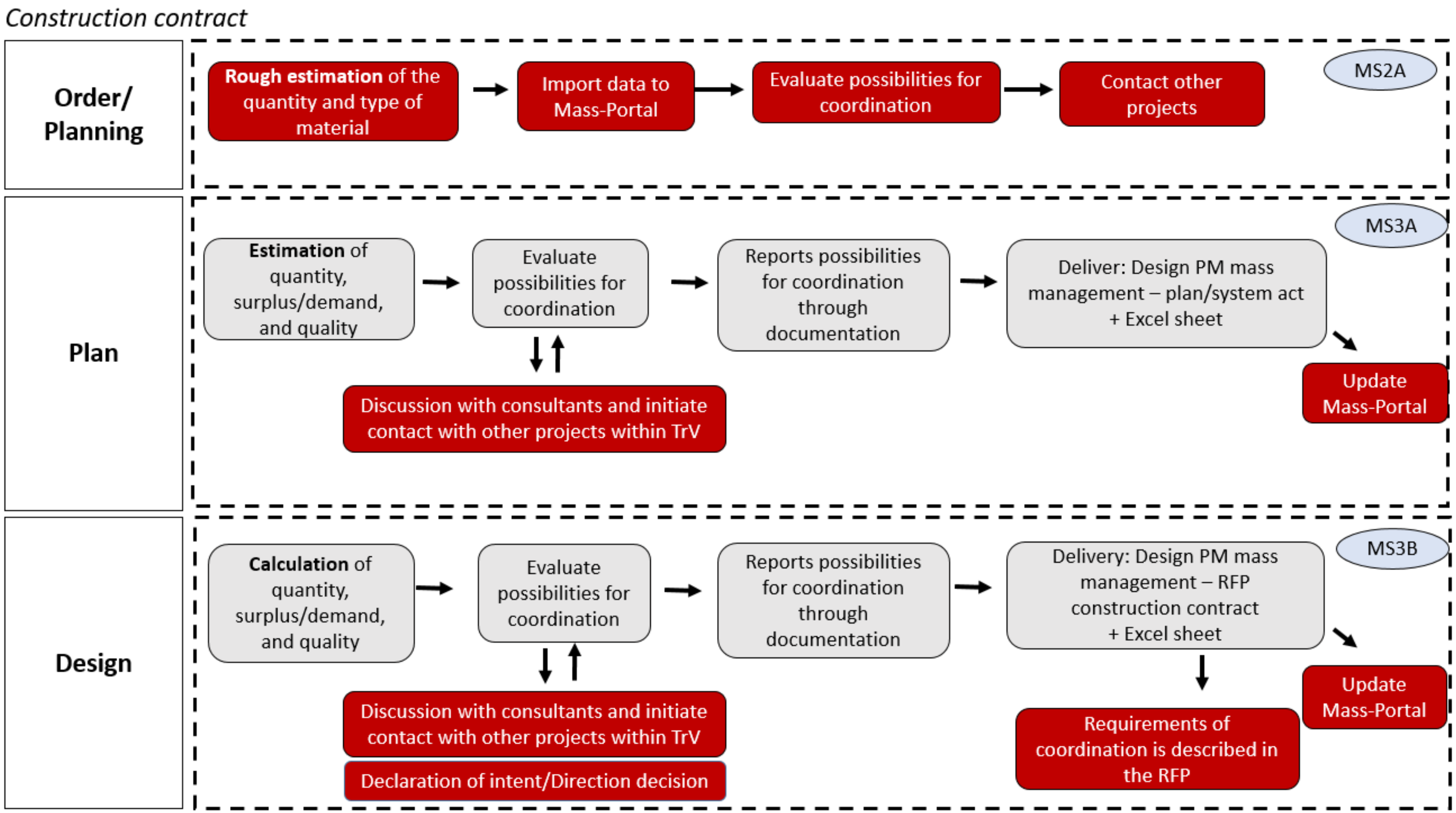

Figure 11. Methodology for coordination of excavated material for construction contract. Red boxes represent the tasks that will be conducted by TrV and grey boxes represent the tasks for the consultant.

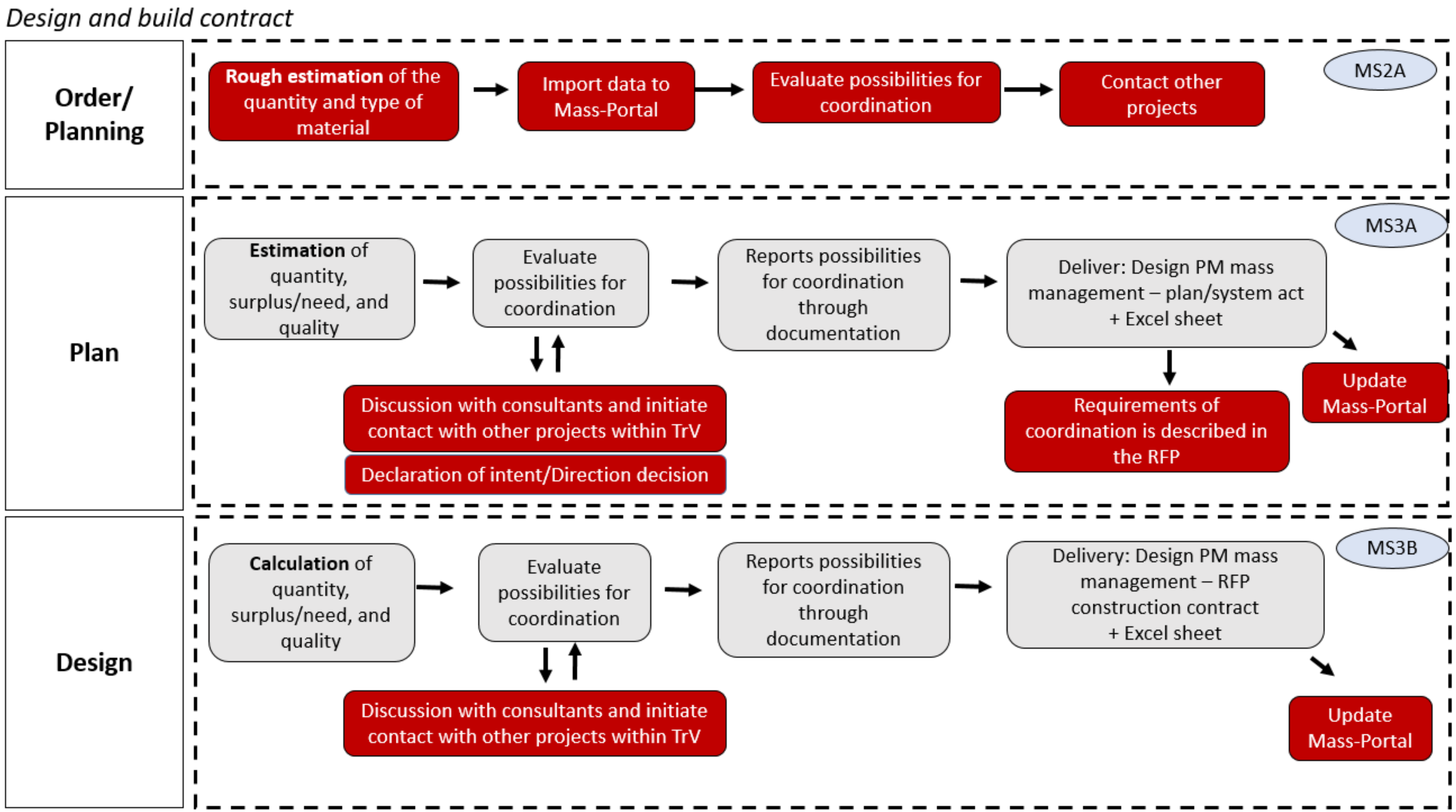

Figure 12. Methodology for coordination of excavated material for design and build contract. Red boxes represent the tasks that will be conducted by TrV and grey boxes represent the tasks for the consultant.

6 Discussion

The results from any interview study reflects the views of the participants. In this thesis, the majority of participants in the interview study were employees at TrV, with only about one third of participants representing external actors. This is worth noting when analysing the results as it greatly influences what conclusions can be drawn. There were also a few relevant roles that was not included in the interview study, such as geotechnical engineers and site managers. These roles were not deliberately left out of the study, but not included due to time restraint and difficulties finding relevant contacts. The views of environmental specialists at TrV may also be overrepresented as they were the exclusive participants of the experience exchange meeting.

If the interview study was structured in a different manner, for example by mainly focusing on the contractor or consultants' point of view, the results may be different. A majority of views and opinions expressed by external actors in this interview study does however align with that of employees at TrV. The sample size of external actors is however quite small, and may not be sufficient enough to draw clear conclusions on a sector wide scale. It is however sufficient to draw conclusions from the perspective of TrV.

6.1 Enhancing user experience for Mass-Portal

There were varied opinions regarding the extent of information and the number of attachments that should be included for the projects in Mass-Portal. Some interviewees advocated for comprehensive extraction of information from the documents to Mass-Portal, including all details related to the excavated material. Other interviewees preferred the most important information, focusing on essential parameters such as surplus/demand, quantity, and quality of the material.

One parameter that was frequently mentioned during the interviews but excluded from the final table structure was the name of the project manager. This decision was based on the frequent turnover of project managers at TrV, which makes it challenging to obtain reliable information in Mass-Portal. The inclusion of the project manager's name was intended to facilitate project contact and collaboration. However, given that the assignment number is already included as a parameter, users can easily access updated project information, including the current project manager and project status, through the project portal at TrV. The assignment number plays a crucial role in data automation and needs to be included in the table. It was therefore decided that the name of the project manager was unnecessary.

The interviewees were asked if they had a preference for any specific unit for the measurement of quantities. Quarries and disposal sites commonly use tonnes as units when receiving excavated material, while for projects, the calculated values are often described with volumetric units. Weight units are relevant when transporting the material between projects. Clear and uniform conversion factors are necessary for all parties involved in these processes, but are often lacking. Given the lack of consistent conversion factors, the decision was made to use a volumetric unit for quantifying the surplus and demand. Specifically, the quantity of the surplus is defined as undisturbed volume in theory, and the quantity of the demand is described as the actual applied volume.

One of the main findings from the interview study was that almost everyone interviewed at TrV was very adamant that the responsibility for using and updating Mass-Portal should not fall on the project manager or specialist involved in the project. The knowledge of ArcGIS and FME may not be as profound in these roles, which would make it difficult to ensure an updated platform. With this in mind, an automatic data entry system was created to minimize manual labour. The user who wants to update the platform does not need to have knowledge of ArcGIS or FME to update the platform. Instead, a user-friendly interface was created with clear instructions on which data to import. If there are any problems with the script or FME flow application, TrV has in-house personnel who work with FME and ArcGIS and can potentially provide support if problems arise.

It was initially not clear what type of program to use when automating the data entry. The decision to use FME was based on recommendations from people at TrV working in the field of data automation, as well as it already being a licensed software at TrV.

For future development of the FME script, it is possible to achieve full automation, where the Excel sheet is directly imported from the delivery system at TrV and the data is uploaded to Mass-Portal. Project documents are currently delivered to a system where each document is assigned a specific code and placed within a folder structure. Implementing code to automatically import new information from this location instead of requiring manual import into the FME flow application, could further reduce the amount of manual labour. This should however be done with caution, as faulty information would have a much wider reach if this system is put in place, as it would not require any human verification. Other projects that use the platform would have access to the faulty information and proceed with their coordination work based on it. It is therefore important with continuous dialogs with involved parties to avoid it.

6.2 Establishing coordination structure

The result from the interview study showed that there is no elaborated process for the coordination of excavated material currently implemented at TrV. It was unclear which part of the organization should be responsible for driving the work forward, as well as who should be responsible for the maintenance of Mass-Portal. These challenges need to be addressed to be able to coordinate excavated material on a larger scale.

As there was no established process within TrV at the start of the Master's thesis project, one had to be created, detailed in Figure 11 and Figure 12. During the thesis work, an internal process at TrV for coordinating excavated material was however published. This process outlines important activities for coordination related to various processes within TrV. It is based on interviews conducted with people working at TrV. Given that the majority of the interviewees in this thesis were from TrV, it is not surprising that the two processes align with each other.

One distinguishing factor is that the coordination process published by TrV begins at an earlier strategic stage of the process, with only estimations and very limited information (Jansson et al., 2023). This suggestion was discussed in the scope of this thesis, but was deemed too burdensome compared to the benefits it provided. Due to the large uncertainties in the early stages, some projects may not even be initiated due to various reasons. Apart from that difference, the processes align with each other and have identified the same important factors for achieving coordination of excavated material. Once the order is placed, an evaluation regarding the geographical location and time of construction for the two projects can be conducted to determine if coordination is feasible (Jansson et al., 2023). If there is information about surplus or demand, the project can include it in the project information on the platform. Later in the process, parameters such as surplus/demand, quantity, and quality must be reported.

The involvement of a mass management coordinator is recommended in both processes. The result from this Master's thesis indicates that a key factor to coordinate material is early involvement. Therefore, it is beneficial if this individual or role is engaged as early as possible after the internal order, to remind the project of important factors to consider during the planning, such as temporary storage locations or application for temporary use of area in road or railway plans.

Knowledge in the area of coordination of excavated material is limited due to the scarcity of case studies. To initiate the coordination process without an established process or support function like a mass management coordinator, a document will be included in Mass-Portal for users to read and obtain suggestions on important factors for successful coordination. The information and tips in the support document are gathered from the results and insights of the interview study. This document can be updated as more and more projects coordinate material and gather insights and experiences on the subject of coordination.

6.2.1 Digital tool for the planning and design stage

Based on the other digital tools focused on coordinating excavated material, both currently available and discontinued, there is a clear gap in the planning and design stages of projects. The existing tools that predominantly focus on available excavated material all have a marketplace structure in place on their platforms. These include buyer/seller contracts, pricing and delivery structures, etc. This type of structure has purposely been left out of Mass-Portal, as it is not to be seen as a marketplace for material, but rather a tool for the planning and design stage of a project.

The parameters in Mass-Portal that describe the material, such as technical and environmental properties, are similar to those of other digital tools. Since there are legal obligations to not spread contaminants, the environmental properties of the material are always important. The suitability of the material for the planned purpose also needs to be ensured, therefore the technical parameters of the material are also essential.

What mainly separates Mass-Portal from the other digital tools is the usage of the platform. As it is designed to be used during the planning stages of a project, it cannot be substituted by any of the other currently available digital tools. Mass-Portal is however limited to TrV and can be seen as an internal tool for the organization. This also means that it is not in direct competition with any of the other digital tools identified in this thesis.

There is currently no traceability function for the material incorporated in Mass-Portal. This might not be a top priority if the platform is only to be used internally at TrV, but if it is scaled up to include other actors, there would have to be some way to verify where the material is going, and that it is handled correctly. This could potentially be solved by incorporating the software called ELSA, which works with digital documentation for transports of excavated material (Swedish Transport Administration, 2024a). This would not change how Mass-Portal is supposed to be used, but rather add more complete functions to it by allowing users to see what material was coordinated and between which projects.

Additional functions could be added to Mass-Portal, such as calculating the environmental and financial benefit of coordinating material between two or more projects. This could be done by comparing the transport distance between the projects and the closest quarry and disposal site, as well as incorporating the cost of buying new material and disposing of the excavated material. By using default values for the transport and disposal cost, as well as the cost of new material, a rough estimate could be made which would indicate the potential financial benefit of coordination. The same thing could be done with transport-related emissions. It is currently possible to do this calculation manually, but an incorporated function in Mass-Portal would save both time and resources. This has purposely been left out of Mass-Portal as there is no clear way of adding this type of function in an ArcGIS Web App, and would most likely entail substantial coding.

The information in Mass-Portal also allows for a visualization of the regional mass balance over time, within TrV. This is done by compiling the surplus and demand for all the projects included in Mass-Portal. By presenting the data in this way, TrV can get a better understanding of the regional flow of material and how it is impacted over time by their projects. This may also allow for a clearer and more transparent dialog with the municipalities in the areas that are impacted by TrV's projects. As of today, there is currently no data regarding the regional mass balance within TrV's organization, which in turn leads to difficulties in assessing the accuracy of the data in the platform. Since the projects that are included are all in different stages and have different degrees of uncertainties in their information, it is hard to put a number on the overall certainty of the regional mass balance. However, as the data becomes more accurate in the latter stages of the projects, the data that is closest in time to the regional mass balance can be assumed to be the most certain.

6.2.2 Inclusion of coordination in Milestones

To ensure that investigations regarding the possibility of coordinating excavated material are conducted using Mass-Portal, it is suggested that a requirement should be implemented in the checklist for three milestones (MS2A, MS3A, MS3B). Several alternatives to milestones were investigated, as no requirements existed initially and coordination was based on internal initiatives. While pursuing initiatives independently could serve as an alternative to milestones, it requires significant knowledge and interest in the subject. However, without a requirement, as this type of investigation leads to increased administrative tasks, there is a possibility for this subject to be deprioritized.

The addition of a requirement to the milestone checklist carries both positive and negative aspects. It can increase the understanding and potential of coordination, create standardization, and increase process predictability. Implementing the requirement through three different stages ensures that changes in conditions during the different stages do not affect the feasibility of coordination. However, a requirement entails increased administrative work and subsequently higher costs. Nevertheless, coordination of excavated material should be seen as an investment when initiated in the early stages, as it can save money in the construction stage and preserve environmental resources. It can also be challenging to implement a requirement and expect all involved parties to fully comprehend the subject. It is therefore important for Mass-Portal to be user-friendly and informative for new users. It would also be beneficial to educate and inform regarding how the platform should be used and the importance of resource efficiency in infrastructure projects. As more projects coordinates excavated material, it is important to highlight and make easily accessible examples of successful cases of coordination.

Other operational processes investigated included tollgates and the implementation in the PA and IA process. The goal of tollgates, which are based on reached milestones, is to finish one stage and begin another. Since the focus of a tollgate is crucial orientational decisions rather than particular documents and subjects, it is not deemed appropriate to use tollgates. The likelihood of missing a milestone is reduced since project managers regularly use and are familiar with the milestone checklist. The processes PA and IA are not seen as appropriate processes to include coordination requirements. These processes include more general requirements and advice for mass management instead of more specific requirements, which is possible to include in the checklist for each milestone.

Certain projects might not even need to consider coordination because of a variety of circumstances, such as limited quantities of material, particular project types, or economic considerations. The requirement will apply to all project types, and the project manager will decide whether or not planning the reuse of excavation of material from an economic, social, and environmental perspective is practical or appropriate. It is recommended that all project types adhere to this checklist criterion until the point at which a pattern of projects emerges that is unsuitable for coordinating excavated material. Thereafter, these types of projects can be excluded from Mass-Portal as they are deemed unsuitable for coordination,

6.2.3 Implementation in different contract types

The process for coordination of excavated material between two projects, with the involvement of Mass-Portal, has been structured for both construction contracts and design and build contracts. It can be implemented for both contract types, but is deemed to be more suitable in construction contracts.

It is crucial to include a detailed description of the case with coordination of excavated material, along with the corresponding quantities, in the RFP for both contract types, as the contractor needs to be able to estimate costs based on correct conditions. Several large contractors in Sweden have their own subsidiary companies that manage the excavated material and fill material for a lower cost than market value. The contractors therefore have large potential to submit a lower bid because of this, which was mentioned by several interviewees. If demands arise for coordination after the contract has started, the contractor risks losing their advantageous deal with their subsidiary, resulting in costs higher than anticipated. This would lead to increased expenses for TrV, as they need to cover the expenses due to changed conditions. In addition to the expenses, legal and administrative consequences and discussions may arise which can harm the cooperation between TrV and the contractor. There is a risk of increased costs for TrV regardless of the approach taken, resulting from the uncertainties regarding feasibility. However, the environmental gain should be the primary motivation for the action.

The RFP is published at the end of the plan stage for the design and build contract and at the end of the design stage for the construction contract. The data available to base a decision on whether coordination of excavated material is feasible or not varies. As the design stage progresses, the data from field tests becomes more detailed and accurate, making it easier to assess if it is possible to coordinate excavated material. It also minimizes the risk for TrV, as the data is more reliable. TrV should not interfere with the execution of the construction for a design and build contract to a large extent, as it is a contract form that entails own decision-making for the contractor and encourages creative and innovative solutions to problems. Because of this, a construction contract is a more suitable contract form for the coordination of excavated material. However, to achieve successful coordination of excavated material between projects, it is important to have an open and transparent dialog between TrV and the contractor.

How TrV chooses to coordinate excavated material is up to them, this report proposes that a declaration of intent or an orientation decision is agreed upon by the involved parties, to keep it flexible since there are a lot of uncertainties at play. If legally binding contracts are signed it may result in unnecessary juridical work for TrV.

6.2.4 Consultant involvement

Consultants have been included in the proposal of the process for coordination of excavated material between projects. Currently, they are required to deliver a Design PM mass management for both the plan stage/system act and RFP for the construction contract and design and build contract. In the Design PM mass management, it is required to include information regarding the material suitability for coordination with other projects.

It was discovered during the data collection phase for Mass-Portal that none of the projects' Design PM mass management had sufficient information to complete the Excel sheet. Based on these results, a specific table structure was developed to guide the consultants in reporting the data required to import it into Mass-Portal. The table will be in an Excel file since it is a format that is universally accessible and easy to learn and use. Because each feature in ArcGIS has an attribute table with an identical structure to the Excel table, the table format can also be used with ArcGIS data. The table does not need to be fully completed, as all the required information will not be available during the early stages of a project. As the project progresses, more and more information will be available and the table can be updated. An empty column indicates insufficient data or large uncertainties. However, the consultants are able to make informed estimations regarding e.g., quantity, contamination level, or material classification, as it is necessary during the early planning of the design stage. The uncertainties with these assumptions should be assessed by TrV.

There have been discussions on whether the Excel sheet should be sent in before the consultant uses Mass-Portal or at the end of the stage when Design PM mass management is delivered. After the interviews with consultants, it was decided that consultants should deliver the Excel sheet at the same time as the delivery of Design PM mass management. Consultants finish the document at the end of the project timeline as all subject areas need to finish their work first. It is therefore realistic to demand the information in the table to be presented simultaneously as Design PM mass management is delivered. If the table were to be delivered earlier in the different stages, e.g., when the consultant investigates the possibility of coordination, there may be parameters that could be changed as more data becomes available. This results in an unnecessary update of information in the platform. Even though the information is released at a later time, Mass-Portal still serves the same purpose. The location of the project is already imported to Mass-Portal in an early stage, which makes it possible for other projects in the vicinity to have knowledge of their location and contact the project manager to open a dialog.

6.3 Uncertainties and risk assessment in early stages

To successfully coordinate excavated material, one of the most important aspects is to classify the material as a resource, and not waste. If the assessment is made according to the guidelines presented by the Swedish EPA, see Figure 2, the excavated material should not be seen as waste. The assessment done by TrV needs to be reported to the regulatory authority and approved to be able to coordinate excavated material between projects. In the end, it is the individual case officer working at the regulatory authority who approves it and therefore takes the risk, which is most likely why they often make the more cautious decision. It is clear that more dialogue and guidelines are required in this area, to ensure that resources do not go to waste, but also so that the reuse of excavated material is done in a safe and environmentally friendly way.

To ensure that the material is suitable for coordination, investigations and documentation is required to assess the feasibility and potential benefit of the action. Because of this, extensive testing of the technical and environmental properties of the material is necessary in early stages to be able to prove that the material is fit for purpose and does not bring any environmental risks associated with it. Soil is however a naturally occurring material with varying conditions, and the sampling needs to be performed in such a way that it accurately represents the field conditions (Swedish EPA, 2010). The types of tests and quantity of samples affects the results and can minimize the uncertainties regarding the material. If more information is available in earlier stages of the project, there is less chance of encountering unknown conditions during the construction stage. Therefore, how the sampling is conducted should be taken into account when evaluating the feasibility of coordinating excavated material.

The risk is on TrV when including information regarding the coordination in the RFP, as the quantity, technical- or environmental properties may vary from what is specified. If the contractor is assigned a project where coordination of material is required, and it turns out that it is not possible, due to unforeseen circumstances, the contractor needs to dispose of the material by other means. This leads to additional costs for TrV, since the work is not included in the contract. However, the material is not always of worse quality than expected, it may also be of better quality, both regarding technical and environmental properties. If this is the case, the original project may want to use the material themselves instead of transporting it to another project. It is cheaper than buying new material and decreases the total transport distance, which is a more sustainable management of the material. This puts TrV in a situation where two (or more) projects depend on one another. In a design- and build contract, the contractor is generally responsible for the excavated material and if they find a use for the material that is more beneficial from an economic, social or environmental point of view, they have the right to use it. The other projects that are to be coordinated with will then have to change their plans and would likely have to buy material from a quarry, which would lead to an increased cost for TrV.

To create flexibility if unwanted changes occur or if the surplus and demand does not arise during the same time span, TrV needs to plan for temporary storage location, which can be both internal and external. To enable storage within the project, the decision to coordinate material between project need to be decided in the plan stage as temporary use of land is filed for in this stage. These areas need to be restored at the end of the project, which reduces the flexibility if for example one of the projects are delayed. The most flexible solution is therefore to plan for an external temporary storage location. To enable these areas, it requires a lot of administrative work which is suitable to perform in early stages to avoid missing opportunities which could contribute to more efficient use of material. It can be hard to decide with certainty that a temporary storage location will be used to coordinate material between projects as unforeseen factors can affect the projects. It is therefore a risk that needs to be assessed regarding the certainty that coordination with another project will take place or whether it is possible to use the area for another purpose within the organization.

Discussion regarding the ownership of these areas, the economic division, and responsibility for restoration of the area needs to be assessed before the area is in use. This has not been addressed further in this thesis but has been mentioned in interviews as an important factor in succeeding with the coordination of excavated material between projects.

6.4 Coordination on a sector-wide scale

This report focuses on the coordination of excavated material between TrV projects, but these projects only account for a fraction of the total circulation of excavated material. If a similar platform was created that included projects from all major actors, both public and private, the potential to coordinate material would drastically increase. By limiting the extent to only TrV projects, the possibilities to coordinate material are smaller and the margins narrower. However, by starting relatively small, Mass-Portal can be tested and evaluated on a smaller scale before including other actors and stakeholders, preferably by a couple of pilot projects.

To be able to scale this up and include all relevant actors, the platform would need to be in the public domain, as previous attempts from private companies have resulted in bankruptcy caused by the lack of use from their competitors. This was brought up during the interview study where Norway was in the process of launching a nationwide, publicly owned platform to coordinate excavated material. Their platform is to be owned and maintained by a municipality that started the initiative within a smaller region, on behalf of the Norwegian government.

During the interview, it was also mentioned that public actors have an international right to use each other's systems without having to go through public procurement, to benefit society. This means that a public actor in Sweden could buy the rights to use the Norwegian work and implement the same type of platform, without having to go through the years of groundwork and investigations that Norway has gone through, and in doing so, saving both time and taxpayer money. This might be relevant to investigate further as the Norwegian platform is based on years of research and background studies that would have to be redone in order to create the same type of sector-wide platform.

If a platform like Mass-Portal would be scaled up to include all relevant actors, it is not quite clear which public actor should own and maintain it. It is quite a large task for a municipality to do unless the platform is only for their region, but it does not fall under the mission of TrV either. In France, the French Geological Survey is in charge of a similar platform, since they had a tracking system in place for excavated material which the platform could be based upon.

6.5 Benefits of Mass-Portal

By coordinating excavated material between TrV projects, resources can be utilized more efficiently, transportation minimized, and taxpayer funds allocated effectively. This leads to reduced environmental impact and promotes principles of sustainable development within the industry.

Through a combination of project data and geographical information, it is possible to evaluate possibilities related to coordination comprehensively and clearly through Mass-Portal. Visualization of data contributes to increased transparency and communication with other stakeholders, such as regulatory authorities and consultants. Mass-Portal will be an especially viable tool in dialogs with local regulatory authorities. When stating that there is a certainty of the use of the material in the project, a visualization in some way of the involved projects is needed according to the Swedish EPA (2023a). It is also beneficial with digital data management and automated data entry, not only does it require less administrative work, but it also minimizes the possibility of missing essential information to the platform. As the script for automated data entry has already been created, it is easier for people with less knowledge of ArcGIS and FME to use and update the platform. The anticipation is that it will be fairly self-sustaining and not lead to an increased workload, which will increase the interest in the coordination of excavated material between projects at TrV.

As there is currently no strategy for gathering information regarding surplus material within projects at TrV, Mass-Portal provides a new and innovative way of gathering information for evaluation and for making decisions regarding the feasibility and profitability of coordination. With more accessible and detailed information, the risk of misguided assessments leading to financial consequences is greatly reduced. By gathering data from early stages in the process, the platform creates opportunities for early-stage planning and informed decision-making that benefit coordination efforts. However, there will always be a risk of unforeseen events occurring in the process, which can terminate the possibility of coordination. One important aspect is therefore to be flexible and change the planning depending on the conditions at the given stage.

7 Conclusions and recommendations

7.1 Conclusions

Coordination of excavated material is a challenging but necessary step toward achieving a more circular economy and reaching the climate goals. It brings an increased administrative load in the early stages of a project to create the right conditions for coordination to be possible, as well as minimize the risks. It is an additional cost initially, but this cost can be viewed as an investment that brings substantial benefits later on, both financially and environmentally. The conclusions from this thesis are:

- Mass-Portal can be used to identify projects to coordinate excavated material with.
- Coordination of excavated material plays a significant part in reaching the climate goals, but established processes, routines, and tools are required to facilitate coordination.
- There are currently no established processes or routines to investigate coordination of excavated material for projects within TrV.
- There are no identified tools to investigate coordination of excavated material during the plan- and design stage of a project.
- Waste legislation leaves room for interpretation which contributes to uncertainties in the decision-making process.
- Temporary storage locations are often required to facilitate coordination, which needs to be accounted for in the early stages of a project, as the permit process may be long and intricate.
- Extensive testing needs to be done in order to minimize the risks associated with coordinating excavated material.
- The contract types affect the possibility for coordination, where a construction contract is to be preferred.
- The examples of coordination mentioned in the interviews show that increased coordination contributes to a circular economy, where resources are used efficiently.
- The concept of this platform is possible to scale up, but it is unclear who should be responsible for maintaining it in such case.

7.2 Recommendations for implementation to the Swedish Transport Administration

The recommendations for the implementation of Mass-Portal into the processes of TrV are the following:

- Incorporate a requirement for evaluating the feasibility of coordination using Mass-Portal in the milestone checklist for MS2A, MS3A, and MS3B.
- Add a requirement in the document Design PM mass management to complete the provided Excel sheet as input data to Mass-Portal.
- If coordination of excavated material between two projects proves to be suitable and feasible, it is recommended to detail the specific case and the circumstances in the RFP for both contract types.

- It is recommended to create a function or role at TrV, responsible for supporting projects with knowledge and experiences regarding the coordination of excavated material between projects. This function could also be responsible for the maintenance of Mass-Portal.

7.3 Future implications and further development

Future implications and developments of Mass-Portal that have been identified in this thesis are:

- Scale up the concept of Mass-Portal to include more actors and relevant stakeholders.
- Carry out pilot projects to evaluate the benefits of Mass-Portal.
- Further research on the topic of temporary storage locations and its applications when coordinating excavated material.
- Incorporate a traceability function of materials in Mass-Portal.
- Add a function in Mass-Portal to visualize the regional mass balance.
- Additional functions in Mass-Portal to calculate the financial and environmental benefit of coordinating material based on transportation and material costs.
- Further improve the process of adding data to Mass-Portal through FME.

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9 Appendix

A. Description of interviewees

In this chapter are the interviewees described. They are described by category of actor, professional title and the quantity of people interviewed with the same title, in order to keep the interviewees anonymous.

Table 7. Description of participants in the interview study.

Category	Professional title	Quantity
TrV	Project manager	5
TrV	Cost estimator	1
TrV	Road engineer	1
TrV	Environmental specialist	4
TrV	Mass management coordinator	2
TrV	Subject supervisor mass management	1
TrV	Rock engineer	1
TrV	Procurement officer/qualified buyer	2
TrV	Environmental specialist (planning)	1
Municipality	Coordinator for excavated material	1
Municipality	Case officer – Regulatory authority	3
County administrative board	Case officer – Regulatory authority	1
Design Consultant	Rock engineer	1
Design Consultant	Environmental specialist	2
Design Consultant	Road designer	2
Contractor	Cost estimator	1
Bærum municipality - Norway	Project director	1
BRGM (French geological survery) - France	Project manager for contaminated sites and soils.	1

B. Interview questions

In this appendix, interview questions are presented for all actors and positions.

Actor: TrV
Positions: Project managers, road engineer, environmental specialist, mass management coordinator, subject supervisor mass management, rock engineer and environmental specialist (planning)

1. Could you briefly describe your role, your experiences, and how you work with mass management?
2. Have you been a part of any projects where excavated material has been coordinated with other nearby projects?
    - What type of project and when was it constructed?
    - What quantities were coordinated?
    - Was there a need for temporary storage of the excavated material?
3. What does the process to coordinate excavated material currently look like?
    - How do you find projects to coordinate with?
    - What does the division of responsibility look like?
    - What does the division of costs look? Who pays for what?
    - Are there cases where it is not financially beneficial to coordinate excavated material between projects?
    - Is there a demand to coordinate material regionally?
4. What obstacles have you faced when trying to coordinate excavated material between projects?
    - How does the form of contract affect the coordination of excavated material?
5. Have you previously used any digital tools to coordinate excavated material? What did/didn't work?
6. What are the most important parameters to know when an exchange of excavated material between different projects is to happen?
    - What unit should the material be presented as? (tonnes/m^3)
7. At what stage in the process can necessary data be made available?
    - Is it possible to make data available earlier and put some sort of uncertainty on it?
8. Who should use/be responsible for a platform like this? What should this role look like?
9. Is there anything you would like to add that may be of interest for us?

Actor: TrV
Position: Procurement officer/qualified buyer

1. Could you briefly describe your role, your experiences, and how you work with mass management?
2. What are the biggest differences, with regards to mass management, for the different types of contracts (construction/design- and build)?
3. Who is responsible for the excavated material in a construction contract? (Where they are sent and the ability to track them)
4. Do you have any experience of projects where mass management has been separately procured?
   - What type of project and when was it constructed?
   - What form of contract was used?

- What was the overall impact on the project? Positive or negative?

5. What type of contracts do you think will be the most effective to use when coordinating excavated material?
6. What would the requirements for coordinating excavated material look like in the procurement documents?
7. What limitations are there with regards to sharing data?
8. How should the use of the platform be included in the procurement documents? For example, giving the consultant access to the platform.
9. Is there anything else you would like to add that may be of interest for us?

Actor: TrV
Position: Cost estimator

1. Could you briefly describe your role, your experiences, and how you work with mass management?
2. Have you been a part of any projects where excavated material has been coordinated with other nearby projects?
    - What type of project and when was it constructed?
    - What quantities were coordinated?
    - Was there a need for temporary storage of the excavated material?
    - What does the process to coordinate excavated material currently look like?
    - How do you find projects to coordinate with?
    - Is there a demand to coordinate excavated material regionally?
3. What obstacles have you faced when trying to coordinate excavated material between projects?
    - How does the form of contract affect the coordination of excavated material?
4. How would the cost estimation be impacted if you were to coordinate excavated material between projects?
5. What does the division of costs look like? Who pays for what?
6. What aspect of mass management is the most cost-driving?
7. Are there cases where it is not financially beneficial to coordinate excavated material between projects?
8. Have you previously used any digital tools to coordinate excavated material? What did/didn't work?
9. What are the most important parameters to know when an exchange of excavated material between different projects is to happen?
    - What unit should the material be presented as? (tonnes/m^3)
10. At what stage in the process can necessary data be made available?
11. How do you work with uncertainties connected to mass management, and how could we include this in our platform?
12. Who should use/be responsible for a platform like this? What should this role look like?
13. Is there anything else you would like to add that may be of interest to us?

Actor: Municipality
Position: Coordinator for excavated material

1. Could you briefly describe your role, your experiences, and how you work with mass management?
2. Have you been a part of any projects where excavated material has been coordinated with other nearby projects?

- What type of project and when was it constructed?
- What quantities were coordinated?
- Was there a need for temporary storage of the excavated material?

3. What does the process to coordinate excavated material currently look like?
    - How do you find projects to coordinate with?
    - What does the division of responsibility look like?
    - What does the division of costs look? Who pays for what?
4. Are there cases where it is not financially beneficial to coordinate excavated material between projects?
5. What obstacles have you faced when trying to coordinate excavated material between projects?
    - How does the form of contract affect the coordination of excavated material?
6. Are you currently working with any digital tools to coordinate excavated material? What are the pros- and cons?
7. What are the most important parameters to know when an exchange of excavated material between different projects is to happen?
8. At what stage in the process can necessary data be made available?
    - Is it possible to make data available earlier and put some sort of uncertainty on it?
9. What do you think are the most important aspects when creating a platform to coordinate excavated material between different projects?

Actor: Regulatory authority
Position: Case officer

1. Could you briefly describe your role, your experiences, and how you work with mass management?
2. What is your position on the transition towards an increased coordination of excavated material between different infrastructure projects?
3. Have you been a part of any projects where excavated material has been coordinated with other nearby projects?
    - What type of project and when was it constructed?
    - What quantities were coordinated?
    - Was there a need for temporary storage of the excavated material?
4. What information/parameters do you need to be able to assess and allow the coordination of excavated material between projects?
5. Is there anything else you would like to add that may be of interest for us?

Actor: Design Consultant
Positions: Rock engineer, environmental specialist and road designer

1. Could you briefly describe your role, your experiences, and how you work with mass management?
2. Have you been a part of any projects where excavated material has been coordinated with other nearby projects?
    - What type of project and when was it constructed?
    - What quantities were coordinated?
    - Was there a need for temporary storage of the excavated material?
3. What does the process to coordinate excavated material currently look like?
    - How do you find projects to coordinate with?

- Is it possible for you, as a consultant, to give recommendations on projects to coordinate with? Is this legally binding or just a suggestion?

4. What obstacles have you faced when trying to coordinate excavated material between projects?
5. How does the client (TrV/contractor) effect the possibility to coordinate excavated material?
6. Have you previously used any digital tools to coordinate excavated material? What did/didn't work?
7. What are the most important parameters to know when an exchange of excavated material between different projects is to happen?
8. Could you describe your working process, when you get access to volume data, and what part of the process this data becomes available?
9. How should the use of such a platform be configured if it were included in the contract?
10. Is there anything else you would like to add that may be of interest for us?

Actor: Contractor
Position: Cost estimator

1. Could you briefly describe your role, your experiences, and how you work with mass management?
2. Have you, as contractors, any experience of coordinating excavated material between different projects?
    - What type of project and when was it constructed?
    - What quantities were coordinated?
    - Was there a need for temporary storage of the excavated material?
3. What does the process to coordinate excavated material currently look like?
    - How do you find projects to coordinate with?
    - How does the coordination of excavated material affect the production planning in a construction project?
4. Does the type of contract (construction/design- and build) affect the possibility to coordinate excavated material between projects?
5. What obstacles have you as contractors faced when trying to coordinate excavated material between projects?
6. Have you previously used any digital tools to coordinate excavated material? What did/didn't work?
7. How would you as contractors view it if TrV were to include coordination of excavated material in the procurement documents.
8. What parameters and preconditions are important to present regarding coordination of excavated material in order for you to be able to calculate the project costs?
9. Is there anything else you would like to add that may be of interest for us?

Actor: Foreign actors – French geological survey (France), and Bærum municipality (Norway)
Position: Project manager for contaminated sites and soils, Project director

1. Could you briefly explain your role and how you work with the management of excavated material?
2. What were/are the biggest obstacles to achieve a more resource effective management of excavated soil and rock, and how can you overcome them?
3. Is it common in your work to coordinate excavated material between different projects?

- How does that process look like?
- Who is responsible for what?

4. What are the biggest obstacles when you're trying to coordinate excavated material between different projects?
5. How has the local laws and regulations regarding excavated material effected your work and progress?
6. Do you use any/know of any digital tools meant to increase the coordination of excavated material between different projects?
7. Do you have anything you would like to add that you think could be of interest for us and our work?

C. Experience exchange meeting questions

The following text and questions were provided to the participants included in the experience exchange meeting. They were asked to answer four questions and answer the questions based on their knowledge of the subject.

The following questions were provided:

1. Provide examples where excavated materials have been used outside of the technical facility?
2. Give some examples from the plan stage where a well-designed technical layout of a road or railway has been planned to achieve mass balance?
3. Provide examples from the construction stage where material handling has been optimized within the work area.

For the fourth question, a brief introduction to the aim of the master thesis was provided and several questions to answer.

Information regarding the master thesis
The overall aim of this thesis is to develop a digital platform for the coordination of excavated material between The Swedish Transport Administration's infrastructure projects to achieve an efficient use of resources.

Information regarding the platform:

- The platform is supposed to be used during planning and when the quantity can be estimated / calculated.
- Coordination should not only be seen as a just-in-time solution, but rather a solution that involves temporary storage locations to increase the possibility of coordination.
- The platform will be accessible through ArcGIS online, a web-page.
- Projects within the West region will be included in the platform.

4. Share your thoughts and ideas concerning coordination of excavated material between projects

This is a concept which not everyone has worked with, therefore several sub-questions are mentioned below and can be answered depending on where you experience lay.
Questions to answer based on the level of experience:

1.1 What are the most important parameters to know when an exchange of excavated material between different projects is to happen?
1.2 Have you been a part of any projects where excavated material has been coordinated with other nearby projects? What factors need to be defined before starting the construction stage?
1.3 How does the type of contract affect the coordination of excavated material?
1.4 Who should use/be responsible for a platform like this? What should this role look like?

D. Excel table – Example

In Figure 13, an example of a completed Excel table is presented.

Project name	Surplus / Demand	Total quantity [m3]	Material type according to AMA	Total content of contaminants	Presence of invasive species	Start of construction	End of construction	Assignment number	Type of project	Stage	Funding	Other	Last updated
Project A	Demand	3000	2,3A,4A	MRR-KM	No	2025-01-01	2026-01-01	188888	Railway	Design	National	Upcoming political decision	2024-03-15
Project A	Demand	50 000	6A	KM-MKM	No	2025-01-01	2026-01-01	188888	Railway	Design	National	Upcoming political decision	2024-03-15

Figure 13. Example of an Excel table with fictional values to exemplify how the table should be used.

E. FME script

The script in FME Workbench is presented in this appendix.

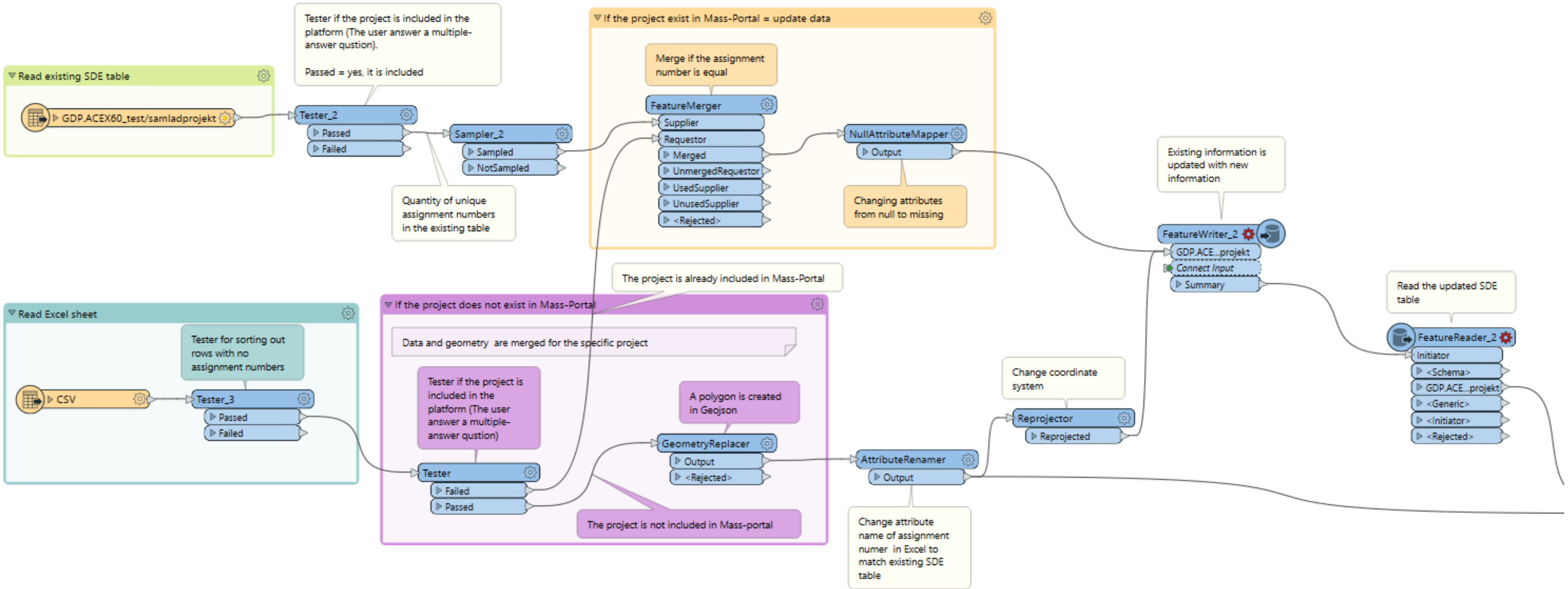

Figure 14.Part one of the FMe script. Decription on what each reader, transformer and writer are doing are presented in the figure.

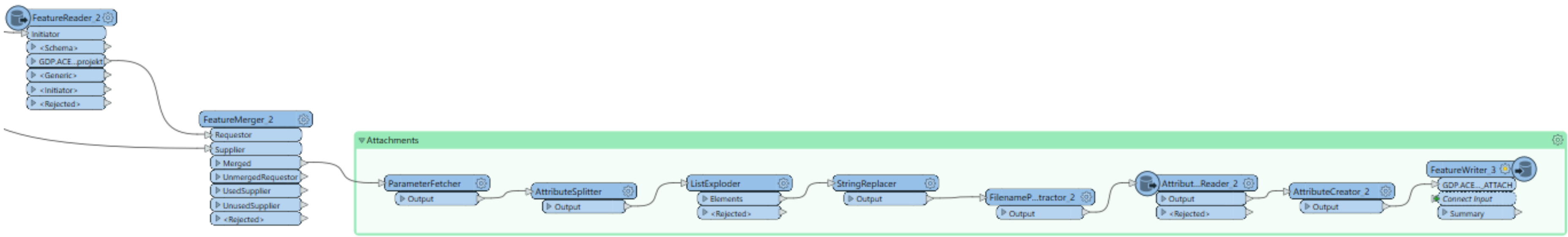

Figure 15. Part two of the FMe script, where the imported atachments are added to the spatial database table.

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