Norwegian University of Science and Technology

Applying material flow analysis for optimizing construction aggregates management in the road sector

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Master in Industrial Ecology
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MASTER THESIS

for

Student Marie Katrine Rasch

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Modelling mineral construction aggregate stocks in road infrastructures in Trondheim

Modellering av bestanden av mineralske byggeråstoffer i veiinfrastruktur i Trondheim

Background and objective

The built environment (including mainly buildings and infrastructures) is a key resource consumer as well as a key provider of secondary resources once the structures become obsolete. Road networks are particularly important as they require and store large quantities of mineral construction aggregates derived from natural sources (sand, gravel, and crushed hard rock) and industrial processes (recycled or manufactured aggregates) for extended time. In turn, the construction of roads itself can be a key resource provider due to the generation of excavation material from tunnels or road cuts. Although resource management is an increasingly important issue, there is a lack of tools that would allow civil engineers and spatial planners to anticipate construction mineral demand and supply of secondary resources for alternative road placement and designs.

There are two principle ways to estimate the material stocks in built environment structures: top-down and bottom-up. The top-down approach depends on historical information about the use of materials in different applications and their lifetimes, statistical data that are usually aggregated and not available for individual applications. The bottom-up approach is much more detailed and informative, but relies on data for individual structures and their composition, which are not readily available.

Progress in dynamic material flow analysis (MFA) and the development of software tools for integrating geographic information systems (GIS) and component-resolution building information models (BIMs) provide new opportunities for anticipating construction aggregates demand and secondary resource supply. The use of model-based processes gives architecture, engineering, and the construction industry the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructures. The development of city information models (CIMs) integrates the natural and legal environment on a city or regional scale, thus facilitating more integrated planning. In combination with MFA, BIM/CIM application supports the planning of primary resource supply, waste management, recycling, as well as energy use and climate change mitigation in these sectors.

The aim of this master thesis is to use a bottom-up approach that re-models the existing road infrastructure in Trondheim.

The following tasks are to be considered:

1. Literature study on (i) the management of sand, gravel, and crushed stone in Norway, (ii) the use of geographic information systems (GIS) and building information modelling (BIM) in road planning, design, construction, and management, (iii) road design standards in Norway, (iv) data sources for spatial and time resolved material flow analysis (MFA) for Norwegian roads, and (v) potential applications of prospective MFA for roads.
2. Re-model the road network of Trondheim in GIS using a standard road type definition or suitable road design parameters or indicators. Quantify the total stock of sand, gravel and crushed hard rock in the road infrastructure, visualize the results in a map, and interpret them.
3. Develop a time resolved MFA model for the existing road infrastructure in Trondheim (with one or several reference years) to assess the stock change and derive material in- and outflows. Visualize the results in a map and reflect on the usefulness (advantages, barriers) of this bottom-up approach and on ways to improve it.
4. Investigate possible applications of spatially resolved prospective MFA models and scenario forecasting of construction aggregates use in roads, such as for calculating the carbon footprint of aggregates in the existing roads, or for evaluating emission reduction potentials of using on-site/short-travelled/secondary materials, or different transport modes.
   → Support will be provided by Statens vegvesen Vegdirektoratet (Bob Hamel)
5. Describe how spatially resolved digital information models with 3D component resolution (BIM, CIM) are used for raw materials management today, visualize key aspects by means of a MFA system, and discuss how BIM/CIM may be coupled with MFA for improving resource management on various scales (conceptual development).
   → Support will be provided by Thomas Müller (Mensch und Maschine, Zurich)
6. Document the approaches used and reflect on their usefulness. What are advantages and disadvantages or barriers? How could the barriers be overcome?
7. Write a final thesis report.

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Within 14 days of receiving the written text on the master thesis, the candidate shall submit a research plan for his project to the department.

When the thesis is evaluated, emphasis is put on processing of the results, and that they are presented in tabular and/or graphic form in a clear manner, and that they are analyzed carefully.

The thesis should be formulated as a research report with summary both in English and Norwegian, conclusion, literature references, table of contents etc. During the preparation of the text, the candidate should make an effort to produce a well-structured and easily readable report. In order to ease the evaluation of the thesis, it is important that the cross-references are correct. In the making of the report, strong emphasis should be placed on both a thorough discussion of the results and an orderly presentation.

The candidate is requested to initiate and keep close contact with his/her academic supervisor(s) throughout the working period. The candidate must follow the rules and regulations of NTNU as well as passive directions given by the Department of Energy and Process Engineering.

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Pursuant to "Regulations concerning the supplementary provisions to the technology study program/Master of Science" at NTNU §20, the Department reserves the permission to utilize all the results and data for teaching and research purposes as well as in future publications.

The final report is to be submitted digitally in DAIM. An executive summary of the thesis including title, student's name, supervisor's name, year, department name, and NTNU's logo and name, shall be submitted to the department as a separate pdf file. Based on an agreement with the supervisor, the final report and other material and documents may be given to the supervisor in digital format.

☐ Work to be done in lab (Water power lab, Fluids engineering lab, Thermal engineering lab)
☐ Field work

Department of Energy and Process Engineering, 15. January 2018

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Academic Supervisor

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Mark Simoni (NTNU & NGU): primary contact person
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Bob Hamel (Statens vegvesen Vegdirektoratet, Trondheim)

Preface

This MSc thesis is written under the Industrial Ecology Programme at the Norwegian University for Science and Technology.

The content and title of the MSc thesis was changed from the original problem description to better reflect the content of the thesis. While most tasks of the problem description are approached, they do not make up the main body of the thesis work. The changes were done with the consent of the thesis supervisors.

During the preparation work prior to this thesis, it was found that data are currently insufficient to support tasks 2 and 3 as outlined in the original problem description (Rasch, 2017). In this thesis, the development of a Material Flow Analysis (MFA) model, which supports data collection and storage on material flows and stocks in the road construction industry, is therefore undertaken. It is also demonstrated how the model can be used to determine flows prior to construction by the comparison of old infrastructure to the new infrastructure outlined in contractor proposals (current stock vs. future stock), which it is argued will support optimized utilization of construction aggregates across all road construction.

The following tasks were formulated:

1. Investigate the current material management within the road construction industry.
2. Develop an MFA model, which organizes and illustrates material flows and stocks within the road sector, and which implements spatiality and differentiation between material types.
3. Demonstrate how the application of MFA can support material flow management across the construction industry to optimize material utilization across the industry as a whole.
4. Validate tasks 1 and 2 by examining material flows and stocks within an actual road construction project, and use the case study to demonstrate the findings of task 3.
5. Investigate the current reporting scheme within the road construction industry, and evaluate whether it will support a systematic quantification of the MFA model.
6. Investigate the current potentials for utilizing BIM software as a tool for reporting as well as a tool for securing better material management.
7. Investigate what barriers currently exist for utilizing demolition and excavation material in the most appropriate way.

Abstract

The construction of infrastructure presents large issues of environmental impacts, land-use conflicts, and resource scarcity. Good resource management streamlining the material use and waste production is essential to target these issues, however, there are indications that current management of construction aggregates in the construction industry does not comply with the circular economy mindset. In addition, we find a lack of data and tools to support mitigation. In this thesis, we suggest a MFA, which: 1) Visualizes current material management in the road sector, and thereby allows us to evaluate the system's compliance to circular economy. 2) Acts as a framework for storing data on material flows and stocks within the system over time. 3) Can be used to quantify supplies of and demands for material for a given road project prior to construction, supporting an optimized utilization of material across the construction industry. The MFA is developed specifically to incorporate spatial resolution and differentiation between material types due to the importance of these aspects to the potential for material utilization. Through the development and testing of the MFA, we found four areas, which should be further investigated to properly allow for an optimization of material utilization by the suggested approach. This includes testing the system definition through a regional quantification of material stocks and flows in road infrastructure, developing a good reporting scheme on material stocks and flows, approaching current limitations of 3D software, and modelling current road infrastructure in 3D. In addition, we investigated what underlying barriers prohibit contractors from managing material in a way more compliant to the circular economy mindset. These barriers must also be approached, to really secure the possibility of optimizing material management on construction aggregates.

Key words: material flow analysis (MFA), spatial resolution, construction aggregates, road, infrastructure, land-use planning, BIM

Samandrag

Bygging av infrastruktur skaper ofte store utfordringar, slik som stor miljøpåverking, konfliktar rundt arealbruk og skort på resursar. God handsaming av resursane effektiviserer materialbruken og avfallsproduksjonen, og er grunnleggjande for å redusere desse påverkingane. Det finst indikasjonar på at dagens handsaming av byggeråstoff i byggenæringa ikkje er i samhøve med tankegangen innan sirkulær økonomi. Attpåtil, manglar det data og verktøy for å hjelpe med tiltak. I denne oppgåva kjem vi med forslag på ein MFA som, 1) syner dagens handsaming av byggjeråstoff i vegsektoren, og på den måten gjer det mogleg å evaluere om systemet samsvarer med sirkulær økonomi, 2) fungerer som eit rammeverk til å lagre data om materialstraumar og -lager innan eit system over tid, og 3) kan bli brukt til å kvantifisere forråd og etterspurnad av material i eit vegprosjekt før bygginga tek til, og på den måten fører til optimal bruk av byggeråstoff i byggeindustrien. MFA´en er spesielt utvikla for å innlemme den romlege komponenten og for å skilje mellom materialtypar, fordi desse faktorane er viktige for bruksområdet til byggematerialet. Gjennom utviklinga og testinga av MFA´en, fann vi fleire område som må betrast for å verkeleg optimalisere materialbruken i byggjeindustrien ved hjelp av den foreslegne tilnærminga. Dette inkluderer testing av systemdefinisjonane gjennom ei regional kvantifisering av korleis material blir handsama i byggenæringa, utvikling av ei god rapportordning for materialstraumar og -forråd, ta høgde for avgrensingane i dagens 3D-program, modellere dagens vegsystem i 3D. Attpåtil, undersøkte vi kva for underliggjande hinder entreprenørar møter dersom dei handsamar byggjematerial på ein måte som er meir i tråd med tankegangen innan sirkulær økonomi. Ein må ta tak i desse hindera for å verkeleg sikre optimal handsaming av byggjeråstoff.

Stikkord: materialstraumsanalyse (MFA), romleg komponent, byggjeråstoff, veg, infrastruktur, arealplanlegging, BIM

Acknowledgement

I would like to thank my thesis advisor Professor Daniel Beat Müller for sharing his extensive knowledge, for his encouragement, and for our inspiring discussions throughout my thesis work. I would also like to thank my co-advisor PhD candidate Mark Uwe Simone for his thorough feedback and guidance, and for securing structure when all felt like chaos. I am grateful, I was given the opportunity to work on this innovative and challenging project.

For my thesis work, I was fortunate to have two external advisors. I would like to thank Bob Hamel from Statens Vegvesen and Thomas Müller from Mensch und Maschine for showing enthusiasm for my thesis and expanding my understanding on the subject by giving me inputs from "the real world".

A great share of this thesis relies on the accounts and feedback from different stakeholders in the construction industry. I was overwhelmed by the amount of time and knowledge these people decided to share with me. Therefore, a special thank you to Hans Petter Johannessen (Skanska Industrial Solutions), Adrian Rodriguez Vicario (ÅF Engineering), Beth Carlsen (ÅF Engineering), Odd Jostein Haugen (Statens Vegvesen), Arne Aakre (EBA), Vegard Olsen (Franzefoss Pukk), Lars Aamodt (NyeVeier), Johan Hedlund (PEAB Anlegg), Thomas Hartnik (Miljødirektoratet), and Rolf Brødreskift (Trondheim Kommune). Without your contributions, this thesis would not have been possible.

I would also like to thank NGU and the employees at the Raw Material department for taking their time to enlighten me, to lend me an amazing southern-facing office, and least not to make me feel as part of the team.

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To my family, I am simply grateful that you have always supported me in my proceedings even when they have been strange and unfamiliar to you (and me).

Finally, to Odd André, thank you for going above and beyond in so many ways to make me happy.

Trondheim, June 2018

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Student at the Industrial Ecology Programme
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Abbreviations and definitions

Abbreviations

LCA:	Life Cycle Analysis
KLD:	Klima- og miljødepartementet (Norwegian Environment Agency)
MFA:	Material Flow Analysis
NGU:	Norges Geologiske Undersøkelser (Geological Survey of Norway)
NVDB:	Nasjonal vegdatabank (Norwegian National Road Database)
RFP:	Request for Proposal
SSB:	Statistisk sentralbyrå (Statistics Norway)
SVV:	Statens Vegvesen (Norwegian National Road Authority)

Definitions

Bottom-up approach: The piecing together of components and subsystems to create a bigger picture of a system. In MFA, this entails the collection of data on flows and stocks to define the system definition. The bottom-up approach is opposite to the top-down approach.

Circular Economy: Concept seeking to minimize resource input and waste output by maintaining the value of products and materials for as long as possible.

Construction aggregates: Sand, gravel, and crushed hard rock used for construction of infrastructure. May either be virgin, demolition, excavated, or recycled material.

Construction project: The physical and timely content of construction and demolition. Includes both initial demolition of old infrastructure and excavation, as well as the construction of new road infrastructure. In this thesis, we use construction project and road construction project indifferently. If we mean the construction of other infrastructure, this is clearly specified.

Demand: The material, which is needed by a construction project for road infrastructure.

Demolition material: Material, which was formerly a component in infrastructure but now removed during demolition in a construction project. In this thesis, we are only concerned with volumes of construction aggregates.

Downcycling: The reuse or recycling of material, but where the material quality or functionality is lower than for the original material.

Excavation material: Material, which was formerly a component of the lithosphere but now removed during excavation in a construction project. In this thesis, we are only concerned with volumes of construction aggregates.

External material flows: Material flows out of a construction site. The material is demolition and excavation material from the construction site, which is transported out of the construction site.

Flow: The movement of material or energy between two processes and/or stocks over a certain period of time.

Infrastructure: All physical structures of the entire built environment, including roads, buildings, power supplies etc.

Internal material flows: Material flows occurring inside one construction site. The material is demolition and excavation material from the construction site, which is being utilized in new infrastructure at the same construction site.

Internal supply: A supply of material, which derives from inside the system (construction industry) or sub-system (construction site) dependent on the context, and which is being utilized within the same system or sub-system.

Road infrastructure: Roads and supportive physical structures in proximity to the road, including light poles, crash barriers, noise embankments etc. In this thesis, the *road infrastructure stock* only includes construction aggregates.

Stock: Classification of material, which is kept at the same locality over a certain period of time.

Supply: Material provided either from quarries or as demolition and excavation material.

Top-down approach: The breaking-down of a system to gain insight into its subsystems and components. In MFA, this entails an understanding of the system in order to derive flows and stocks. The top-down approach is opposite to the bottom-up approach.

Virgin material: Material, which is extracted from natural reserves, thus has not formerly been used in manufactured products.

1 Introduction

Infrastructure, constituting the entire built environment, is essential to human wellbeing as it provides shelter, energy, clean water, and food, as well as allows for transportation and communication (Müller *et al.*, 2013). Infrastructure is also key to secure economic growth (Démurger, 2001; Müller *et al.*, 2013), and is thus crucial both directly and indirectly for the level of welfare in a country. However, infrastructure is also a main consumer of resources as well as a producer of waste, both in the construction phase and once the infrastructure reaches its end-of-life (Bergsdal *et al.*, 2007; Augiseau and Barles, 2017; Miatto *et al.*, 2017). This has several problematic consequences, including environmental impacts, land-use conflicts, and resource scarcity; Greenhouse gas emissions and other environmental impacts from extracting, transforming, and transporting resources are significant (Müller *et al.*, 2013; Augiseau and Barles, 2017; Miatto *et al.*, 2017). Overlapping land-use claims together with a spatially uneven distribution of resources and high transport costs can lead to local resource scarcity and insufficient designated land area for waste disposal and/or recycling terminals, especially in urban regions (Augiseau and Barles, 2017; Johannessen, 2018a). The extension of the area, which supplies resources for infrastructure implies increased transportation of materials and thus costs, environmental impacts, potentially loss of farmland and forests, noise, and additional road damage (Eriksen, 1997; Kennedy, Cuddihy and Engel-yan, 2007; Augiseau and Barles, 2017).

Due to the long lifetime of infrastructure and the risk of lock-in situations (Müller *et al.*, 2013), early planning is essential to accommodate these challenges. Several studies apply dynamic material flow analysis (MFA) to quantify the infrastructure stock, resource inflow, and outflows of waste over time (Bergsdal *et al.*, 2007; Brattebø *et al.*, 2009; Miatto *et al.*, 2017). This allows for early land-use planning securing access to required resources and area for waste management, as well as to gain an understanding of the potential for utilizing waste flows from the infrastructure stock as secondary materials. Dynamic MFAs also allow scenario development, where the system implications of different policies can be tested. Dynamic MFA studies have been done for a variety of spatial scales ranging from supra-national to urban scale (Augiseau and Barles, 2017). For Norway, the concrete and wood demand and waste flows for housing are estimated until 2100 by Bergsdal *et al.*, (2007). However, we argue that results on national level are inadequate for local resource planning on construction aggregates; high transport costs both economically and environmentally imply the need for short transport distances and planning that accounts for availability of and demand for local resources. Only a few studies undertake dynamic MFA on an urban scale, however, these studies all apply a top-down approach (Augiseau and Barles, 2017), which again leads to insufficient resolution for local planning. We argue that bottom-up dynamic MFAs are premature in Norway, as they require knowledge on material quantities in the Norwegian infrastructure stock, which is currently not available with sufficient resolution (Rasch, 2017). In addition, an optimization of resource management targeting resource scarcity, land-use conflicts, and environmental impacts, initially requires an elaborate understanding of the targeted system. There are indications that this understanding is not yet explicit in Norway.

Both in terms of quantities and production value, construction aggregates are the most important mineral resources in Norway (Norges Geologiske Undersøkelse & Direktoratet for Mineralforvaltning, 2015). Due to the high demand but low value-to-weight of construction aggregates, issues of local resource scarcity and land-use conflicts are especially relevant for this resource. Figure 1.1 illustrates the supply and demand of construction aggregates into and out of the construction industry, underlining two important issues: 1) There are indications that within the construction industry, construction aggregates are not used according to the circular economy mindset, and 2) Analysis and potential suggestions for increasing the circular economy in the construction industry is challenged by the lack of data on the material management.

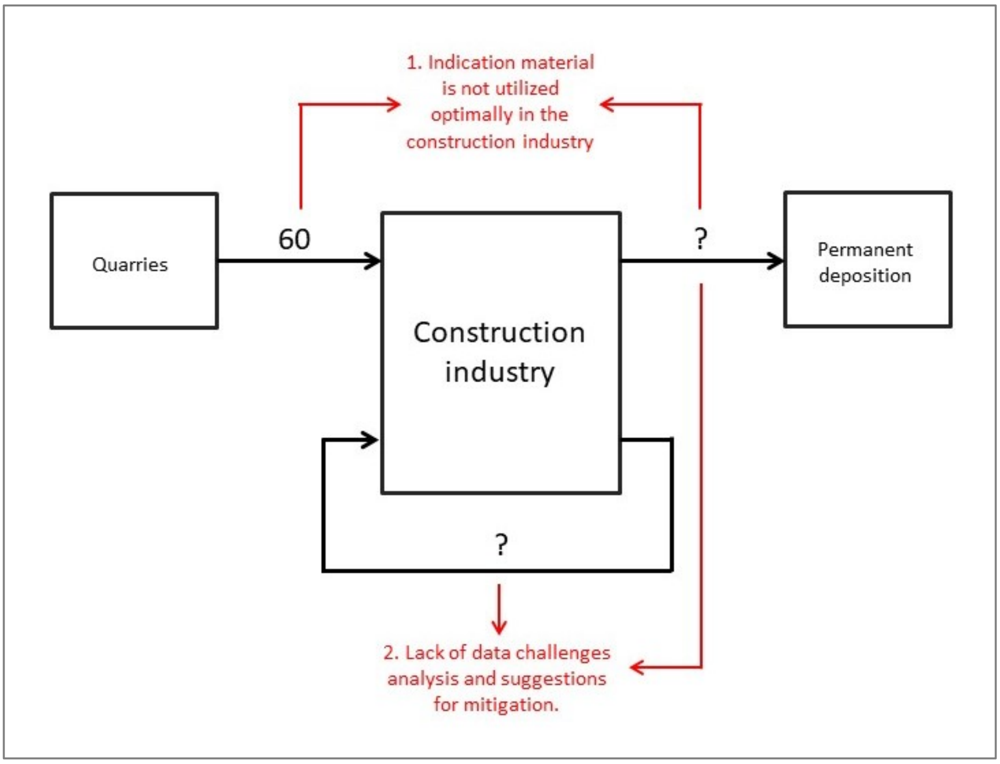

Figure 1.1 *Schematized inflow and outflow of construction aggregates to the construction industry underlining two main issues in regards to resource utilization. Material flows are in million tons material.*

In regards to the first issue, interview accounts reveal that material is brought to landfill or other permanent deposition (Hedlund, 2018; Johannessen, 2018a; Vicario, 2018) concurrent with an existing high demand for virgin material. This indicates a poor utilization of internally released material. Infrastructure may acquire construction aggregates from quarries, but in addition, the construction of infrastructure itself produces corresponding raw material by demolition of old infrastructure and excavation into the lithosphere. Quantities of demolition and excavation material released during construction and their purpose of use are not reported to statistical authorities (Akershus Fylkeskommune, 2016; Hartnik, 2018), however, the Norwegian association for Mountain Blasting (*NO:Norsk forening for Fjellsprengningsteknikk*) estimates that blasted rock material in Norway amounted to 19 million tons in 2016 (Li, 2018). In addition to this comes the masses from drilled tunnels as well as unconsolidated masses. Interview accounts reveal that that demolition and excavation material is either utilized within the same construction project, mainly for filling purposes, or permanently deposited (Johannessen, 2018a; Hedlund, 2018; Vicario, 2018). Concurrently, approximately 60 million tons of domestically quarried construction aggregates are sold on the Norwegian market every year (Norges Geologiske Undersøkelse & Direktoratet for Mineralforvaltning, 2015). In the circular economy mindset, supply and demand should to the highest possible degree be satisfied from within the system, "closing the loop" (European Commission, 2018). Quarrying of virgin material may still occur in a circular economy system, but only when the internal supply of material is not sufficient to meet the internal demand for material. This also implies that material should not be downcycled creating a need for new high-quality material, as may be the case when using demolition and excavation material for backfilling purposes. The concurrent flow of material to permanent deposition indicates that material is not utilized optimally in the construction industry.

Different initiatives in the construction industry have targeted the issue of poor management of construction aggregates and its derived effects. In practice, the biggest initiative is probably the pursue of contractors to utilize as much as possible of demolition and excavation material within their individual construction projects (Johannessen, 2018a; Hedlund, 2018; Carlsen and Vicario, 2018). Different methods for optimization are presented (Kandil and El-Rayes, 2006), including the potentials of 3D and 4D software to support better material management within each project (Chau, Anson and Zhang, 2004; Wang *et al.*, 2004). Another initiative targets the reduction of environmental impacts from road construction. The consulting company Asplan Viak has on commission from the Norwegian National Road Authority (*NO: Statens Vegvesen* (SVV)) developed a life cycle analysis (LCA) tool, VegLCA, which evaluates the environmental impacts from road construction projects. The tool may help reveal the activities with highest related emissions (Hamel, 2017) and allows for an implementation of requirements on environmental impact reductions in requests for proposals (RFP). However, these efforts target resource management within individual construction projects. While the efforts may be effective for good management within one project, we need to understand management within the entirety of road construction to secure an optimization of the system as a whole.

TippNett and LoopRocks are two applications on the Norwegian market, which seek to support management of material deficits and surplus across the construction industry. These applications are still of limited use on the Norwegian market (Zide, personal communication, 2018). Registered contractors announce the quantity, material type, and locality of material surplus or deficit to the applications, and the applications inform the contractors of equivalent surplus/deficit of opposite character in the area (TippNett, 2018). However, while the applications potentially support increased material utilization, they do not evaluate whether material is used for quality-relevant purposes or is downcycled. In addition, the applications do not provide overall transparency on material flows within the construction industry, and thus support neither the identification of necessary measures to improve material management nor the evaluation of whether resource management targets are met.

The ongoing project *Kortreist Stein,* managed by SINTEF Byggforsk and Veidekke Entrepenører, currently seeks to identify barriers for increased utilization of construction aggregates in road construction and suggests mitigation measures (SINTEF Byggforsk and Veidekke Entrepenører, 2016). The project approaches the barriers and initiatives with a holistic approach through four working packages: 'H1: Planning processes and resource management', 'H2: Contracts, business models, and incentives', 'H3: Production and utilization' and 'H4: Environment and energy consumption' (SINTEF Byggforsk and Veidekke Entrepenører, 2016). The topic of resource management is also addressed by public authorities. Akershus and Rogaland counties have both developed regional material management plans seeking to mitigate issues of resource scarcity and land-use conflicts (Akershus Fylkeskommune, 2016; Rogaland Fylkeskommune, 2017). While most of the mentioned initiatives point towards the lack of data being an obstacle for their investigations and securing better material management, few of them suggest concrete methods for increasing data availability. This brings us back to the second issue indicated in Figure 1.1, i.e. fact that lack of data, inaccessibility of data, and incompatibility of data is a key challenge for understanding material management in the construction industry. We argue that in order to take initiatives, including policy development, to secure better material management, there is a need for solutions that help provide data on the current material management.

Rubli and Schneider (2008) developed a MFA (the KAR-model), which illustrates the material flows related to the construction and demolition of infrastructure in Switzerland. Currently, the model is applied individually to ten cantons, and material flows are since 2010 collected and made available on an annual basis. However, material flows are collected with a top-down approach and do not include spatial resolution below carton level. This makes the model insufficient for local resource planning. Johansson (2006) investigates the aggregates flows in two municipalities in the Göteborg region applying a bottom-up approach. The incentive is to better understand the regions construction aggregate situation to evaluate, whether national objectives are met. Investigated flows are applied to a conceptual MFA on construction aggregates flows. Johansson (2006) creates transparency on materials flows for the given region with sufficient resolution for local land-use planning. However, neither Johansson (2006) nor Rubli and Scneider (2008) approach material stocks in infrastructure, but only material flows. While material flows allows us to analyze the current pitfalls of material management, in order to understand management in a dynamic context, we still need to include material stocks of the infrastructure. We argue that stock development is the source for material flows, and it is a better starting point for the MFA to approachstocks over time. In addition, neither models include considerations to different material qualities, which is necessary to evaluate the actual potential for recycling as well as to what degree material is downcycled.

In this thesis, we discuss how improving transparency on material stocks and flows within the road sector is necessary to identify and address several critical issues derived from current construction aggregate management. We develop an MFA model on the road construction industry, and demonstrate how it can be used 1) as a database for material stocks and flows in the construction industry securing data availability and consistency, which 2) allow us to gain an understanding of material management and point out where it is currently insufficient. We argue that in order to reduce landfilling and downcycling of demolition and excavation material from the road sector as well as to reduce virgin material extractions, we need foremost a system, which gives insight into material availability and demand across the construction industry prior to initiating these activities. We demonstrate how the MFA model can also 3) be used to predict material flows over time based on plans for stock development in an entire region to support cross-industry utilization. The MFA is developed specifically to incorporate spatial resolution and differentiation between material types. A differentiation of material types allows us to approach the risk of downcycling as well as potentials for recycling. Spatial resolution allows for the MFA model to be used for local land-use planning, while concurrently acting as a national database on material stocks and flows. We illustrate how 3D models are effective tools to decide quantities and qualities of material in the road stock, and we discuss further advantages of the application of BIM software to material management.

The MFA model is applied to a case study on the resource management within the *E6 Jaktøyen – Sentervegen* road construction project, and it is illustrated how the model could have supported a prediction of the material flows caused by the project.

Further, we investigate the main barriers in the construction industry, in addition to lack of data, which prohibit contractors from managing construction aggregates in a way more compliant with the circular economy system. The MFA approach allows us to understand current material management and to optimize the coordination of material flows between projects, however to actually allow for an optimization on construction aggregates management, these barriers must also be approached.

Note, in this thesis, it has been decided to focus on the management of construction aggregates within the road sector, instead of infrastructure as a whole. This has been decided to reduce the complexity in the development of a first generic MFA system definition. In the discussion, we discuss the implementation of other infrastructure to the MFA.

2 Methodology

2.1 Conceptual approach

Currently all contractors seek to optimize the material management within individual construction projects as the most important measure for reducing costs (Johannessen, 2018a; Vicario, 2018b; Aakre, 2018). This means that all internal supplies of demolition and excavation material are utilized for material demand within the *same* project, if the supplies are of suitable quality. We argue that optimization should instead be considered for the entirety of active construction, because an optimization of individual parts of the system does not necessarily lead to an optimization of the system as a whole. Figure 2.1 illustrates the ideal effects of increased coordination between projects by comparing two management scenarios of three fictive construction projects. In scenario A, material optimization is sought within each project. Surplus demolition and excavation material from each of three construction projects is brought to landfill, while material demands are covered by material import from quarries. In scenario B, coordination is sought across the construction projects as a whole, eliminating virgin material extraction, landfilling, and also downcycling.

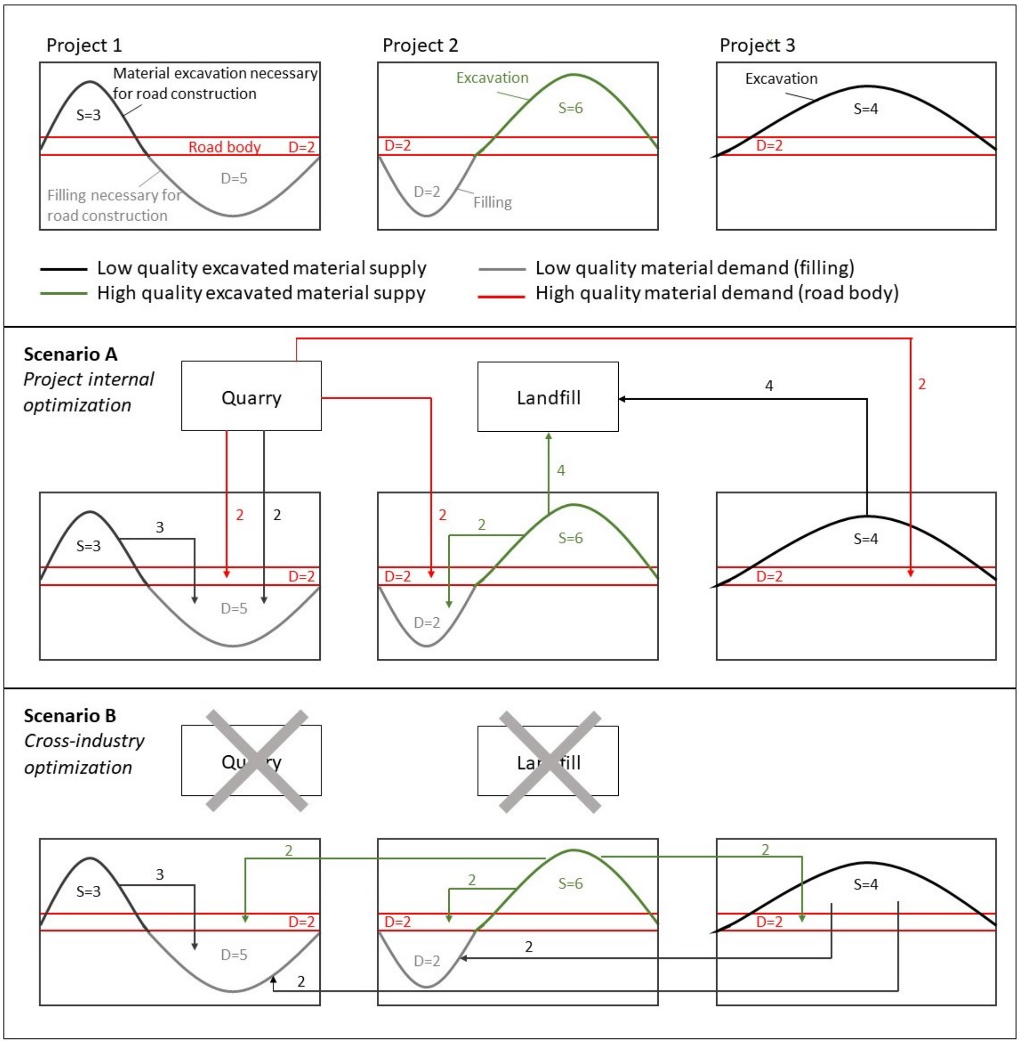

Figure 2.1 *Effects of two material management scenarios. Three road construction projects with material supply (s=value) and material demand (d=value).*

Such optimization requires that information is available on quantities and qualities of supplies and demands across concurrent construction activity. Currently there is no system, which makes this information available in an organized way (Aamodt, 2018). We point out that for individual construction projects contractor proposals are currently used to estimate material flows, which will occur during the construction. This allows for an optimization of material utilization within each individual construction project prior to initiating the construction phase. We argue that the same approach is applicable to the entirety of road construction, if all future projects were collected into one system. This would reveal all concurrent material supplies and demands, supporting cross-industry optimization. For this, we suggest a MFA framework (Figure 2.3). In Figure 2.2, we use MFA methodology to illustrate how material flows are derived by comparing the stock prior to a construction project and the stock after a construction project. Where stocks prior to and after construction are inconsistent, this indicates stock changes and inherently flows. We reuse the three example construction projects and scenarios from Figure 2.1. Material for excavation represent the stock before construction, which will generate supplies of material during construction. Material required for roads and filling and roads represent the stock after construction, and suggesting material demands during construction. To incorporate differentiation of material types and spatiality, stocks are indicated as matrices with materials on the column axis (high vs. low quality) and spatiality on the row axis. Spatiality is given by each road project being divided into three or two sections, roads making up their own section. Stock changes are derived from the inconsistencies between the two stocks in regards to the stock after construction. Scenario A represents the current situation, where contractors are only aware of stock changes within their individual construction projects. For scenario B, contractors have been provided information on stock changes across the entire construction industry, and cross-industry coordination is possible, optimizing material management for the system as a whole. We underline that material supplies and demands within the construction industry should be paired appropriately, such that materials are utilized for quality-relevant purposes, avoiding downcycling.

In this thesis, we demonstrate the usefulness of MFA in three regards: 1) To provide a framework for collecting and storing data on material stocks and flows in the road sector to secure data availability for analysis purposes. 2) To illustrate flows and stocks in the construction industry to provide an understanding of current material management and to point out areas within the system with the highest potential for improvement. 3) To predict material flows based on current stocks and planned stock development to support coordination across the industry (as just demonstrated). In addition, we discuss the potentials of prospective dynamic MFA for future material management and land-use planning. For the MFA to sufficiently support these purposes, it should: 1) Incorporate the whole road construction industry in order to evaluate optimal material utilization for the entirety of road construction, rather than for individual road projects. 2) Incorporate a differentiation between material types to approach the current risk of downcycling as well as potentials for recycling. And 3) include spatiality.

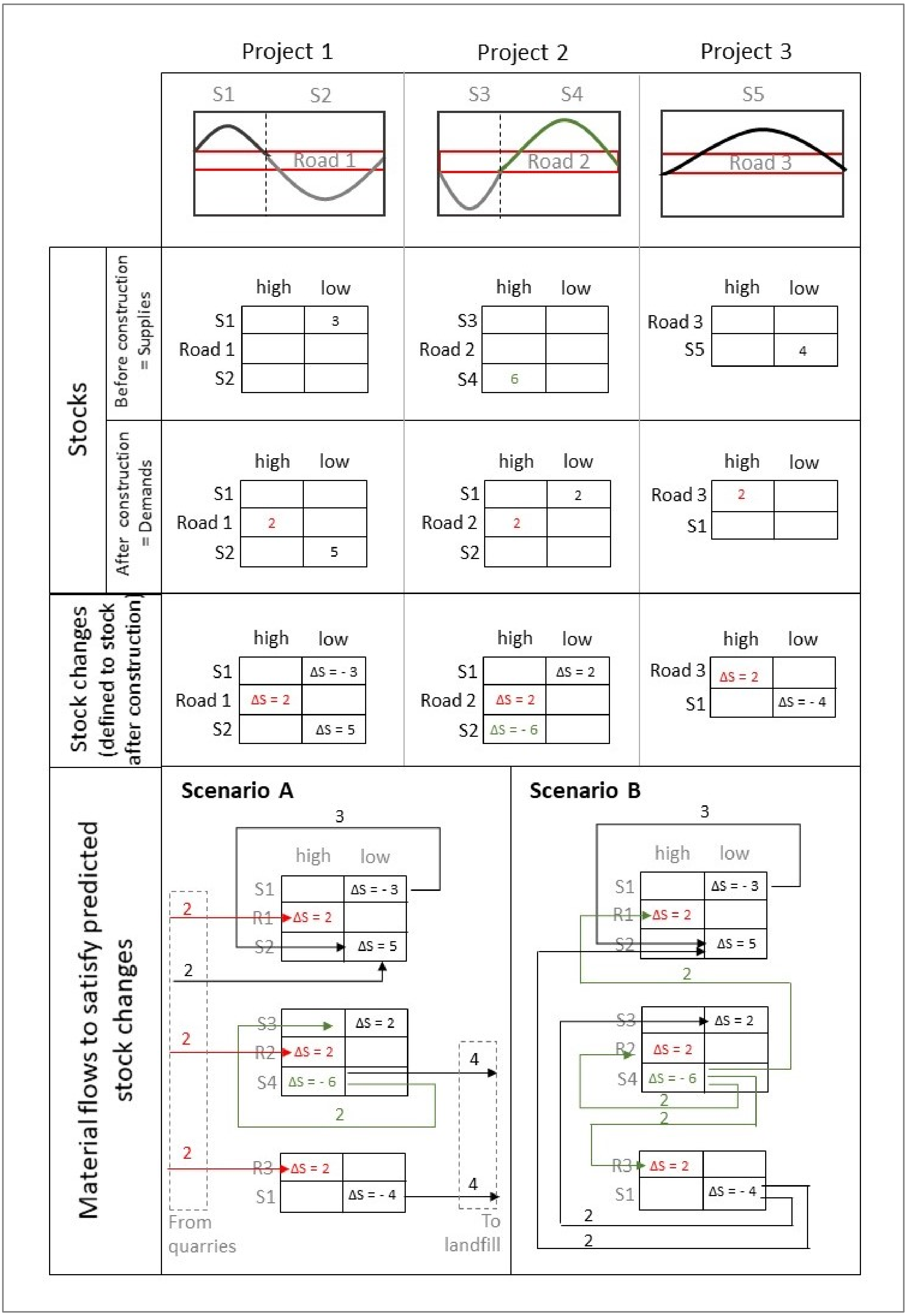

Figure 2.2 *Illustrating material flows derived from stock inconsistencies. Changes in the material stock before and after construction imply stock changes (here defined in regards to stock after construction) and inherently flows. Flows may be managed differently, here in two different scenarios.*

Spatiality to the MFA is important because: 1) It will enable us to expand the physical boundary infinitely for database purposes, without compromising the ability to perform analysis on different spatial scales. 2) A segmentation of road projects is necessary to evaluate the degree of downcycling, as indicated in Figures 2.1 and 2.2. And 3) transport distances is a decisive factor for material management in the construction industry, making spatiality inherently important. In addition, by including spatiality, we may utilize current use of spatial software in contractor proposals and SVV databases to incorporate stock material quantities directly into the MFA, estimating road material stocks with a bottom-up approach. This secures a level of detail necessary for local land-use planning. In preparation to the current MSc thesis, we investigated the potential of using 2D software as the foundation for a database on the infrastructure material stock, but concluded that it was insufficient. The reasons for this are: 1) It does not sufficiently indicate the actual location of material in space. 2) Material content is likely underestimated due to road body simplification and exclusion of fillings. And 3) impacts of topography on material availability and demand is ignored (Rasch, 2017). Therefore, we point towards the increased use of 3D software in the construction industry. Most models of construction projects are currently developed in BIM software. With an adaptation of MFA to incorporate the spatial representation from BIM models, material stock quantities can be integrated directly into the MFA.

2.2 System definition

We present a MFA system definition for construction aggregates management in the road construction industry in Norway (Figure 2.4). The system definition is based on investigations on the current situation through literature and interviews. The results of this investigation are presented in Chapter 3.1. The system driver is the demand for road infrastructure, which is outlined by the government in National Transport Plans (Det Kongelige Samferdselsdepartement, 2017). The system boundary is the road construction industry, while the system boundary of the subsystem are the individual road construction sites. The system consists of three processes and six stocks. In addition, we include the stock *Quarry* outside the system boundary, because its spatiality is important due to the aspect of transport in construction aggregates management. Each process and stock is described in Table 2.1.

Centrally in the system is the sub-system *Road construction sites*. This indicates the flows, which happens within individual construction sites. Within a construction site, demolition and excavation material may be used directly in new road infrastructure, recycled on-site and reused in new infrastructure, or stored on-site. If demolition and excavation material is transported to other construction sites, this is visualized as a flow going through the transport processes 6 or 7 (flows $A_{4\text{-}6}$ or $A_{3\text{-}7}$) and then back to the road infrastructure stock (flows $A_{6\text{-}3}$ or $A_{7\text{-}3}$). The material may otherwise be brought to *Temporary storage and/or recycling*, *Asphalt production*, *Landfill*, *Permanent deposition,* or it may exit the system to be utilized in other infrastructure. From *Temporary storage and/or recycling* and *Asphalt production*, material may reenter the road infrastructure stock. In addition to the imports to the system from quarries, there are additional three imports: *Other demolition asphalt*, *Other demolition material*, and *Other excavation material*. These are demolition and excavation material from other infrastructures.

In order to approach the risk of downcycling and potential for recycling, we include the following two aspects in the system definition: 1) Vertical disintegration of roads into road compartments, and 2) Segmentation of material types. The vertical segmentation of the road stock into road compartments is important to reflect the purpose of use of transferred material, holding the assumption that road compartment and required quality of the material are correlated (Statens vegvesen, 2014). We disintegrate the road stock into: surface course (S.C.), base course (B.C.), sub-base course (SB.C.) and filling (Fill.). Differentiating between material types allows for an evaluation of whether material is downcycled, if the material type and the road compartment are not cohesive. In addition, we incorporate the dimension of spatial resolution accordingly to the arguments given in the conceptual approach (Chapter 2.1). To reflect material types and spatial resolution, each stock contains a table in which the row axis considers spatial resolution, P indicating each point in space, while the colums axis allows for a differentiation of material types, M indicating each material type (Figure 2.3). This, in theory, presents the opportunity to include infinite space and an infinite amount of material types.

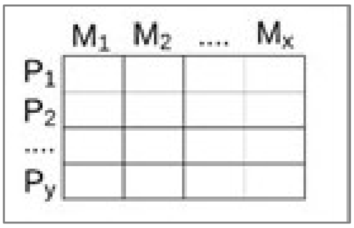

Figure 2.3 *Dimensions of spatiality and material types in stocks by implementation of matrix.*

Flows are seperated by color in order to indicate how the material is percieved in the construction industry, i.e. currenlty into four main types: demolition material, excavation material, virgin material, and recycled material. If a higher resolution has been defined for the material type dimension of stock matrices (e.g. distinguishing excavation material between clay, sand, rock etc.), then the material flows can be understood more precisely by the disintegration of the main flow into its underlying flows. For example, the flow A_{4-6} visualized as excavation material is really the collective flow of many individual flows from different points in the lithosphere (4) to the transport process (6). Each of these flows will be indicated with its locality within each stock, e.g. $A_{4.P1-6}$, if material is derived from excavation into position 1 (P1) in the lithosphere stock (4).

The MFA system may also be reflected in the form of a matrix (Müller, 2016a) (Figure 2.5). Each process and stock is represented both on the row axis and column axes. The flows are indicated in the pixels going from the row axis to the columns axis. Such a representation is good for data collection and storage on material flows, to provide an overview of material management. Note that matrix notation only includes flows and not stocks (Müller, 2016a).

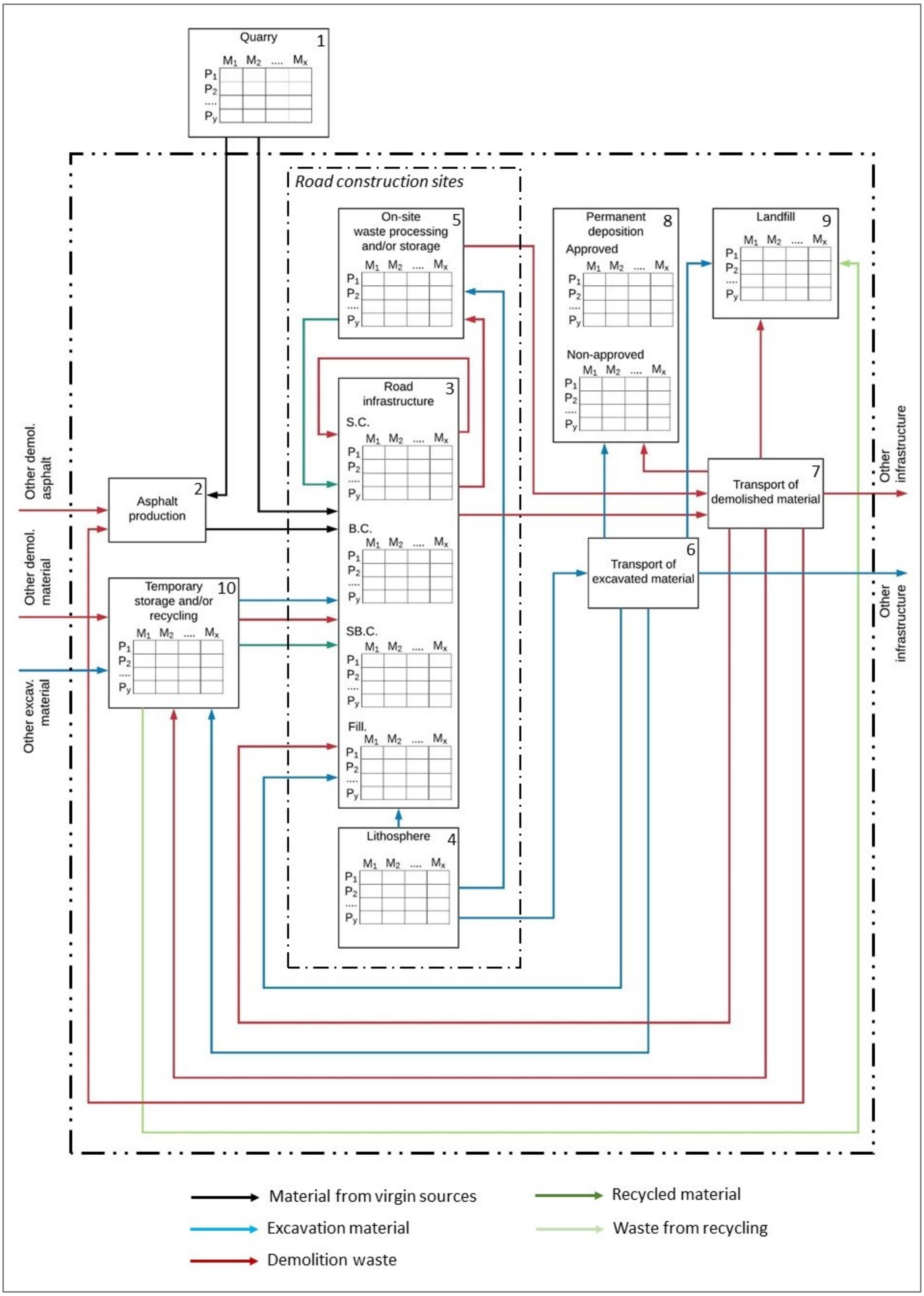

Figure 2.4 *System definition for construction aggregates in the road construction industry.*

To stock/process

From stock/process	0	1	2	3	4	5	6	7	8	9	10
0			A_{0-2}								A_{0-10} A_{0-10}
1			A_{1-2}	A_{1-3}							
2				A_{2-3}							
3				A_{3-3}		A_{3-5}		A_{3-7}			
4				A_{4-3}		A_{4-5}	A_{4-6}				
5				A_{5-3}				A_{5-7}			
6	A_{6-0}			A_{6-3}					A_{6-8}	A_{6-9}	A_{6-10}
7	A_{7-0}		A_{7-2}	A_{7-3}					A_{7-8}	A_{7-9}	A_{7-10}
8											
9											
10				A_{10-3} A_{10-3} A_{10-3}						A_{10-9}	

Figure 2.5 *Matrix notation of the system definition. Representing material flows as a matrix is good for data collection and storage. Note, that the matrix notation only includes flows and not stocks.*

Table 2.1 *Description of stocks and processes in the MFA system definition*

Nr.	Process/Stock	Description
S-1	Quarry	The material in a quarry, which for a given year is considered a profitable reserve.
P-2	Asphalt production	The process of producing asphalt, virgin as well as recycled asphalt.
S-3	Road infrastructure	All material, which is either in the road body itself or in fillings that are related to the road. The infrastructure stock is distinguished between *surface course, base course, sub-base course,* and *filling*. Processes of road construction and demolition are included in the road stock.
S-4	Lithosphere	The source for excavation material during construction and demolition.
P-5	On-site waste processing and/or storage	On-site processing of demolition and excavation material to be used within the same construction project. At some construction sites, space is reserved for storage.
P-6	Transport of excavation material	The transport of excavation material *out of a specific construction site*, and from there further distributed. The destination has been determined, when the transport begins.
P-7	Transport of demolition material	The transport of demolition material *out of a specific construction site*, and from there further distributed. The destination has been determined, when the transport begins.
S-8	Permanent deposition	The deposition of material in such a way that it can not be reused for other purposes at a later point in time. This includes deposition on farmland, filling purposes, terrain management etc. Permanent deposition is distinguished between as *approved* and *unapproved*. The Norwegian Environment Agency (*NO: klima- og miljødepartementet* (KLD)) must approve all allocations outside construction sites, which are not recycling (Hartnik, 2018). Unapproved deposition is all permanent deposition, which has not been approved by KLD.
S-9	Landfill	The permanent deposition of material at sites, which has been approved for landfill by the county authority. It is considered a landfill, if material is stored at a site for more than two years.
S-10	Temporary storage and/or recycling	The storage of material without treatment and/or recycling with or without prior storage. Demolition and excavation may be stored at temporary storage sites for up to one year before final treatment, or up to three years if it is going to recycling (§9-2, Avfallsforskriften; Hartnik, 2018). The recycling of demolition and excavation material happens at recycling terminals.

2.2.1 Road sections and compartments

By road compartment, we mean a specific segment of the road profile. All roads are approached with a four layer terminology: surface course (S.C.), base course (B.C.), sub-base course (SB.C.), and filling (Fill.) (Figure 2.6). These layers are in reality often disintegrated into several more layers (e.g. upper base course, lower base course), however, the four layers indicate general levels of material quality requirements increasing from filling purposes towards the surface course (Statens vegvesen, 2014). The segmentation is implied in the system definition by four separate matrices in the road infrastructure stock.

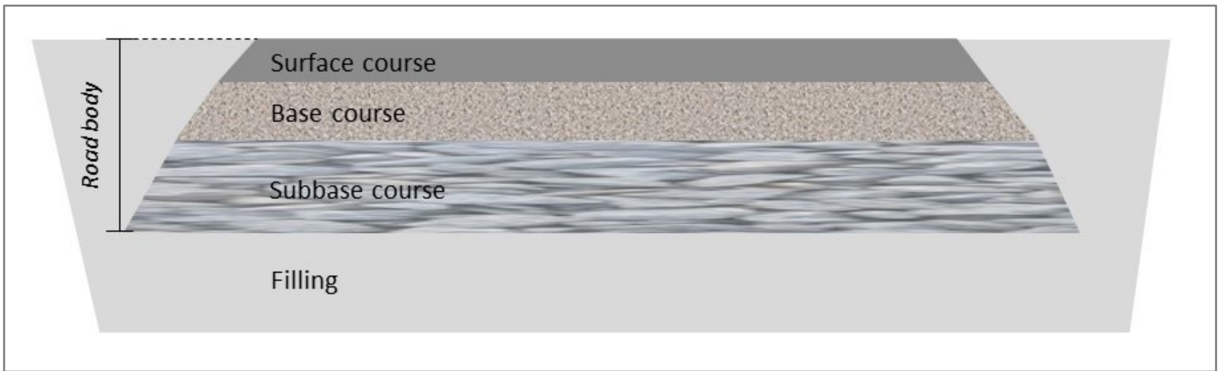

Figure 2.6 *Four layer terminology for roads: Surface course, base course and sub-base course (making up the road body) and filling.*

2.2.2 Material type definitions

Some applications set particular requirements to the properties of material, why distinguishing between different material types is important to: 1) Identify suitable material for each application. And 2) Detect if high quality material is downcycled by deployment in low-requirement applications. In order to implement a separation of material into the system, we need to define criteria against which the material can be evaluated. No units of material are completely identical. Variations occur in mineral composition and/or genesis, which in terms lead to variations in the properties of the masses. Therefore, we need to decide on a level of resolution, which balances a sufficient understanding of the material quality, with a reasonable level of investigation.

A meaningful division of materials is not within the scope of this thesis, but should be developed in corporation between road authorities and contractors. For the case study, we use a division, which is compliant with the information, we were able to gather on material stocks.

2.2.3 Spatial resolution and 3D software

By including spatial resolution, we 1) allow for the MFA to be a comprehensive database on material stocks and flows, where the physical boundary can be defined according to analysis purposes, and 2) are able to couple quality-corresponding material with considerations to transport distances. Disintegration of space is natural to 3D software, where space is divided into 3D voxels of a given resolution (e.g. 1m x 1m x 1m). This is illustrated in Figure 2.7. The position of a voxel is given by its relative position in the grid. When 3D models are applied to the MFA system, each row will indicate the location of a voxel. Material type is indicated on the column axis of the table of each stock.

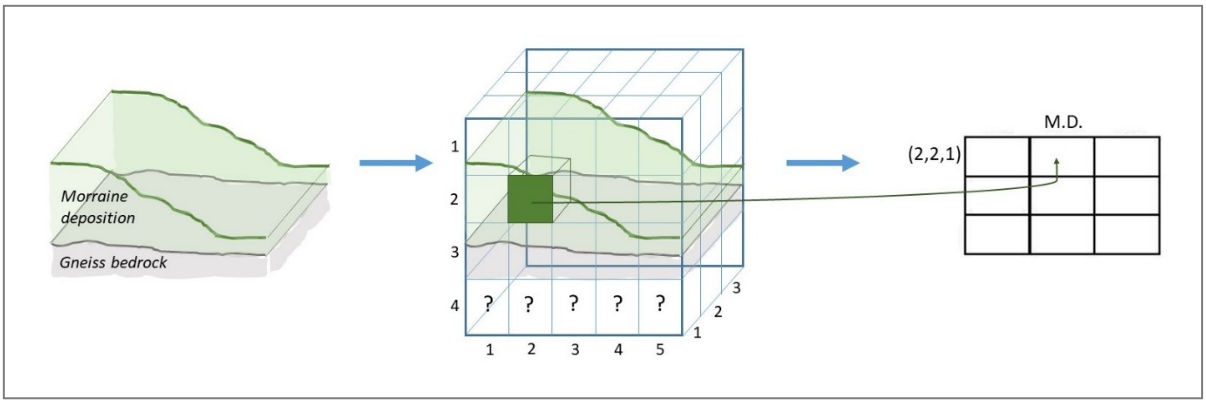

Figure 2.7 *Landscape divided into voxels by the application to 3D software. Numbers on the axes indicate the relative position of a voxel in the grid. Thus the selected voxel has the spatial reference (2,2,1). Question marks indicate voxels, where the material content is not yet known. The transfer to MFA with locality on row axis and material type (M.D. = Moraine deposits) on the column axis.*

When the MFA is applied for database purposes, the physical boundary for each stock is infinite. The entirety of space is divided into voxels, which allows for a continuous expansion of our knowledge on the content of the stocks, without having to redefine the system boundary. This is illustrated by question marks in Figure 2.7. By making the physical boundary infinite for all stocks, we also mitigate the issue of areas transforming into another stock type. Physical definitions should not move between stocks, only masses. For example, when the lithosphere is excavated for road construction purposes, the spatial location is implied for all stocks, and for the particular location the content is simply regarded as zero in the lithosphere stock after excavation.

Note that for analysis work, we need to define a physical boundary for the system in order to make materials flows and stocks consistent with one another. The boundary must be defined for all three spatial dimensions.

Currently only road projects are designed in 3D software, while other stocks in the MFA system are known with much lower spatial resolution. Therefore, for other stocks, the spatial location may be comprised to location types. In the case study, excavation material is transported to fields for permanent deposition. The contractor knows that material is deposited on fields, but not on what specific field, and definitively not how the material has been distributied onto the given field. In this case, the spatial location of each deposition will be comprised to one: *fields*.

2.3 Data

This thesis is highly based on interviews with different stakeholders related to the construction industry. In total, six open interviews and four semi-structured interviews were carried out. In addition followed email correspondence with the same interview subjects. A total list of interview subjects is found in Appendix A. Interview notes from the open and semi-structured interviews are found in Appendix C.

Open interviews and literature were used to gain an initial understanding of material management within the road construction industry and to develop a first generic system definition. Legislative and regulatory documents were important to understand the framework for material management and thus flow, stock, and process definitions (Plan- og Bygningsloven, 2008; Avfallsforskriften, 2004; Mineralloven, 2009; Forurensningsloven, 1981). Handbooks from SVV were used to understand requirements for road body components and material types, providing an understanding for the disintegration of the road infrastructure stock (Statens vegvesen, 2013, 2014). The preparation work carried out prior to the current MSc thesis, provided an understanding on 3D spatiality of stocks (Rasch, 2017). The system definition was tested and adjusted accordingly by the conductance of a second round of open and semi-structured interviews, as well as by the application of data from the case study. Interviews, literature, and the case study also provided information on the current barriers for better material management.

A road section of the *E6 Jaktøyen – Sentervegen* road construction project was selected as a case study for testing and exemplifying the system definition. Data was gained from the contractor of the project, PEAB (Hedlund, 2018). The project is ongoing (estimated to finish is 2019), but a section which is already finished was selected, why data represents actual figures. The figures were estimates from the contractor, and were not extracted directly from 3D models on the material stocks.

2.4 Interviews

10 interviews were carried out with nine interview subjects. We sought to include a range of different stakeholders from the construction industry, and the interviewed stakeholders include representatives from contractors (Johannessen, 2018a; Hedlund, 2018; Johannessen, 2018b), consultants (Carlsen and Vicario, 2018; Vicario, 2018), industry organizations (Aakre, 2018), mining industry (Olsen, 2018), road authorities (Haugen, 2018; Aamodt, 2018), and other authorities (Hartnik, 2018). All interview subjects were asked, if they wished to stay anonymous; all interview subjects allowed referencing.

Interviews were carried out as open interviews and semi-structured interviews. In total, six open interviews and four semi-structured interviews were carried out. In Appendix A, the interview type is indicated for each interview subject. No interviews were recorded, and therefore for all interviews, notes were written during the interviews. Interview notes are available in Appendix C.

The open interviews were carried out as conversations starting out at a pre-defined theme, but with room for the conversation to develop into other topics. Prior to the interview, we presented the problem understanding to the interview subject as described in the introduction (Chapter 1) and in the conceptual approach (Chapter 2.1). Further we discussed the interview subject's relevant competences to set the frame for the interview.

For the semi-structured interviews, we developed a generic interview guide including questions on five topics of interest: 1) Material management, 2) Optimized material utilization, 3) Reporting on data, 4) Timing, and 5) 3D software. The interview guide is given in Appendix B. Semi-structured interviews secure that investigated topics are approached, while still leaving freedom for the interviewer to follow up on potential new and interesting aspects. No interviewees were given the questions in advance, although they were informed of the five themes.

The collected data was visualized in a display with interview subjects on the row axis and selected themes on the column axis (Appendix D). The themes of the display analysis correspond roughly to the themes given in the interview guide: 1) Mass management, 2) Accounting and reporting, 3) Barriers and initiatives, and 4) 3D software. By presenting a display, an entire data set is assembled in an organized way in one place, which creates an overview for the analyst (Dahler-Larsen, 2010). To extract data to the display, all interview notes were reviewed and statements were color coded according to the appropriate theme. All marked statements were introduced into the display.

All interview subjects were invited to look through the results chapter. They were given a week to respond to any content they disagreed on. Three of nine interview subjects responded; one had no comments, while two had minor feedbacks, which were then corrected for.

2.5 Quantification (case study)

For accessibility reasons, we decided to use the *E6 Jaktøyen – Sentervegen* road construction project as the case study for testing and quantifying the system definition and exemplifying how stock models are used to predict material flows for a project. The contractor's headquarter is located in Heimdal in Trondheim municipality, which made in-person communication between the contractor and the author possible.

Note, the quantification only concerns one road, and therefore not all flows and stocks in the system definition are active. We focus on the material flows generated for the sub-system *Road construction sites* from the stock development of one road section. When including the entire system definition, we exemplify the impact of one project to the system.

The entire road construction project is expected to finish in 2019, however, several sections of the road are already finished. We wanted to inspect an already finished section to illustrate the actual material management, rather than projections, allowing us to validate conclusions on material management gained from the interviews. Together with the contractor, we decided on a road section in the southern part of the road construction project by Klett. The premises for the selection were:

- The road section should already be finished.
- The road section should include demolition of old road infrastructure and excavation to illustrate material management of both demolition and excavation material.
- The road section should be representative for the general material management of the road construction project.

Material quantities for transportation within and out of the construction site, i.e. material flows, are derived prior to construction in the comparison of the current stock to contract proposals, i.e. the stock after construction (Figure 2.8). We define the stock prior to construction as the stock on 1 January 2016 and the stock after construction as the stock on 31 December 2019.

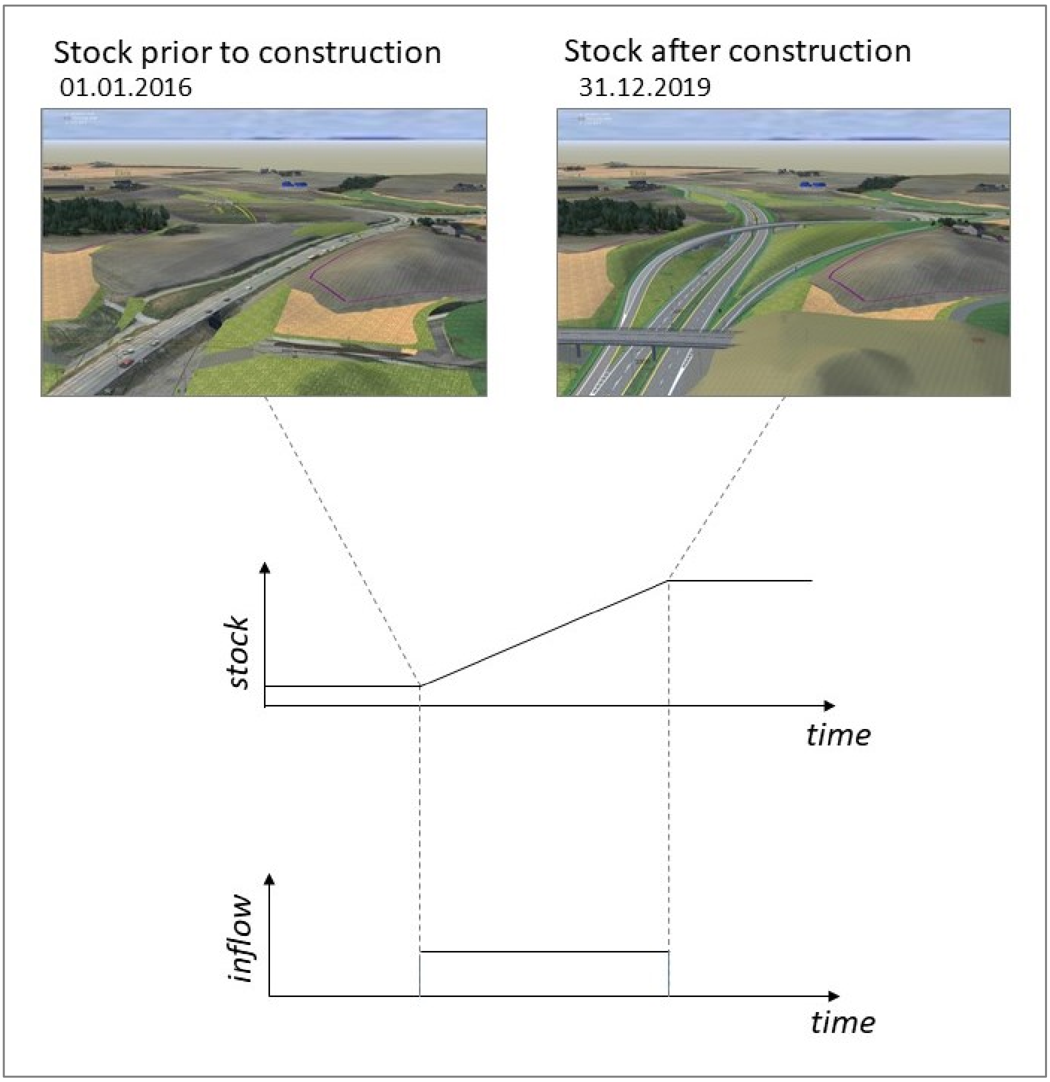

Figure 2.8 *Deriving material flows through stock models. 3D models from PEAB Anlegg on E6 Jaktøyen – Sentervegen before and after construction.*

Prior to construction, the new road project was designed in Gemini 3D software. The 3D model does not provide material quantities in voxel format, but allows for quantifying the infrastructure stock by extracting cross-sections from the model, usually at 10 meter intervals, and deciding the volume between the cross-sections. In this thesis, the quantification of the road infrastructure stock is not based on quantifications through the model due to it being a time-consuming process, but instead on estimates by Hedlund (2018). However, the process was demonstrated to the current author. The volume (V) of a given road compartment (c) for a given section (s) is determined by deciding the mean of the areas (A) of each cross-section (cs) and multiplying it with the distance (D) between the two sections (eq. 1). α and β imply two arbitrary cross-sections. The distance between two cross-sections are decided dependent on how drastic changes are along the road and the required level of precision.

$$V_{c,s(\alpha,\beta)} = \frac{A_{c,cs(\alpha)}+A_{c,cs(\beta)}}{2} \cdot D_{\alpha\beta} \qquad \text{(eq. 1)}$$

The material content in the stock by 1 January 2016 was poorly quantified prior to construction. The lithosphere for excavation was quantified, but it is difficult to determine the exact quantities, which will be of use, due to the extensive risk of quick clay in the area. In addition, the material content in the old infrastructure was not properly documented when originally constructed due to the age of the road. Therefore, material quantities in the old infrastructure were not entirely understood prior to construction. Still, the purpose of use for the demolition material was already partly determined by the contractor. In this thesis, we illustrate the principle of deciding flows based on comparisons between the stocks prior to and after construction, although in reality, the stock prior to construction is partly determined retrospectively.

As the 3D model was not used as the basis for quantification, spatial resolution was comprised to location types rather than individual voxels. Five stocks were active in the quantification: *Road infrastructure*, *Lithosphere*, *Quarry*, *On-site waste processing/storage*, and *Permanent deposition*. For the road body of the *Road infrastructure* stock, the location types aligned with the road body composition given in Figure 3.3, while *filling* was separated into three localities: *stream 1*, *stream 2,* and *construction road*. The spatiality of *On-site waste processing/storage* was just depicted *On-site storage*. Spatiality of *Quarry* was given by producer (*Franzefoss Pukk at Vassfjellet* and *Ramlo Sandtak at Vassfjellet*), while *Permanent deposition* was comprised to *fields* with no specific spatial indication.

For the *Road infrastructure* stock, material type resolution corresponds to requirements in Statens Vegvesen (2014). For other stocks, the material resolution is determined by the terminology of Hedlund (2018), i.e. clay from excavation.

To determine flows, quantities are indicated from the calculated stock changes, while it is the contractor's decision on material management, which determines how stock changes are satisfied. From interviews with Hedlund (2018), we gained an understanding of material flows into, out of, and within the selected road section of the *E6 Jaktøyen – Sentervegen* road project. In that way, the case study was also used to validate the material management on construction aggregates in road construction suggested in interviews. In addition, the case study revealed the need for an *On-site waste processing/storage* stock, which had otherwise not been included.

2.6 Uncertainties

2.6.1 Interview

The risk of bias must always be considered for interview data. Interview subjects account on their personal experience and interpretation of a subject, presenting the risk of bias in the dataset. In this thesis, we sought to include interview subjects from a range of different stakeholder groups, thereby including several different approaches to the same central topic of material management. While a wider scope of stakeholders should mitigate the risk of bias, a total of ten interviews may be regarded in the low end (Baker and Edwards, 2012). For this smaller interview sample size, the risk of bias will be especially evident for topics, which concern only one stakeholder group. For example, a topic like *On-site practical issues towards better management* concerns mainly the stakeholder group *Contractors*. As we have only carried out interviews with well-established contractors, we potentially neglect different aspects from smaller construction sites to the topic. In addition, interview subjects were chosen because of the subjects' prior interest and knowledge on the topic of improving material management in the road sector. Therefore, interview subjects may hold a stronger opinion to the topic than the stakeholder group in general. However, interview subjects with former experience on the topic will provide a greater in-depth understanding of the topic.

Display analysis organizes data in an approachable manner, but is equally a tool, which supports evaluating the risk of uncertainty in data. The display visualizes how saturated data are, if the opinions of certain stakeholders are overrepresented (holding the risk of bias in data), and whether there are disagreements between different stakeholders. Data is less saturated for the topics *Accounting and reporting* and *3D software*, however, we expect this to be a consequence of the general understanding of these topics being lower among the stakeholders. We find a slightly greater representation of industry stakeholders (contractors, consultants, industry organization, mining industry) to public authorities (road authories, other authorities). This is a natural consequence of a lower availability of stakeholders within public authorities. However, this may understate potential conflicts in the public, legal, and regulatory systems in the shift for a better material management. Lastly, we find, no apparent disagreements between interview accounts, however, different interview subjects emphasized different topics.

As with all other communication, it cannot be neglected that the interviewer will interpret the message differently than what the interviewee intended. By inviting interview subjects to read the result section and approve statements for which they are cited, we seek to reduce the risk of citing wrongly because of misunderstandings. The respond rate was 33 %.

2.6.2 System definition and quantification

We must be confident that our system definition is defined correctly. Initially we can test this by checking the system for mass balance consistency. If the mass balance principle is violated this is an indication that either 1) the system is defined incorrectly, or 2) flow data are wrong (Müller, 2016b). In this thesis, to define our system definition with confidence, we have performed interviews with several stakeholders as well as applied a case study to test the system definition. However, in the case study, not all flows are quantified, and therefore we cannot check for mass balance consistency for the entire system. To thoroughly check for mass balance consistency and secure more robustness in the system definition, a regional quantification would be suggested.

For the case study, we quantified the stock prior to and after construction as well as material flows, based on estimates from Hedlund (2018). However, no estimates of the uncertainty of these values were gathered. Quantifications of the stock prior to construction (stock on 01.01.2016) should probably be guarded with some uncertainty, although reviews on drawings of the old infrastructure as well as inspections of the lithosphere were done prior to initiating construction (Carlsen and Vicario, 2018). Samples of the lithosphere are collected with certain intervals and to certain depths, and the material outside of these sample points may show to differ from what was expected. In the current project, it was not possible to predict exactly the quality of the excavated clay, and hence the potential purpose of use, due to extensive quick clay formation in the area. Neither was the material content in the old infrastructure known properly, as project drawings were not updated according to changes during construction of the old infrastructure. Poor knowledge on the material content in the stock prior to construction is a general issue in the construction industry.

The stock of the infrastructure after construction (stock on 31.12.2019) may be more precisely determined from road modelling prior to initiating the work. Today road models are mainly carried out in 3D software, which provides a good understanding on the road geometry and thus the required material. When volumes are determined in Gemini 3D software, precision may be increased by reducing the distance between road sections. In addition, due to the importance of these masses to the project economy, land surveys are carried out after the construction of each road course to decide the exact material content of the stock after construction (Hedlund, 2018). This equally provides a high confidence in material inflows to the *Road construction site* subsystem. These quantities may also be validated by comparison to excavation data from quarries.

Demolition and excavation material being used internally on the construction site are regarded with higher uncertainty. Contractors are not obligated to report on these masses to the infrastructure owner, and the material hold less importance to the project economy. The material is often used for filling purposes, for which handbook requirements are less strict providing greater flexibility for ad hoc changes in the final design. The exception is asphalt, which holds a high value due to its bitumen content. Material outflows from the construction site should also be regarded with low to medium uncertainty, also due to its importance to the project economy due to high transportation costs. However, the quantity of these masses are not checked systematically in the same way as material inflows. Material outflows may equally be validated against reported quantities from landfills, temporary storages and recycling terminals, but, expectedly not for permanent deposition. Data on material transport from transport companies could possibly be used to validate both inflow and outflow of material from construction sites.

One aspect, which should be considered in regards to flows for permanent disposition, is the illegal deposition (*NO: villfyllinger*) of materials outside approved sites. These flows can only be calculated or estimated through mass balance calculations, while not measured. Neglecting these flows will provide uncertainties in target development and evaluation. As a result, recycling rate may be regarded higher than what is actually the case. By the advance of 3D models to include information on the lithosphere, into which excavation will occur, we will have more certainty to material outflow and to a larger degree avoid the problem of illegal deposition.

3 Results

Chapter 3.1 outline the current situation for material management, which has provided the foundation for developing the system definition. In this chapter, we also present the quantification of the MFA model by the application of material flows and stocks from the selected road section of the *E6 Jaktøyen – Sentervegen* construction project. We illustrate how the MFA model would have supported an optimized management of material flows, if it had been applied prior to construction. In Chapter 3.2, we elaborate on the current accounting and reporting scheme on material flows and stocks, which is necessary to support a quantification of the suggested MFA.

Chapter 3.3 presents the main barriers, which prohibit contractors from managing construction aggregates in a way more compliant with the circular economy system.

Lastly, Chapter 3.4 elaborates on the benefits and barriers of using BIM software in the construction industry.

3.1 Material management in the construction industry

Currently all construction projects seek to optimize the material management within individual construction projects as the most important mean for reducing costs. The purchase, transport, and deposition of material is often determining the profitability of a construction project, therefore, internal supplies are utilized for internal demands if the demolition and excavation material is of suitable quality (Johannessen, 2018a; Vicario, 2018b; Aakre, 2018; Hedlund, 2018). Some consultants and contractors use specialized software, such as DynaRoad, to plan and optimize the material transfers within the project. The software analyzes where for instance excavation materials may be used internally and it suggests a work progress, which among other reduces transport distances and required temporary storage time and space (Vicario, 2018; Johannessen, 2018b). However, one contractor pointed out that such tools are more useful for projects with mainly large fillings and less useful for projects with smaller fillings. This is due to the time flexibility for larger fillings as compared with smaller fillings. In projects with smaller fillings, the transfers between supply and demand are done on ad hoc basis as they occur (Hedlund, 2018).

When internal supplies and demands are not comparable, external material transfers are necessary (Figure 3.1, *simplified version of the system definition Figure 2.2*). Demands are satisfied by purchasing materials from quarries (1d), purchasing material from recycling stations (2d), purchasing material from temporary storage (3d), or receiving material from other construction projects (4d). Supplies are disposed of by depositing material to landfill or other permanent deposition (1s), transporting material to recycling (2s), transporting material to temporary storage sites (3s), or transporting material to other construction projects (4s). When material is transported outside a construction site and reused, the material must be CE-marked (ReStone AS, 2018). Thus flows 1d, 2d, 3d, 4d, 2s, and 3s are CE-marked.

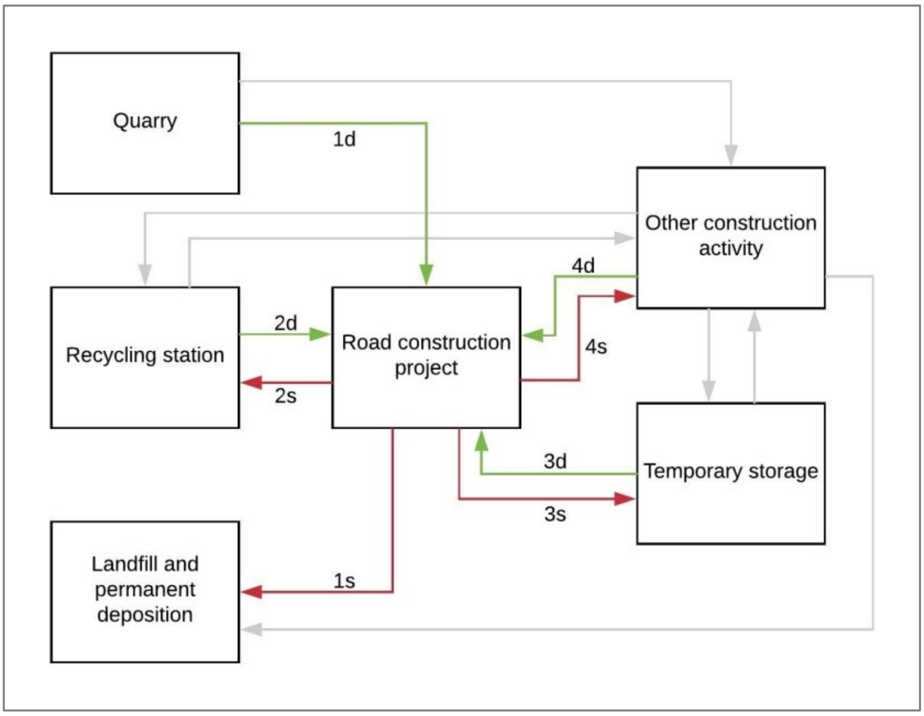

Figure 3.1 *External material transfer from construction project . Green arrows indicate material flows into the construction projects to meet a material demand. Red arrows indicate material flows out of the construction project because of excess of internal material production.*

Material transfer between two construction projects

According to interview accounts, the material transfer between construction projects is limited (Johannessen, 2018b). Coordination must generally happen in the planning phase of a construction project for transfers to be realized (Zide, 2018; Vicario, 2018). The coordination may either happen on initiative of the infrastructure owner and included in the RFP, or the consultants and contractors may include it as advancement in their proposal (Vicario, 2018) as a measure for reducing costs and promoting an environmentally concerned profile. In either case, such coordination mainly happens if either the infrastructure owner or the consultant/contractor by coincidence knows about or is involved in other projects nearby (Vicario, 2018). There is currently no central and organized system that facilitates cross-project coordination (Aamodt, 2018). Increased coordination is one aspect currently targeted by the Kortreist Stein project, running from 2016 until 2019 (SINTEF Byggforsk and Veidekke Entrepenører, 2016). At least two applications, TippNett and Looprocks, provide web-based platforms for marketing excess material, but they are currently only small players on the market (Zide, 2018; Johannessen, 2018b).

When material is acquired directly from other projects, the material quality has to be declared, but the material has usually not been sorted by size (Johannessen, 2018b). The material must be CE-marked (ReStone, 2018). The contractor may choose to process the material in mobile recycling units on-site to use it in e.g. the road body, but generally the material is used for filling purposes (Johannessen, 2018b). It seems that currently the material utilization both within and between projects mainly regards the utilization of quantities rather than qualities. Asphalt is an exception to this, due to the high value of bitumen. Asphalt is usually either crushed and used in the base course, or melted and reused as asphalt in the lower surface courses (Hedlund, 2018).

The use of mobile recycling units are limited and mainly confined to larger projects. This is due to 1) the durable application process for a permit from the county for setting up the unit (Johannessen, 2018b) and 2) the cost of moving and setting up the unit is only compliant with larger construction projects (Olsen, 2018).

Material from quarries and to/from recycling terminals

Whether material is acquired from quarries or recycling terminals, it has been processed (washed, sorted, and quality-tested) and holds corresponding declarations of type, quality, and grainsize (Olsen, 2018; Johannessen, 2018b). Contractors usually request only information on quality and price (Johannessen, 2018b), and due to the corresponding qualities, the buyer can usually not distinguish between recycled waste and similar quality virgin material. Both the mining industry as well as several contractors including Skanska and AF Gruppen own recycling terminals (Johannessen, 2018a; Olsen, 2018).

When material is brought to recycling terminals, contractors pay a fee. The fee normally corresponds to recycling costs so that recycled material can be sold to a market price equal to that of virgin material (Olsen, 2018). Franzefoss AS is one stakeholder, which concurrently both quarries material and recycles material. Although, currently not set up to take in large quantities of material for recycling, the enterprise joins the sustainable mindset, and is positive towards a shift with increased recycling rather than virgin material extraction, provided that it is economically beneficial (Olsen, 2018). Asphalt currently has a high recycling rate due to the high value of the product, making recycling profitable (Olsen, 2018; Hedlund, 2018).

Landfill and permanent deposition

Currently, a great share of demolition and excavation material is assumed to go to landfill and other permanent deposition in Norway (Carlsen and Vicario, 2018; Johannessen, 2018b; Haugen, 2018; ReStone, 2018). Barriers for a better material management are outlined in Chapter 3.3.

Landfill and permanent deposition are separated in terms due to their difference in regards to legislation. According to the Waste Regulation, landfilling is the final and permanent deposition of material (§9-3, Avfallsforskriften). However, regulations on landfill in the Waste Regulation do not apply to '*1) the use of inert masses for terrain regulation and rehabilitation, filling, and construction purposes, 2) deposition of non-polluted soil, nor 3) deposition of mud along rivers, lakes, and fjords'* (§9-2, Avfallsforskriften). Natural clean masses are rarely brought to authorized landfills (Hartnik, 2018), but may be deposited in other ways, in which they are compliant to the landfill regulations.

It is also important to separate between recycling and permanently deposited materials. Although materials are used for specific purposes such as ground leveling, noise embankments, and other filling purposes, it may not always be considered recycling. According to EU, *recycling* is only applicable to situations in which the recycled material replaces virgin material excavation, for purposes that would have been carried out independently of access to recycled material (Hartnik, 2018). Further, the Waste Regulation states '*Use of waste for the manufacture of […] materials, which will be used as […] filling material is not accounted as recycling*' (§1-3, Avfallsforskriften). An example of a useful purpose, which will often not be considered recycling, is the deposition of soil on fields for terrain-development.

Municipalities must approve all permanent deposition outside construction sites which lead to '*significant terrain interventions*' (§20-1 and §20-2, Plan- og Bygningsloven). In addition, the Norwegian Environment Agency (*NO: Klima- og miljødepartementet* (KLD)) must approve all material management outside a construction site, which is not recycling (§29, Forurensningsloven; Hartnik, 2018). KLD allows for permanent deposition only in special cases. When evaluating for such a permit, the social benefit of the potential deposition is an important factor, exemplified by terrain-management allowing for the establishment of a soccer field (Hartnik, 2018; §11, Forurensningsloven). KLD experiences that contractors and infrastructure owners are not aware that an approval from their entity is required, why material is often deposited only in correspondence to municipal land-use plans. KLD is currently developing factsheets to communicate the regulation (Hartnik, 2018).

Another aspect, which should be considered in relation to landfill and permanent deposition, is the illegal deposition of materials. As a consequence of the missing reporting on material flows, there is a risk that some masses are deposited illegally outside approved deposition sites. This was implied in a study for KLD in 2003 on the deposition of construction and demolition waste. Employees at landfills wondered about requests on deposition of polluted masses, which were never followed up (Norges Geologiske Undersøkelse, 2003). The occurrence of illegal deposition is also suggested by Johannessen (2018a).

Temporary storage

Excess of internal material supplies may be transferred to temporary storage sites due to the timely offset between supply and demand. In order to *not* being considered a landfill, demolition and excavation material may be stored at temporary storage sites for up to one year before final treatment, or up to three years if it is going to be recycled (§9-2, Avfallsforskriften; Hartnik, 2018). The use of temporary storage sites is comparably small, as this requires municipalities to have designated areas for this purpose in the land-use plans (Johannessen, 2018b). However, some municipalities are planning to designate areas for temporary storage as they expect large construction projects in the years to come, including Bærum Municipality (Bærum Kommune Rådmannen, 2018).

3.1.1 Case study of material management: *E6 Jaktøyen – Senterveien*

The following chapter presents an example of the material management for an actual road project, the *E6 Jaktøyen – Senterveien* road construction project (Figure 3.2). The case study is used for testing and quantifying the system definition and validating the material management suggested in interviews. We illustrate, how the stock models could have been used to predict material flows for the project prior to construction had the MFA approach been applied.

The road project was specified in regulation plans in 2012, and the construction was initiated in 2016 by PEAB Anlegg with expected opening of the road in 2019. The infrastructure owner is SVV (Statens Vegvesen, 2016). The main prospect of the project is the construction of an eight kilometer four-lane highway. In addition, the project includes the construction of a new railway bridge, a regional road running parallel to the highway, a pedestrian and bike path, and several road intersections (Statens Vegvesen, 2016).

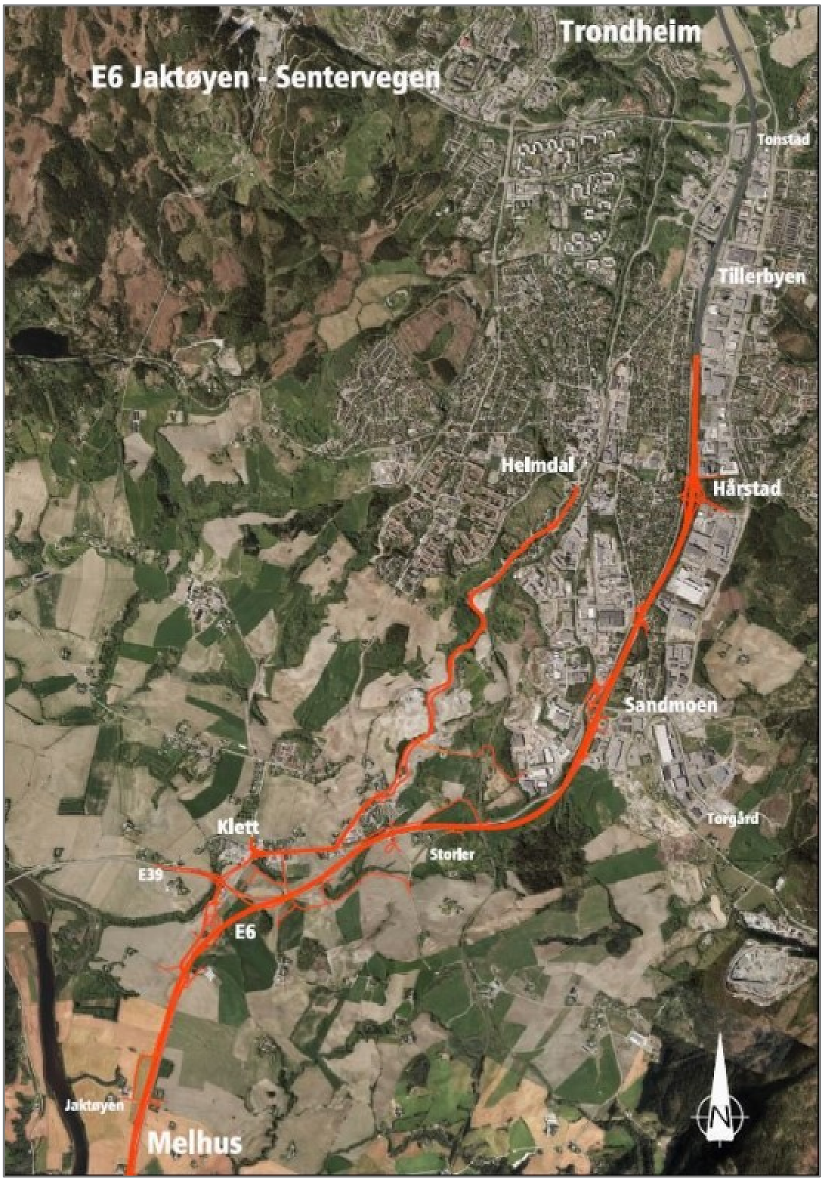

Figure 3.2 *The E6 Jaktøyen – Sentervegen road project indicated by the orange line (Statens Vegvesen, 2016). The project does not extend further south.*

Road section: Deriving stock changes from stock models

Figure 3.3A indicates the 300 m road section for which the quantification is carried out. Figure 3.3B illustrates the given section prior to construction, while Figure 3.3C illustrates how the road section will look once it is in use. The material stock of the given section prior to construction is defined as the stock on 1 January 2016, and the stock after construction is defined as the stock on 31 December 2019.

The road project was designed with the 3D software Gemini prior to construction. This allowed for an estimation of the material content of the stock on 31 December 2019. Prior to construction the stock of 1 January 2016 was also sought estimated by investigating drawings of the old infrastructure and point samples of the lithosphere. The quantification of both stocks is explained in Chapter 2.5.

Figure 3.4 illustrates how stock changes could have been derived from the models of the stocks prior to and after construction, if the MFA approach had been applied. Stock changes essentially indicate the need for flows during construction.

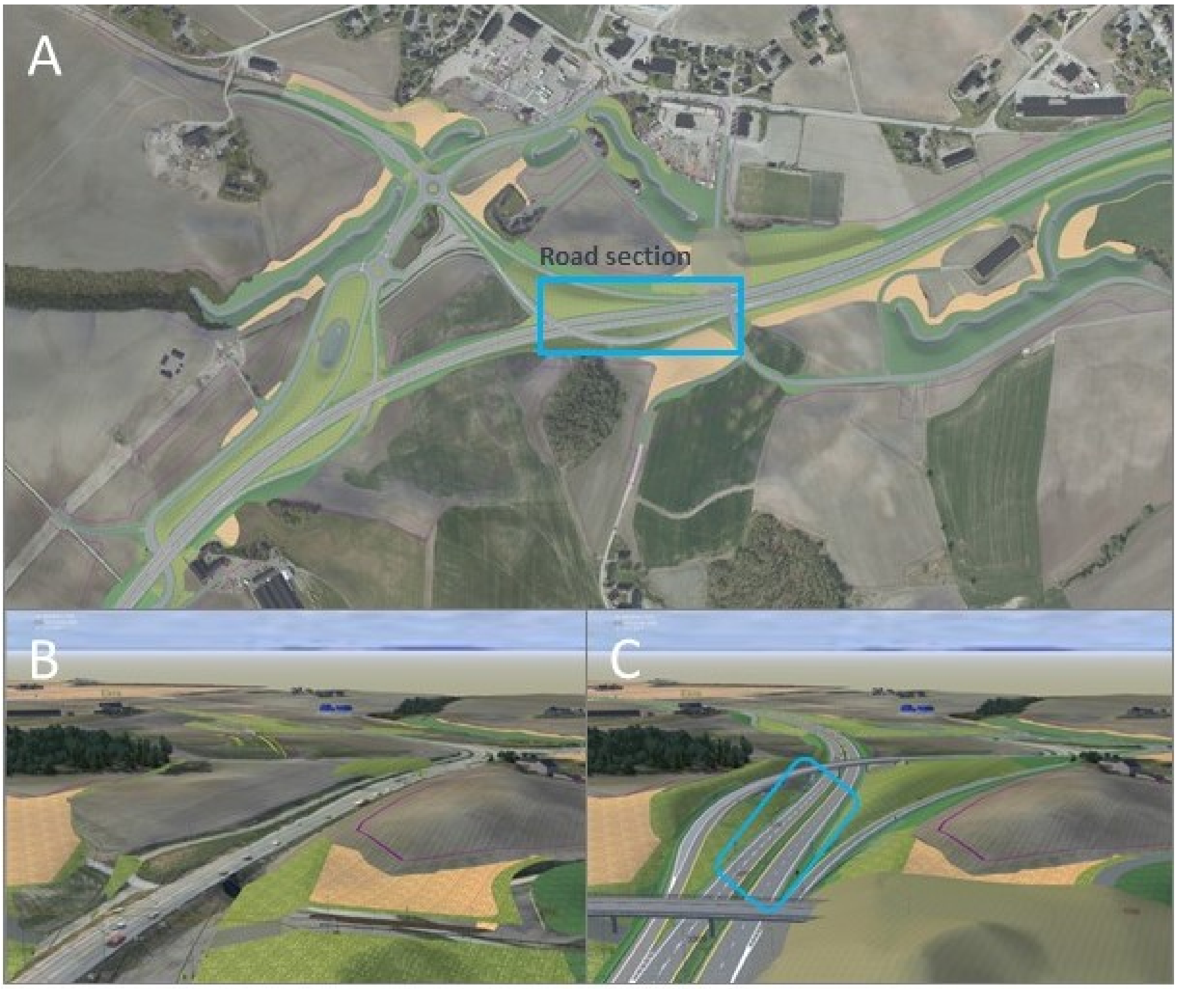

Figure 3.3 *Road section for quantification. A) Overview picture, road section for applied MFA. B) Old road infrastructure at same road section. C) Road infrastructure post construction.*

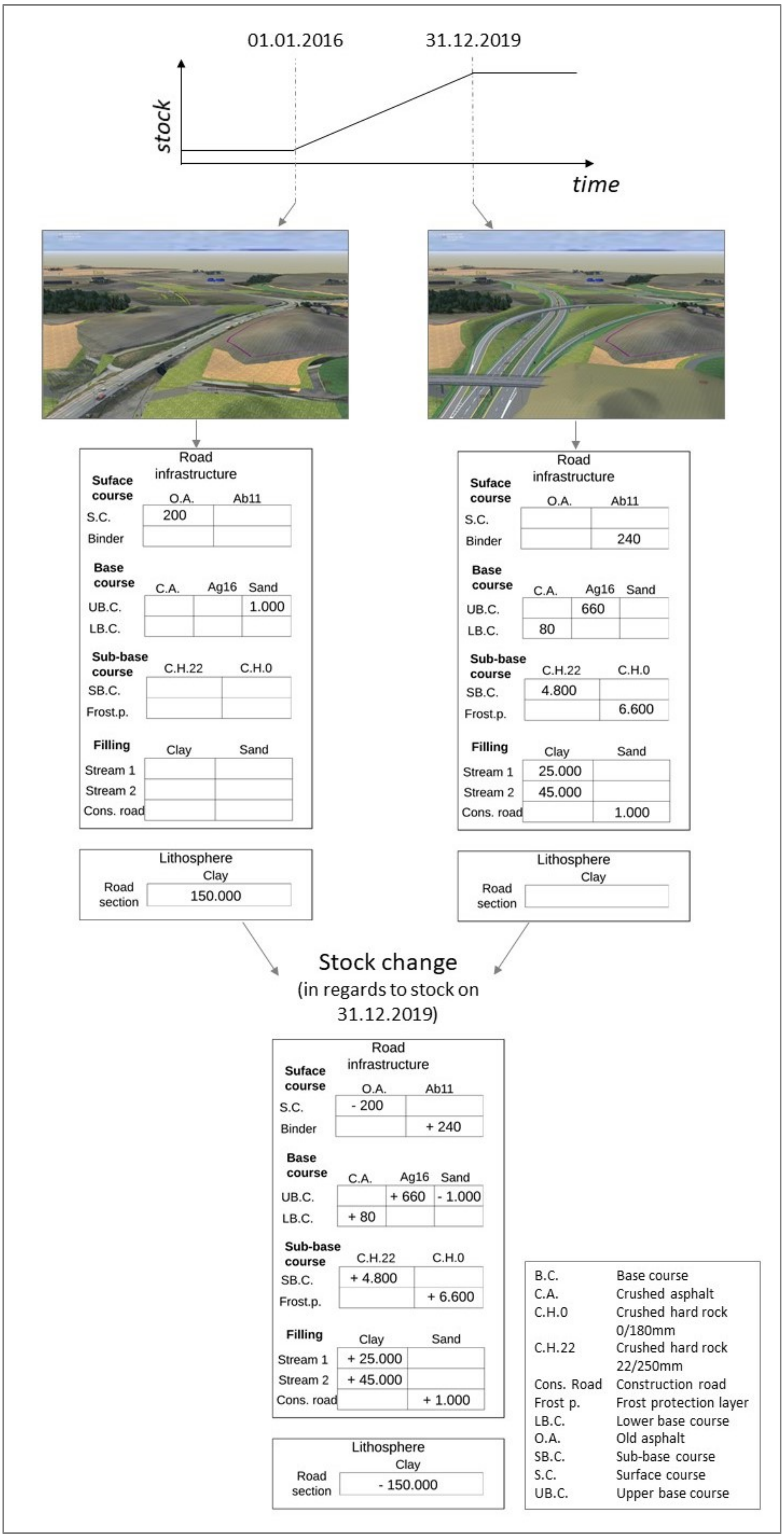

Figure 3.4 *Deriving stock changes from stock models of road section prior to and after construction. The stock changes imply the need for material flows. Quantities are in m*^{3}.

The derived stock changes indicate the quantity of material supplies and demand during construction. This can be used to identify potentials for optimizing material utilization. From Figure 3.4, we can already identify some potentials; There is an extensive supply of clay from excavation, while a concurrent high demand for clay for filling purposes. Also, the demolition of the old road infrastructure will provide demolition sand and asphalt, while the new road infrastructure requires asphalt both in the surface course and base course, as well as sand for construction roads. However, currently the quality of the asphalt in the old infrastructure is not thoroughly determined, and we are not able to evaluate if the asphalt is reusable.

While stock changes indicate supplies and demands for material during construction, and provide a framework to suggest management for better material utilization, it is the management decided by the contractor, which essentially determines the character of the flows. Therefore, in the following section, the material management for the entire *E6 Jaktøyen – Sentervegen* will be described. Afterwards, the quantification of the system definition for the road section will be continued.

Demolition and excavation material (outflows)

In total approximately 2.000.000 m^3 of masses will be excavated during the construction. Peat makes up 25 % of these masses, while the remaining material is mainly clay deposits (Statens vegvesen, 2015a). In the area around Klett, clay deposits may pose geotechnical challenges due to extensive quick clay formation. Therefore cement and lime stabilization is necessary prior to excavation (Statens Vegvesen, 2018). Parts of the old E6 is being demolished, and the resulting masses are sand (20.000 m^3) and asphalt (50.000 m^3). Demolition sand is used for filling or for construction of temporary construction roads. 40 % of demolition asphalt is crushed and used in the lower base course, while the remaining is sold to asphalt producers. So far, approximately 5 % of the asphalt has been sold to PEAB asphalt, while the remaining 55 % is temporarily stored at the construction site, while searching for potential buyers (Hedlund, 2018).

Concurrently, there is a demand for approx. 1.500.000 m^3 material for the road body and filling purposes, of which 1.400.000 m^3 may possibly be satisfied by internally excavated clay and sand material (Statens vegvesen, 2015a; Hedlund, 2018). Internal material transfers are decided on ad hoc basis due to extensive amounts of smaller fillings (Hedlund, 2018). For deposition of clay material, either not suited for filling purposes (e.g. quick clay) or in excess, agreements were made with local farmers prior to construction that the material could be deposited on their fields for leveling. The contractor pays the farmer a deposit fee. Agreements were only made with farmers who had already obtained permission from the municipality for using their fields as disposal sites (Hedlund, 2018).

Road body material requirements (inflows)

Most material required for the road body of the *E6 Jaktøyen – Senterveien* road project is imported from external sources, with the exception of the lower base course consisting of crushed asphalt, 100 % originating from demolished old infrastructure (Hedlund, 2018). Figure 3.3, outlines the composition of the road body. This is representative for the four km highway south of the railroad bridge (Hedlund, 2018). North of the railroad bridge, the road enters another climatic zone, reducing the need for a frost protection layer, and the 110 cm deep frost protection layer is replaced with a 30 cm deep lower sub-base course (Hedlund, 2018). Material for the frost protection layer is purchased from Franzefoss Pukk at Vassfjellet, while crushed hard rock for the sub-base course was purchased from Ramlo Sandtak at Vassfjellet (Hedlund, 2018). The lower base course consists of crushed asphalt of which 100 % is derived from demolition of old infrastructure within the project. The asphalt was stored temporarily on-site until enough material was gathered. Then the asphalt was crushed and applied in the road construction. The asphalt for the upper base course and the binder course were both purchased from PEAB Asphalt (Hedlund, 2018). Estimated 30 % of the asphalt from PEAB is produced from recycled asphalt (Hedlund, 2018). The wearing course will be applied to the road by SVV 2-3 years after construction has otherwise finished (Hedlund, 2018; Statens Vegvesen, 2018).

The project was designed with the 3D software Gemini prior to construction. During construction, some changes occurred compared to the projected plan, e.g. demolition sand was included as filling material. The 3D model was, however, not adjusted with these changes. The economic adjustments, which are necessary due to these changes, are carried out separately from construction models (Hedlund, 2018).

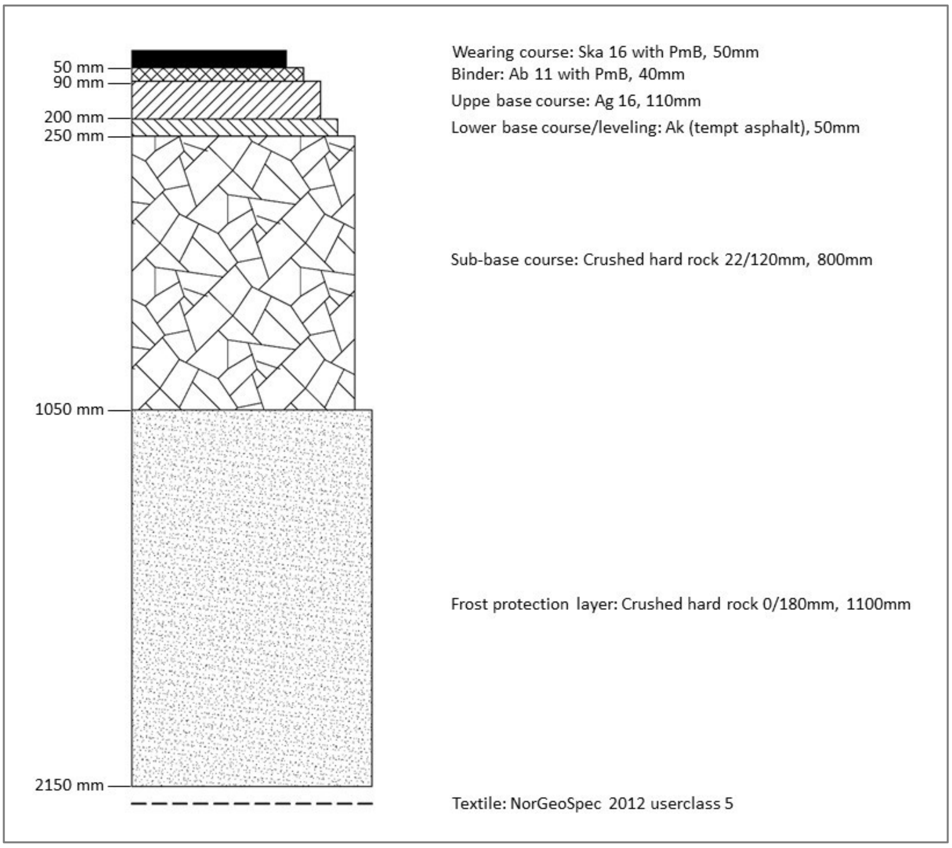

***Figure 3.5** Road body composition of the E6 Jaktøyen - Sentervegen**.** This composition was applied to the 4 km road south of the railroad bridge.*

Road section: Quantifying system definition

Initially the old road structure was removed, in total 1000 m^3 demolition sand and 200 m^3 asphalt. Sand was utilized for filling. Asphalt was crushed and either used in the lower base course, sold, or stored, with transfer coefficients of 40 %, 5 %, and 55 %, respectively. Then, 12 m of clay was excavated. Initially 2-3 m of clay was removed (25.000 m^3). These masses were transported to a stream (Stream 1 in Figure 3.6), which needed lifting for stability reasons. To secure stability of the remaining 9 m of clay, cement and lime pillars were put in the ground prior to excavation. Parts of the excavated clay from the second round of excavation was brought to another stream for lifting (40.000 m^3) (Stream 2 in Figure 3.6), while the largest share was transported out of the construction facility and disposed on fields (80.000 m^3). Then the road body was constructed according to Figure 3.5. In total, for the given road stretch material imports included: 660 m^3 Ag16 and 240 m^3 Ab11 from PEAB Asfalt, 6.600 m^3 crushed hard rock from Franzefoss Pukk, and 4.800 m^3 crushed hard rock from Ramlo Sandtak. Figure 3.6 indicates the volumes moved and their physical locality.

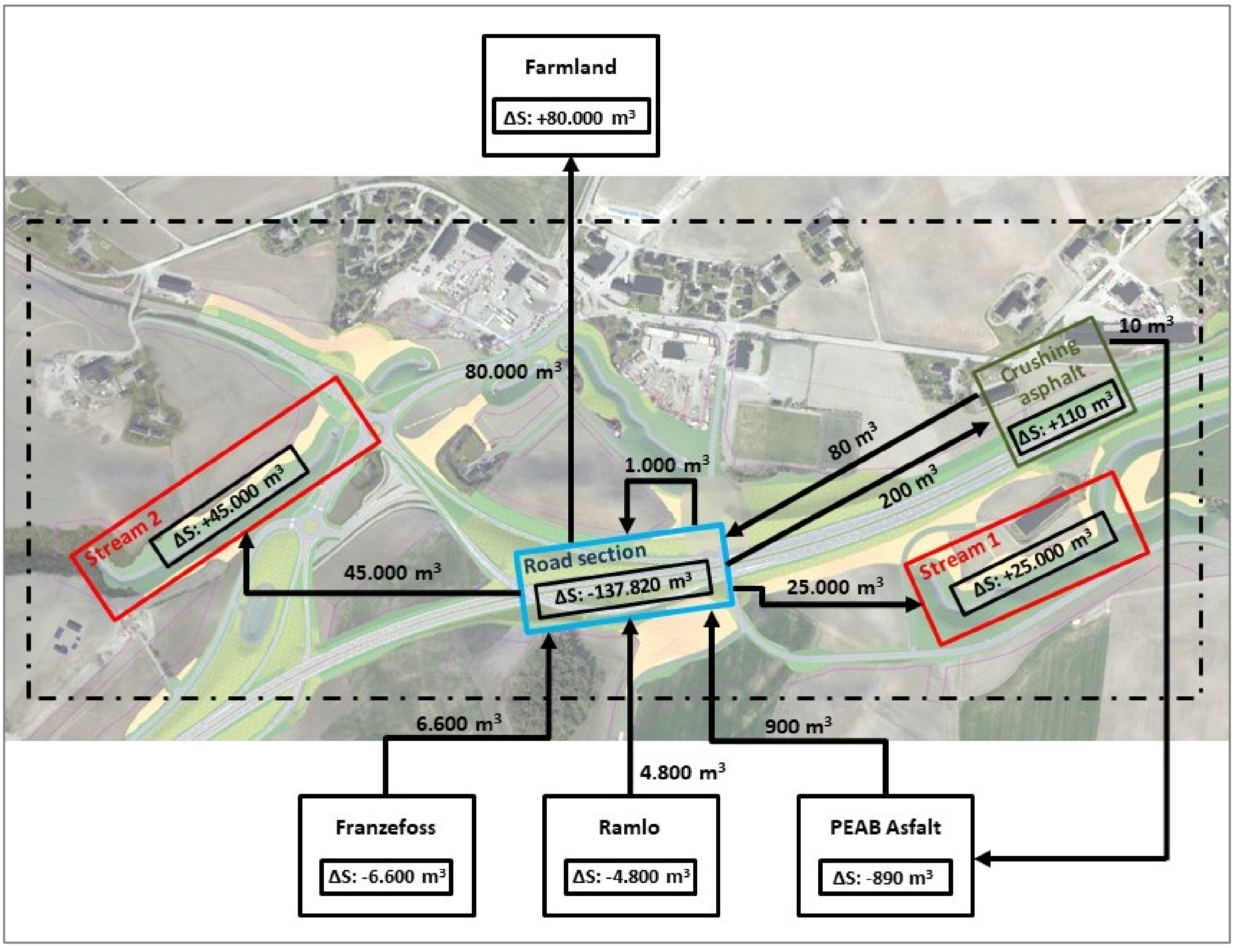

Figure 3.6 *Material flows for the investigated 300 m road section of the E6 Jaktøyen – Sentervegen. Within the construction site, the figure illustrates the actual localities of material stocks.*

The material flows were applied to the MFA system definition. The spatial resolution is not given by coordinates, as the masses were not extracted directly from the 3D model. Instead spatial resolution is given by qualitative descriptions, e.g. “fields”. The material types were defined according to the materials informed by Hedlund (2018). As road infrastructure is defined with a four layer terminology, the frost protection layer is included under the sub-base course. The binder layer is part of the surface course. The results are presented in Figures 3.7 and 3.8. In figure 3.7, the material flows generated for the sub-system *Road construction sites* from the stock development is in focus, while Figure 3.8, illustrates the impact of the one road section to the system of material management for the road sector. Figure 3.9 presents the case study application to the system definition in matrix notation.

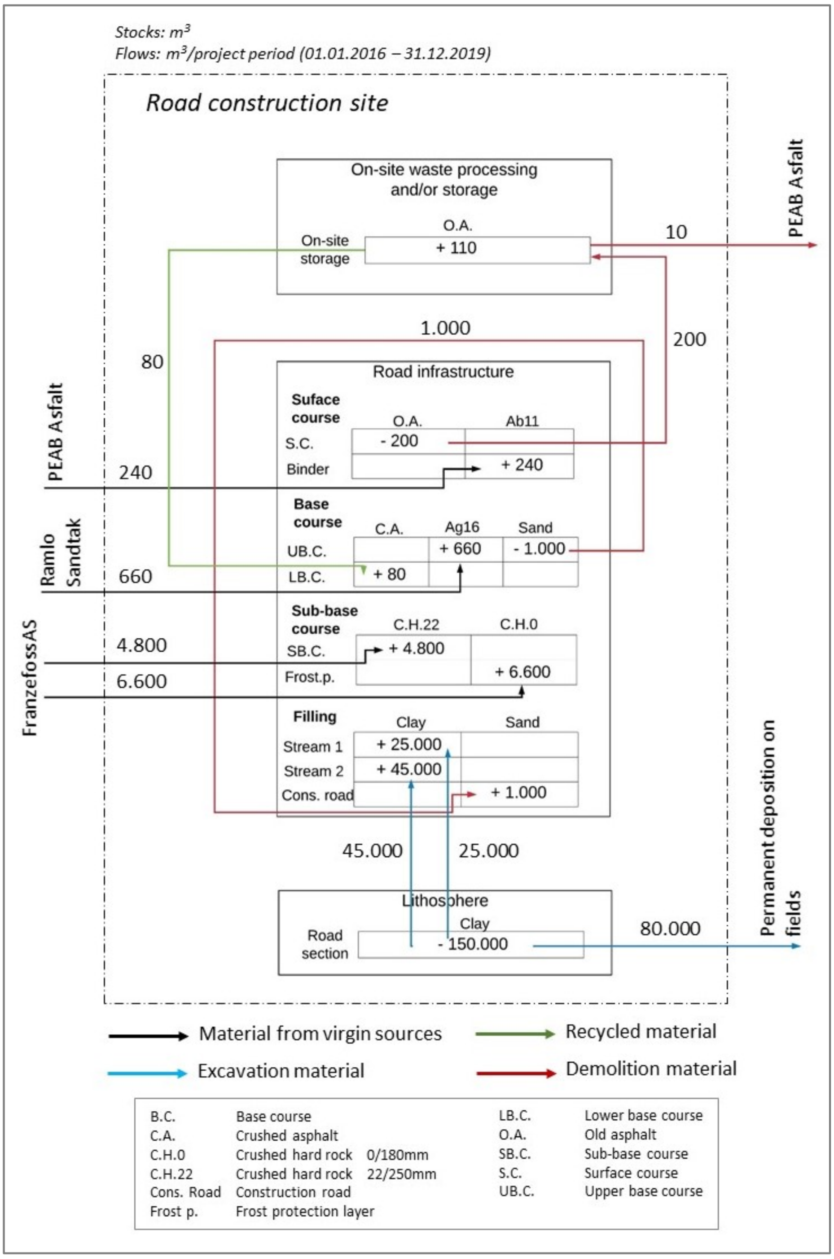

Figure 3.7 *Case study application to sub-system definition. Application of material flows for a 300 m road section of E6 Jaktøyen – Sentervegen. Material flows generated for the sub-system Road construction sites from the stock development.*

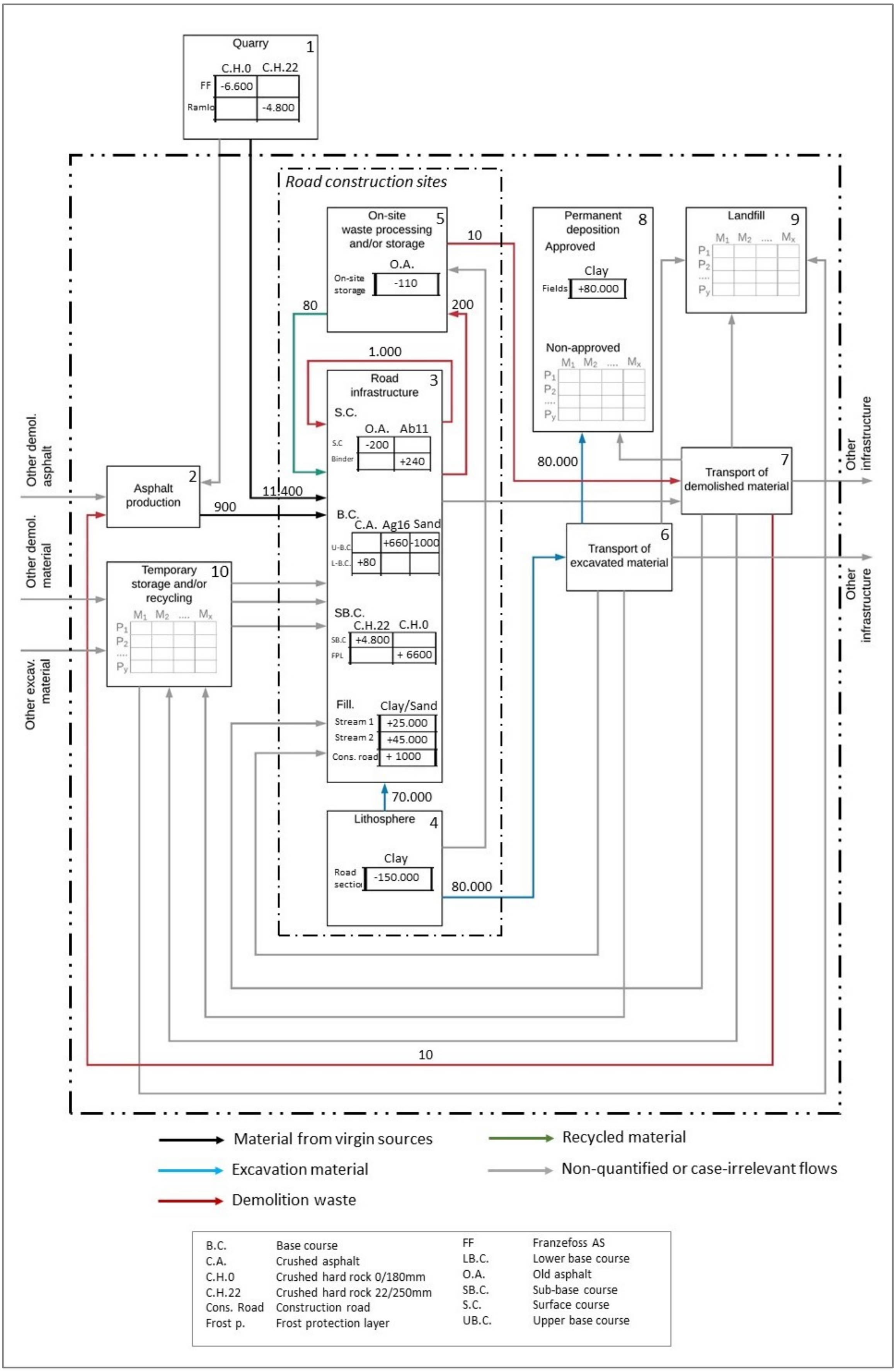

***Figure 3.8** Case study application to system definition. Application of material flows for a 300 meter road section of E6 Jaktøyen – Sentervegen to the MFA system definition. Implications to the system.*

m³/project (From \ To)	0	1 **Franzefoss**	1 **Ramlo**	2	3 S.C. **S.C.**	3 S.C. **Binder**	3 B.C. **Up.B.C**	3 B.C. **Low.B.C**	3 SB.C. **SB.C**	3 SB.C. **FPL**	3 Fill. **Stream 1**	3 Fill. **Stream 2**	3 Fill. **Cons. Roa**	4	5	6	7	8 **Fields**	9	10
0																				
1 **Franzefoss**										6.600										
1 **Ramlo**									4.800											
2						240	660													
3 S.C. **S.C.**															200					
3 S.C. **Binder**																				
3 B.C. **Up.B.C.**													1.000							
3 B.C. **Low.B.C.**																				
3 SB.C. **SB.C.**																				
3 SB.C. **FPL**																				
3 Fill. **Stream 1**																				
3 Fill. **Stream 2**																				
3 Fill. **Cons. road**																				
4											25.000	45.000				80.000				
5								80									10			
6																		80.000		
7				10																
8 **Fields**																				
9																				
10																				

Figure 3.9 *Case study application to system definition, matrix notation.*

3.2 Accounting and reporting

In order to conduct a MFA for road projects on a regional level, it is necessary to know from what stakeholders, information on material flows and stocks can be collected. Currently, there is not established a system for systematic reporting to one central authority on all relevant material flows in the construction industry (Johannessen, 2018b). Therefore, in this chapter we seek to give a brief overview of stakeholder accounting and reporting. Table 3.1 gives an overview on the information each stakeholder holds.

We found that two dimensions are important to consider in the evaluation of accounting and reporting: vertical reporting and lateral reporting. Vertical reporting is reporting between stakeholders at different hierarchic levels, usually corresponding to increasing spatial scales (e.g. contractor (individual)→infrastructure owner (regional)→national authorities (national)). Lateral reporting is reporting between stakeholders of equal hierarchic level (municipality→municipality).

We found that the level of detail, including spatial resolution, with which information is accounted, is highly dependent on the hierarchic position of a stakeholder, meaning that specific knowledge on mass flows increases as the stakeholder's proximity to a given construction project increases. This is illustrated in Figure 3.8 for the deposition of excavated clay on fields.

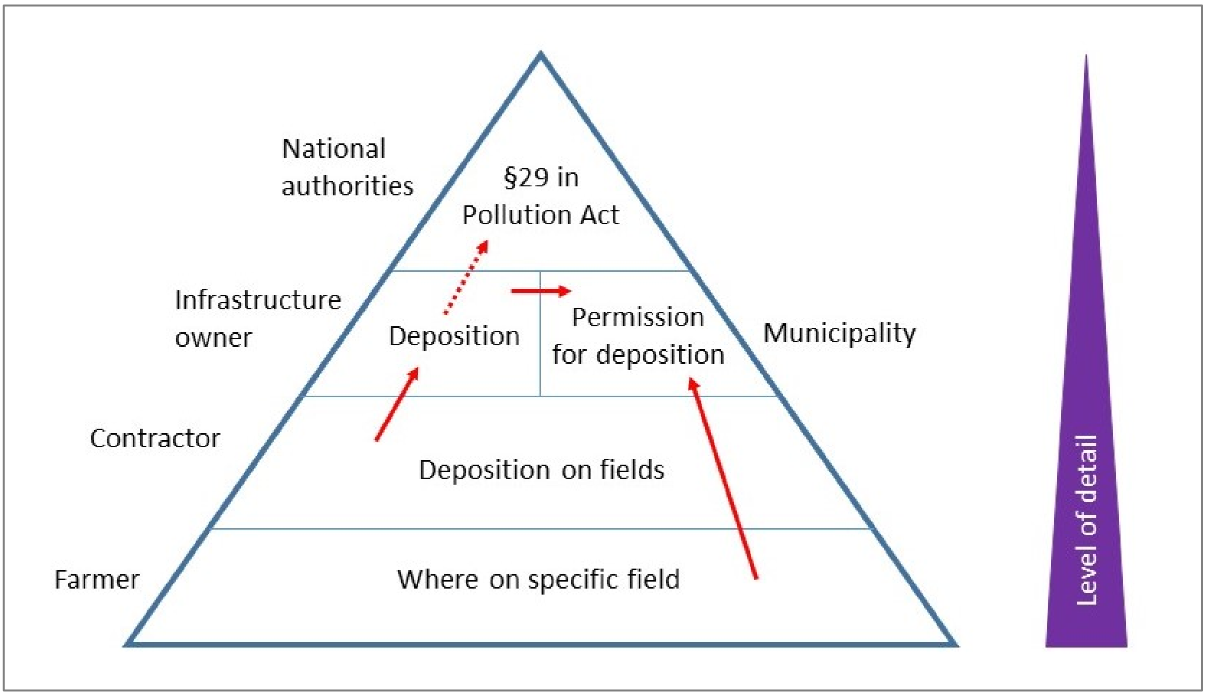

Figure 3.10 *Dependency of hierarchic position to the level of detail with which material flows and stocks are known. Exemplified for the deposition of clay material on fields. Red arrows indicate reporting between stakeholders.*

The material flows of demolition and excavation material are well-known to the contractor, because they are decisive for the project economy (Carlsen and Vicario, 2018). The contractor knows the quality, quantity, and spatiality of material flows and stocks. Meanwhile, although infrastructure owners hold the right to know of all flows within a construction project, generally they are only interested in the volumes, which are transported in and out of the construction site, due to their impact on the project economy (Johannessen, 2018b). In addition, most projects are reported in 1D or 2D format (Vicario, 2018), which reduces the level of detail of the transferred information compared to 3D models. The Norwegian National Road Database (*NO: Norges vegdatabank* (NVDB)) presents the entire road network in Norway in 2D format, however, with limited attributes on material content.

Permission for permanent deposition should be received from KLD, and hence the Norwegian Environment Agency should know of the quantities deposited outside of landfills. However, currently it is poorly communicated to contractors and infrastructure owners that such permissions should be sought out, and hence the authorities do not hold this information (Hartnik, 2018).

To our knowledge, only two additional flows are reported to national authorities. These are the extraction and sales of domestically produced virgin construction aggregates, and waste brought to landfill. The extraction of virgin construction aggregates in Norway is reported to the Directorate of Mining, who, together with the Norwegian Geological Survey, are responsible for the national mineral statistics (Norges Geologiske Undersøkelse & Direktoratet for Mineralforvaltning, 2015). The management of waste, including demolition waste and lightly polluted masses, is reported to Statistics Norway (*NO: Statistisk sentralbyrå* (SSB)) and included in the waste statistics. Natural clean masses are rarely brought to landfill, and as they are not considered waste, they would neither be reported to statistical offices (Chaudhary, 2018).

Table 3.1 *Overview of information held by each stakeholder.*

Stakeholder	**Authority in construction projects**	**Knowledge on ….**
National authorities	Legislative framework	• Virgin material flows (mineralstatistikken, NGU) • Treatment of demolition material and lightly polluted masses (SSB). • Permissions for permanent deposition (KLD).
Municipalities	Approval of municipal land-use plan	• Land-use plans within municipality, including all infrastructure construction.
Infrastructure owner/ road authority	RFPs, owner of demolition and excavation material, handbooks on road construction	• Construction plans within enterprise (partly). • External material flows to/from given construction project. • Right to know of internal mass flows in given construction project.
Consultant/contractor	Closest construction responsible	• Construction plans within enterprise (partly). • Internal and external mass flows for a specific project with spatial resolution.
Mineral producer	Provide virgin material	• Individual consumption by costumers, spatial resolution through transportation.

Concurrently, lateral transfer of information is also limited. Stakeholders along each stage of the supply chain have only partial overlaps of knowledge. In order to secure the competitive basis, contractors cannot provide detailed information on excavation and demolition material to one another (Vicario, 2018). Any detailed coordination must instead go through the infrastructure owner, who is essentially the owner of all demolition and excavation material (Vicario, 2018). However, as already outlined, infrastructure owners rarely have the same level of understanding of the material flows within individual projects. Infrastructure owners may seek to coordinate between several projects within their enterprise, however, this is challenged by projects being provided in different RFPs, and each contractor seeking to optimize within their own project boundary. The E6 Jaktøyen – Sentervegen project was collected into one projects in order to secure better material utilization (Haugen, 2018).

Municipalities, equally, have an overview of all construction activity within the municipality. They are responsible for land-use planning, and designated sites for infrastructure construction, landfills, permanent deposition, temporary storage, recycling, and quarries are all included in the land-use plans of municipalities. However, municipalities rarely communicate across their administrative boundaries (Johannessen, 2018b), which could otherwise support coordination between projects with different infrastructure owners. This leads to deposition of material in one municipality, which could have been of use only a few kilometers away in another municipality (Johannessen, 2018b). The counties of Akershus and Rogaland have developed regional material management plans, which may result in increased cooperation between municipalities within the region (Akershus Fylkeskommune, 2016; Rogaland Fylkeskommune, 2017). Already in the material management plan for Bærum municipality, we see indications of increased corporation (Bærum Kommune Rådmannen, 2018)

3.3 Barriers for better materials management

Stakeholders generally agree that increased collaboration to secure material reuse and recycling is important both for the involved stakeholders (to reduce project costs), but also for the sustainability of the society as a whole (Aakre, 2018; Johannessen, 2018b). Currently, however, they also point out a line of barriers, which are prohibiting cross-industry utilization. The barriers mentioned can be divided into six main groups:

- Lack of incentive for coordination and recycling
- Lack of insight and collaboration
- Timing and intermediate storage space
- Transport costs
- Practical organization at construction site
- Regulations

3.3.1 Lack of incentive for coordination and recycling

Foremost, there is currently a lack of incentives for stakeholders to reuse and recycle. Deposition often carries the smallest logistical burden, and hence becomes the most economically feasible option. Especially for smaller construction projects, the logistical burden of coordinating for reuse is simply too exhaustive (Johannessen, 2018a). In addition, in most cities outside of Oslo and Bergen enough space is provided for deposition nearby such that reuse and recycling are not feasible in terms of reducing transportation costs (Johannessen, 2018a). A measure, which is suggested to increase the incentive for recycling, is setting a public charge on depositing demolition and excavation material. This would decrease the profitability of permanent deposition and landfill. Further, if the profit was directed to recycling terminals, it would decrease the recycling fee, which is necessary to make recycling products comparable in price to virgin materials (Olsen, 2018).

RFPs often prioritize price rather than initiatives like recycling, neglecting an incentive for reuse and recycling. Lately, key infrastructure owners like SVV and NyeVeier have included other aspects to their evaluations of project proposals. SVV has over the last few years started to incorporate consideration to environmental impacts into their RFPs, however, only for larger projects. NyeVeier provide RFPs with only a 25 % consideration to price, while 75 % consideration is given to so-called “the good idea”, this includes new measures for increasing recycling (Aamodt, 2018). However, it is argued that infrastructure owners may not hold enough expertise to properly evaluate the potentials of new suggestions and therefore discard otherwise good ideas (Vicario, 2018).

In regards to changing requirements in the RFPs, the industry organization for contractors, EBA, points out the importance of persistence and predictability to any changes in requirements and regulations. Contractors need security, when they change their business models to apply to the new terms (Aakre, 2018).

3.3.2 Lack of insight and collaboration

Essentially, there is a lack of knowledge on concurrent material supplies and demands across the construction industry, which in turn prohibits coordination for material transfers between projects. As outlined in Chapter 3.2, both lateral and vertical reporting is limited, and knowledge on 1) other projects nearby in the same period of time, and 2) material availability and demand from each of the active construction projects is needed to secure coordination between different stakeholders.

There is a need for tools, which support the coordination between projects. This is currently only provided by applications such as Looprocks and TippNett (Johannessen, 2018a), however, as outlined in the introduction, these applications hold several pitfalls in relation to improving overall mass management. In addition, stakeholders generally agree that the responsibility for coordination lies with the infrastructure owner and road authorities, not the contractor (Aamodt, 2018), as would generally be the case, if such applications were utilized. The infrastructure owner responsibility leads back to the aforementioned ownership of all materials in the project by the infrastructure owner. Formerly, the ownership of material was applied to contractors, which increased the flexibility for cross-project coordination. However, this also led to situations in which project costs increased significantly to the contractor, because they had difficulty getting rid of demolition and excavation masses. The regulations were therefore changed in order to avoid illegal deposition (Aamodt, 2018).

Measuring material flows is important to allow for an understanding of the current material management in the road sector and to evaluate which measures are necessary to take to reach sustainability targets such as improved material management and reduction in emissions (Johannessen, 2018b). However, currently the responsibility to develop reports on demolition and excavation material has not been placed on any authority, although several candidates are mentioned: the Norwegian Environment Agency, the Ministry of Transport and Communication, and the Norwegian Geological Survey (Johannessen, 2018b). It is underlined that reporting is time-consuming for contractors, and it is therefore important that the reported information is actually organized and utilized (Johannessen, 2018b).

It is pointed out, that improved resource utilization is also about expertise on different technologies and methods making material reusable, and it is important that infrastructure owners collect and utilize new capabilities. In a construction project, the infrastructure owner essentially owns everything, including the knowledge that is produced through a project (Vicario, 2018). Infrastructure owners need to gather this information and utilize it in future projects. It is questioned, whether infrastructure owners hold sufficient practical knowledge on construction and the construction industry to uphold this task (Vicario, 2018).

3.3.3 Timing and intermediate storage space

Timing is a main issue in relation to coordinating mass transfers both internally and between projects. Material supplies and material demands need to not only be cohesive in material type and quality, but also in time (Johannessen, 2018b). Generally, infrastructure owners do not plan their construction projects with consideration to timing across the projects (Johannessen, 2018b). It is often considered necessary that material is removed from construction sites immediately after demolition and excavation. This counts especially for construction work in cities like Oslo and Bergen, where construction sites are extremely restricted in space, limiting possibilities for on-site storage (Johannessen, 2018a). Coordination between projects are in these cases very risky, because it creates a cross-dependency that entails the risk of one projects stalling the progress of another project (Haugen, 2018).

A suggested solution for the aspect of timing is the establishment of temporary storage sites, which will mitigate the offset in timing. However, temporary storage sites also hold several drawbacks. Firstly, they require assigned space in the municipal land-use plans. In urban municipalities, there is simply not room for storage sites, why they depend on storage sites in other municipalities (Johannessen, 2018a). This increases the transport distances as well as the subsequent impacts of noise and dust to citizens.

The offset in timing between the planning phase and the time at which necessary information is available also challenges direct material reuse. For larger projects, an action plan (*NO: handlingsplan*) is developed between the infrastructure owner and the municipality (Aamodt, 2018). The plan includes agreements on transport of materials. However, in order to evaluate the potential for transfers between projects, it is necessary to know the quality and quantity of the material, which will be available. However, at the beginning of a construction project, it is often uncertain exactly how much material of a given quality will be released (Hedlund, 2018; Carlsen and Vicario, 2018). There are as such often too little pre-investigations to determine what masses are applicable in relation to reuse (Aamodt, 2018). Thus, often deposition is included in action plans, because this measure is independent of available information.

3.3.4 Transport costs and emissions

Transportation cost is an important factor in determining the profitability of a construction project, and therefore most projects seek to reduce total transport. The most important measure is to reuse demolition and excavation material within the same project (Vicario, 2018). However, this may consequently lead to downcycling of high-quality materials. In addition, the transport of facilities like recycling units between construction sites is also costly (Olsen, 2018) making on-site recycling less likely, especially for smaller projects.

The transportation costs may be determining for the proposal budget and in turn whether the contractor wins the project. Therefore, contractors often reduce the transport budget to a minimum. If a potential buyer of materials should turn up during construction, contractors only have a certain budget for transport, why recycling may not be possible if this implies increased transport (Aamodt, 2018).

Stakeholders are generally not concerned about future scarcity of construction aggregates on a national level, but point out the increased transportation costs due to potential local scarcity (Johannessen, 2018b; Aakre, 2018). Future development in transportation, including electrification, may reduce the direct transportation costs as well as greenhouse gas emissions, however, probably other impacts such as noise and road damage will still prevail (Aakre, 2018), withholding a high societal cost especially if transport distances are increased due to local scarcity.

3.3.5 Practical organization of construction sites

It is suggested that construction sites themselves to a higher degree must be "designed" for reuse and recycling. Construction sites currently present several practical barriers for reuse and recycling, for example:

Mixing of masses: When tunnels are excavated, the material from the bottom of the tunnel cannot be reused because of diesel pollution from construction vehicles. If these masses are not piled independently, then no masses in the pile are reusable (Aakre, 2018).

No surplus space at construction sites: Especially urban construction sites struggle under the lack of surplus space. This prohibits proper sorting as already mentioned, as well as the use of recycling units at site.

If material recycling becomes too demanding due to, among other issues, poor organization of construction sites, then deposition is a more likely option (Olsen, 2018). If authorities approach this issue through regulation, it is important that they include contractors and discuss the practical possibilities at construction sites before taking action (Aakre, 2018).

3.3.6 Regulations

The handbook requirements to construction are pointed out as the main regulatory barrier for increased reuse (Aamodt, 2018), despite the increased flexibility provided by the latest changes to the handbook. Despite of increased flexibility, all material used in the road body must provide extensive documentation on type, quality, and grainsize. By the requirement on documentation, testing of the material is necessary (Olsen, 2018). This may imply that deposition becomes a more favorable option than reuse. Meanwhile, the handbooks must provide sufficient requirements to secure that the road quality is in order. Aamodt (2018) exemplifies that handbook requirements increased a few years ago, as a consequence of an extensive part of the road network being damaged by frost impacts.

Recycling units on-site are important tools for increasing recycling and reducing transportation costs and emissions. However, to use recycling units on a construction site, the contractor needs a permission from the county authority due to the risk of noise and dust. Obtaining such a permission is difficult and time consuming, although contractors argue that most machinery on-site emit equal levels of noise and dust and question the additional impact from recycling units (Johannessen, 2018b). The permission is generally easier to receive for larger projects outside of city centers (Johannessen, 2018b). Generally, time- and resource-consuming application processes could be a barrier for better material management.

Several laws and national strategies are relevant in relation to mass management. This includes, among others, the Planning and Building Act (2008), the Waste Regulations (2004), the Pollution Control Act (1981), the Minerals Act (2009), the National Soil Conservation Strategy (2015) etc. In this thesis, it has been exemplified how infrastructure owners and contractors do not apply to all regulations, simply because they are not aware of them. It is important to secure a transparent legislative system in order to provide flexibility in management to contractors and infrastructure owners, while being confident that they apply by current legislation.

As mentioned for requirements in RFPs, equally the long-term stability in regulations are important for the contractors to feel secure in adjusting their business models (Aakre, 2018).

3.4 3D software in the road construction industry

3D software is widely used by contractors and consultants in the road construction industry (Johannessen, 2018b; Vicario, 2018). Despite of this, the transfer to and use of 3D models by infrastructure owners is limited (Vicario, 2018). All interview subjects are positive towards an increased reporting through 3D models, and point towards the following advantages:

- Better chance of doing the project correctly
- Control of documentation
- Operation and maintenance purposes
- Environmental accounting
- Repetition of the good projects

(Johannessen, 2018b; Aakre, 2018; Vicario, 2018; Aamodt, 2018).

NyeVeier is currently looking into the development of a so-called Enterprise BIM (EBIM) or Assets BIM (ABIM) for the road industry (Aamodt, 2018). This is a 3D model, which includes the organization's entire portfolio of assets (Aamodt, 2018), in this case roads. The development phase includes two areas of investigation. On one side is the evaluation of what aspects and information should be included in the model. On the other side is the technical development (Aamodt, 2018). When asked on the development of an EBIM, interview subjects are generally positive (Vicario, 2018; Aakre, 2018). All stakeholders seem to agree that the responsibility for developing an EBIM as well as setting corresponding requirements on reporting are placed at the road authority/infrastructure owner. However, the development must happen in close corporation with contractors and consultants, as they hold an indispensable practical understanding, which is important to include, to make the EBIM functional in reality.

One consultant points out that 3D models may reversely be implemented into the RFPs as a better foundation for consultants to develop their prospects, by making available aspects such as old infrastructure, soil conditions etc. (Vicario, 2018). In continuation, it is also pointed out, that it is important to consider who should have access to the EBIM in the construction industry. If the EBIM is accessible for all contractors and consultants, this may reveal competitive advantages between different contractors and consultants, which is not appropriate (Vicario, 2018).

3.4.1 Barriers and solutions

Today, 3D modelling in the construction industry is mainly used as a design planning and visualization tool, while linked to other software tools for aspects such as project planning, economic evaluation, environmental evaluation etc. Currently the linkage between the 3D software and the supportive software is done manually (Vicario, 2018). Further, the models are mainly used prior to construction, as a compliment to the prospect, and are not updated if changes occur during construction. The economic adjustments happens parallel to the model (Hedlund, 2018; Haugen, 2018). In order for the 3D models to be implemented into an EBIM and to realize the proposed advantages, the models must correspond to the real situation.

Contractors and consultants emphasize the lack of standards for 3D models to be the greatest challenge for transferring this data to infrastructure owners (Vicario, 2018). This includes format. SVV has developed standards given in handbook V770 (Statens vegvesen, 2015b), however, these standards are very executive. In their RFPs, NyeVeier articulate stricter requirements to 3D models in alignment with the level 3 BIM described in BIM Industry Working Group (2011). However, a consultant evaluate the requirements as currently not reachable (Vicario, 2018). NyeVeier argues that the requirements should be understood as guidelines that will motivate the contractor to develop 3D solutions. NyeVeier also points out that they do not set specific requirements in the contract, because contractors should have the freedom to seek out the best solutions (Aamodt, 2018). This is agreed on by a consultant, who states that if requirements are set, then naturally the industry will implement qualifications in their businesses (Vicario, 2018; Aakre, 2018). The consultant further concludes that holding skills on the use of 3D software in the company is also a competition component (Vicario, 2018).

4 Discussion and conclusion

4.1 System definition and quantification

In the introduction, we outlined two important issues in the construction industry: 1) there are indications that within the construction industry material is not used accordingly to the circular economy mindset, and 2) analysis and potential suggestions for increasing the circular economy in the construction industry are challenged by the lack of data on material stocks and flows.

We defined a system definition, which entails seven stocks, three processes, and 29 flows. The detailed system definition involves many aspects of material management in road construction, including internal management on construction sites and differentiating between *landfill*, *approved permanent deposition*, and *unapproved permanent deposition*. Our results show that this level of detail is necessary, because it is important that the visual aspect of the MFA communicates sufficiently the main problems of material management in the road sector, to identify appropriate mitigation measures. Because of the importance of distance to the management of construction aggregates implied by high transportation costs and emissions, as well as to allow for an evaluation on the rate of downcycling, we developed an approach for including spatial resolution and a differentiation between material types to stocks. The application and testing of the MFA model, demonstrates that it can be used to 1) visualize current material management in the road sector, and thereby allow us to evaluate the system's compliance to circular economy, 2) act as a framework for storing data on material flows and stocks within the system over time, and 3) support an optimization of material utilization by identifying the material flows, which will occur during construction, by comparing the stock prior to construction and the stock outlined in contractor proposals.

The quantification of material flows and stocks for the given road section of the *E6 Jaktøyen – Sentervegen* confirmed the material management suggested by interview accounts, namely that contractors seek to optimize material management internally for one project, while rarely placing themselves in the context of other road infrastructure projects. In addition, the internal management indicates a downcycling of material. Excavated clay and sand from demolition of the old E6 was utilized as filling within the same construction site, by the assumption that road courses correlate with material quality requirements; sand formerly used in the road body is used for filling purposes, and asphalt formerly used in the surface course is crushed on-site and used in the base course. Almost all material inflows to the construction site were from virgin sources, while almost all material outflows went to permanent deposition. This management of resources is not in line with the circular economy mindset, which confirms the suspicions outlined in the introduction. However, it may be discussed if the results from the case study are representative for road construction in general. We point especially to excavation masses, which for the current case study only involves clay, while for many road construction projects in Norway, it will involve the blasting of rock material. Rock material holds different potentials of use than that of clay, and the management of such excavation material may differ from that currently presented in our results. We suggest a regional quantification to be carried out to thoroughly test the system and draw more robust conclusions on the current material management within the road sector.

The potential of the MFA model to support an optimization of material utilization by stock comparison prior to construction, was only illustrated for one road in the current thesis. However, we have suggested the potential for the same approach to be applied to all concurrent road construction projects. Currently three large road construction projects are planned within Trøndelag county, all on the E6. Two of the projects are running concurrently, these are the *E6 Jaktøyen – Sentervegen* and the *E6 Soknedal* (Statens Vegvense, 2016; Statens Vegvesen, 2018). For the *E6 Soknedal*, rock material is released from tunnel development. We suggested material transfer between the two E6 projects, however, no such coordination has been discussed (Hedlund, 2018). Hedlund (2018) revealed that the deposition fee for depositing clay from excavation during the *E6 Jaktøyen – Sentervegen* on fields was half the price of deposition, the other half transport. This, he says, means that material could have been transported all the way to Soknedal at the same price, if deposition would then have been free of charge. The lack of coordination between the three construction projects would be an interesting case for further studies to understand the existing lack of corporation, as well as to illustrate which potential a collaboration could have had for a better material management.

4.1.1 MFA methodology conflicts

Excavation into the lithosphere during road construction provokes a conflict with the consistency of the system definitions commonly used within MFA methodology, both for the system definition presented in this thesis, as well as in other literature. This is an issue, which is currently addressed in the MFA community. In the KAR-model of the Swiss management of construction aggregates in infrastructure (Rubli and Schneider, 2008), there are two outflows from the infrastructure stock, demolition material and excavation material. However, excavation material is derived from the construction of new infrastructure by excavation into the *lithosphere*, which is not a part of the infrastructure stock until the very moment of construction. This either implies that material suddenly appears out of nothing defeating the mass balance principle, or that the physical boundary of the infrastructure stock is inconsistent.

To target this issue, in our system definition, we separate the road infrastructure and the lithosphere into two stocks within the *Road construction sites* subsystem. In this way, we secure mass balance of the infrastructure stock and visualize that excavation material derive from the lithosphere. Due to the infinite physical boundary of each stock, we do not risk inconsistent physical boundaries. The space of excavation is already an inherent part of the road infrastructure stock, the change is simply happening by the flow of material to pre-defined voxels in the road stock, which were prior equal to zero.

However, this derives another issue. If the lithosphere in our system actually entails the entire lithosphere, then material for quarries should also be derived from the lithosphere stock. Thus, our system is inconsistent in this way. To mitigate this issue, it was considered to add another lithosphere stock outside the system boundary, which would feed material to quarries as well as the excavation. However, a flow implies a physical movement of material, while in this case, it would only be the movement of material between different definitions.

4.1.2 Implementing other infrastructure

In this thesis, we decided to focus on the management of materials within the road sector, instead of the built environment as a whole. We did this to reduce the complexity in the development of a first generic system definition. However, excavation and demolition material may be utilized across different infrastructure sectors (roads, buildings, communication, other transport etc.), and infrastructure groups partially strain on the same upstream and downstream resources giving collaborate implications on land-use conflicts and resource scarcity. Therefore, to use the MFA as a background for policy making to mitigate these issues, it will be meaningful to expand the system to include all infrastructure groups.

However, different infrastructure sectors may also hold different implications for the system definition and its quantification. Other infrastructure may entail the implementation of processes and flows not currently in the system, due to the management potentially varying from that of road construction. Therefore, to expand the system definition to include other infrastructure sectors, additional studies should be carried out on material management within these sectors.

In addition, it must be evaluated, which material types should be accounted for in the system definition, and whether the management of these materials are included into the system definition. Mitigating specific upstream and downstream issues may entail consequences within other systems; The current area of investigation is the management of construction aggregates. While within the road sector there is little immediate potential for replacing construction aggregates with other material types, the potential may be larger for other infrastructure sectors, for instance the replacement of concrete with wood in buildings. Limiting the system definition to construction aggregates would ignore the potential impacts on wood management by this replacement. The developed approach for stock visualization makes the system definition flexible towards the implementation of more material types.

Including other infrastructure sectors in the system definition may also hold other difficulties in regards to quantification of the system. For road infrastructure in Norway, infrastructure owners count only three stakeholders: Statens Vegvesen, NyeVeier, and the municipalities. For the building sector, both infrastructure owners (companies and private house owners) as well as contractors are a much larger and more diverse group, and the responsibility for reporting to authorities may be less apparent.

If including all infrastructure groups into one system definition, it would be meaningful to appoint the data management task to one authority. If 3D models were implemented this would include a collective 3D model on the entire infrastructure stock. However, responsibility for different infrastructure sectors is currently placed at different authority units, which may oppose the responsibility for such collective data management and modeling.

4.1.3 Prospective dynamic MFA

Prospective dynamic MFAs are valuable tools to understand the implications of infrastructure development on future material demand and waste production. This again provides valuable insight to mitigate land-use conflicts, resource scarcity, and environmental impacts.

The potential for recycling depends on the timing between material supply from demolition and excavation and the demand for material for infrastructure construction (figure 4.1). In situations with high demolition and little demand for new infrastructure, material must be deposited or temporarily stored (blue scatter). Oppositely, in situations where the demand for material to develop new infrastructure is greater than what is released from demolition and excavation, virgin material extraction is necessary (red scatter). In addition, if surplus material has been temporarily stored at an earlier point in time, this material may be used for the current material demand. This requires a dynamic model, which "memorizes" the material management over time. These dynamics are important, to understand the potentials for recycling and for the development of land-use plans, securing sufficient resource availability as well as sufficient space for temporary storage and recycling terminals over time.

Take an example of town development. This requires material inflows, which may partly be supported by recycling of demolition and excavation material and partly by the extraction of virgin material. The potential for recycling depends on the quantities of current and prior unutilized material from demolition and excavation activity in the area. This concurrently reveals the need for securing space for temporary storage and recycling terminals at certain times. If we subtract the recycling potential from material demand, we derive the demand for virgin material. This allows us to determine if a material reserve is adequate for supporting the outlined infrastructure development, or if other reserves in the area should be secured in land-use plans. It may also reveal probably at what one point in time a quarry is 'empty', relieving that area to other purposes in the land-use plan.

Prospective dynamic MFAs also provide the possibility to evaluate the consequences of different scenarios of development in infrastructure, including the implications of mitigation measures. This provides the opportunity to evaluate whether targets on recycling rates, on reductions in CO2 emissions etc. are reachable. While we may initiate mitigation measures now, which would have us reach the targets at a certain time, if we assume a constant consumption. However, dynamics of demand for new construction over time are historically determined. Demand and its related effects may increase in the future due to a large share of products reaching end-of-life and having to be replaced. Thus, despite taking measures for reducing effects from consumption, consumption may increase, prohibiting us from reaching our target unless additional measures are taken.

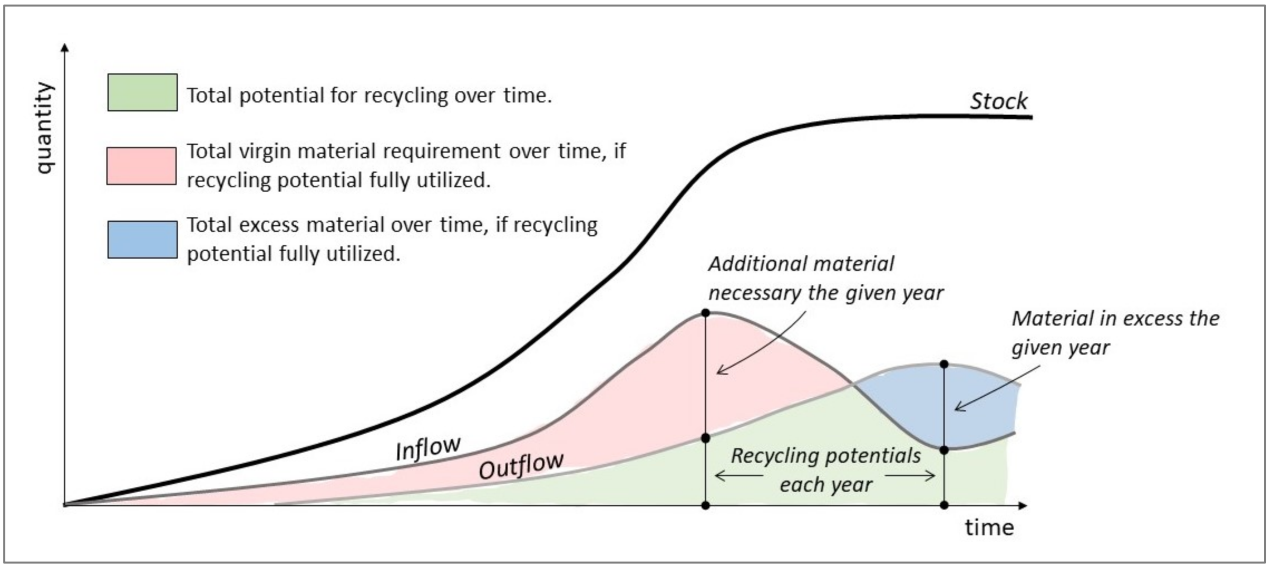

Figure 4.1 *Generic model of dynamic MFA stock, inflow, and outflow. The model visualizes the implications of inconsistency between infrastructure construction and demolition and excavation on material management over time.*

In order for the results from prospective dynamic MFAs to be useful for municipal land-use planning on construction aggregates, the road infrastructure must be determined with a bottom-up approach and should be spatially resolved, as provided by 3D models. The driver of the system is the need for road infrastructure, which prospectively is outlined until 2029 in the National Transport Plan (Det Kongelige Samferdselsdepartement, 2017). We imagine the application of rough 3D models of the outlined road infrastructure to an area, which will then support the estimation of material demand and supply over time. Again, prospective MFA allows us to compare the consequences of different scenarios. We could for example look at the implications on material management of expanding a high-way rather than expanding several smaller roads.

Because roads have a longer lifetime than a meaningful timely resolution for the material flow (often given per *year*), in order to determine the outflow of material, we need to know the material contained in the current infrastructure stock. These are the materials, which will be released over time when roads are demolished. We have little knowledge on the current road infrastructure stock, especially when we set the requirement that the data should be given with spatial resolution. As mentioned, in preparation for the current MSc thesis, we approach the problem of reconstructing the material content of the current road infrastructure stock (Rasch, 2017) by utilizing the 2D outline of the current road network from the Norwegian National Road Database (NVDB). The database was generally insufficient to model road infrastructure, but in addition, the construction year was not indicated for any roads. This is essential for estimating when demolition and maintenance should be expected, and thus for modelling prospectively the stock development.

Prospective dynamic MFA for infrastructure construction differs from MFAs of other commodities such as cars, as the construction of infrastructure itself produces material. Where we usually have an outflow of material as a result of commodities reaching their end of life, for infrastructure construction, the construction itself will provide an outflow of material. Usually material released by demolition will appear as a smoothed, postponed curve of the inflow curve, however, in the case of road infrastructure, the outflow will probably much more correlate to the inflow, and potentially in some cases be larger than the inflow demand, although provided by the need for infrastructure.

4.2 Securing data availability

In order to utilize the MFA on a regional level, it is necessary to have a reporting scheme, which secures the procurement of data on material stocks and flows. Therefore, in this thesis, we gave an overview of the current accounting and reporting scheme for Norwegian road construction. We approached reporting on two dimensions, vertically and laterally, but found that on both dimensions, the reporting was limited. This is a problem, because we generally find a discrepancy between stakeholders holding knowledge on current material management and stakeholders holding the authority to coordinate for better material management.

We found that information on material stocks, necessary to optimize the system by the approach suggested in this thesis, are well-known to contractors. Increased lateral communication between contractors would be a way for increasing coordination on material utilization across construction projects, however, this is prevented to secure the competitive basis between contractors. In addition, such coordination would still happen by chance, which is insufficient. Therefore, we argue that a central database should be provided, which raises the importance of good vertical reporting to a database responsible. We find that the currently limited vertical reporting is due mainly to three reasons: 1) there is seemingly no clear distribution and assignment of responsibilities concerning a systematic collection and management of MFA data among public authorities. 2) There is generally a lack of requirements to the format and content of data, which is especially important if we seek to collect data in 3D format. 3) There is a lack of a system to organize and store collected data.

Further, we found that a main barrier for optimizing material management by the approach of stock comparison is the lack of data on current infrastructure and the low spatial resolution and uncertainty of geological data (material composition and quality) for the lithosphere. This makes it difficult to quantify and to understand qualitatively the material, which will be released during demolition and excavation. As mentioned, in the preparation work prior to this thesis, we sought to model the current infrastructure stock in 2D, but found that data readily available with spatial resolution is insufficient to do so. Modeling the current infrastructure stock will demand extensive processing of achieved data (paper format). In the future, high-resolution models of the infrastructure stock may be available assuming data collection and storage will improve, increasing certainty to material for demolition. The estimation of the lithosphere stock prior to construction will properly always contain some uncertainty, despite better technologies being developed for underground surveys. These methods has to be of reasonable cost to be favorable to use.

When developing a reporting scheme, it is important to consider what analysis purposes the MFA should support, such that data is gathered with sufficient resolution and in an appropriate format. For this, we point especially to the dimensions of material type and spatial resolution for the purpose of local land-use planning. For material types, clustering materials may be meaningful for different analysis purposes. E.g. for one analysis it may be meaningful only to separate between clean masses and polluted masses, then clustering material based only on this property. The properties, which we require for the reported data, should comply with a meaningful subsequent clustering for analysis purposes. In addition, as pointed out, to support prospective dynamic MFA, it is important that the construction year of a road is also stored.

If a common database was developed on road infrastructure and road construction projects, it would be important to discuss, what parts of its content should be available and to whom. We initially suggest full disclosure of all information to the public to allow for assessment of the efficiency of material use both publicly and at research institutions. However, this may provide conflicts with other aspects of the construction industry, for instance the preserving the competitive basis between contractors. The consequences of availability of data from such database should be further investigated.

Lastly, as mentioned by one interview subject, reporting is a time- and cost-consuming process and therefore if information is requested, it must be used meaningfully.

4.3 3D spatiality for better material management

In this thesis, we have pointed towards the use of 3D models of road infrastructure as a good way for providing spatially resolved data to the MFA model. In the overlap between 3D models and MFA, spatial resolution is inherent to the material flows and stocks, which is essential for cases where distance is a deciding factor in regards to how resources are utilized, as for construction aggregates. We envision a 3D database of the entire road network in Norway, where new construction projects can be applied and compared to former infrastructure at the same place. This could make all material supplies and material demands quantitatively and qualitatively transparent across the construction industry with spatial resolution, providing a foundation for optimizing material utilization.

3D software could also be beneficial as a tool for data collection, as it would provide a comprised structure for reporting large amounts of information. However, collecting data by 3D models necessitates requirements to these models such as content and format, as well as the authority responsible for data management to develop a system to keep such models organized. These aspects are currently not met by the authorities.

In preparation for the current thesis, we sought to reconstruct the current infrastructure stock in 2D format, based on the 2D outline of the current road network from NVDB (Rasch, 2017). However, in addition to data being too limited for this purpose, as already mentioned, we also found that use of 2D databases as the foundation for quantification hold especially three pitfalls compared to 3D resolution:

1. Material content on the z-axis is rendered to the 2D infrastructure through material intensities, and hence we do not know the actual location of material in space.
2. The geometric form of the road body and fillings is ignored, when only information on the road width at surface level is available. Vertically, road bodies are constructed with a trapeze structure (figure 2.6), and calculating material content based on material intensities, course depth, and surface width may underestimate the material content of the road.
3. The impacts on material excavation of placing a road differently in the topography is not extractable.

However, to meet the potential outlined for the application of 3D software, the software must undergo further development. Here we mention two areas for which 3D software is currently insufficient for the suggested approach. First, it is currently not possible to derive material flows directly from 3D software by the comparison of stocks at different points in time. This process must currently be done by manual transfers of data to supportive software such as DynaRoad. This is something, which is currently investigated in the community of 3D software. Second, currently 3D software has some limitations when it comes to converting between 3D vector data and 3D voxel data to extract material quantities. As demonstrated, the 3D software used for *E6 Jaktøyen – Senterveien*, Gemini, only calculates volumes by extracting cross-sections, and we are not provided the stock as voxels of a certain resolution, but as calculated volumes of different road compartments within a defined space. Defining such clusters of space may entail problems over time. Take for instance the development of two different roads, which are defined as two separate clusters of space; during maintenance at a later point, parts of each of the two roads may be included into a new project opposing the original separation.

The use of 3D software holds several potentials outside that of optimizing material management during construction as presented in this thesis. An example is implementing knowledge on the geology, other than the material type, for instance faults or areas with risk of landslides, which is useful for deciding on where through an area a road should be placed. The 3D model may also provide information about, when a road needs maintenance. For this a continuous update of the database is necessary. As outlined in chapter 4.1.3, a 3D database will also support the development of prospective dynamic MFA, which in turn can reveal consequences over time of different mitigation measures.

4.4 Barriers for better material management

In this thesis, we have identified a line of barriers to why material is currently not managed in a way more compliant to the circular economy mindset. To allow for an optimization on construction aggregates management, these barriers must also be approached. Several mitigation measures are suggested, however, it is important that we understand the construction industry sufficiently to evaluate which measures are most meaningful to apply.

Due the detailed system definition, for some barriers the quantification of the MFA itself will give an indication of which mitigation measures are most meaningful to apply. For example, *Permanent deposition* is disintegrated between *approved* and *unapproved* deposition, which allows us to more easily identify where to regulate to reduce permanent deposition in general. If material has been approved by KLD, then we should expect that contractors manage the material in the best way possible within the current framework. Extensive material flows to *approved* permanent deposition therefore indicates that the framework, on which KLD approves permanent deposition, should be reevaluated.

If flows are extensive for *unapproved* permanent deposition, then we need to 1) communicate better the approval regime, and/or 2) provide regulations, which reduce the incentive for unapproved permanent deposition (for example illegal deposition). Currently, as outlined in the results section, it is not sufficiently communicated to contractors that they need approval from KLD for deposition. Therefore, permanent deposition is probably more extensive than otherwise would have been, expecting that some applications would have been denied, forcing contractors to find other measures for material management e.g. recycling or temporary storage.

The characteristics of construction projects also determine what mitigation measures are meaningful. In our investigations of barriers, we found that the extend of some barriers depend especially on two characteristics: the size of the construction project and the locality of the construction project, as indicated in Figure 4.2. If the road construction industry is generally characterized by large, rural projects, then a meaningful mitigation measure would be to place a fee on permanent deposition, thereby increasing the incentive for recycling. Oppositely, if the construction industry is characterized by small, urban projects, it may be much more relevant to support coordination, easing the application process for recycling units, and providing space for temporary storage. We suggest that the general characteristics of the road construction projects are investigated, in order to determine, which mitigation measures will have the large effects in the industry.

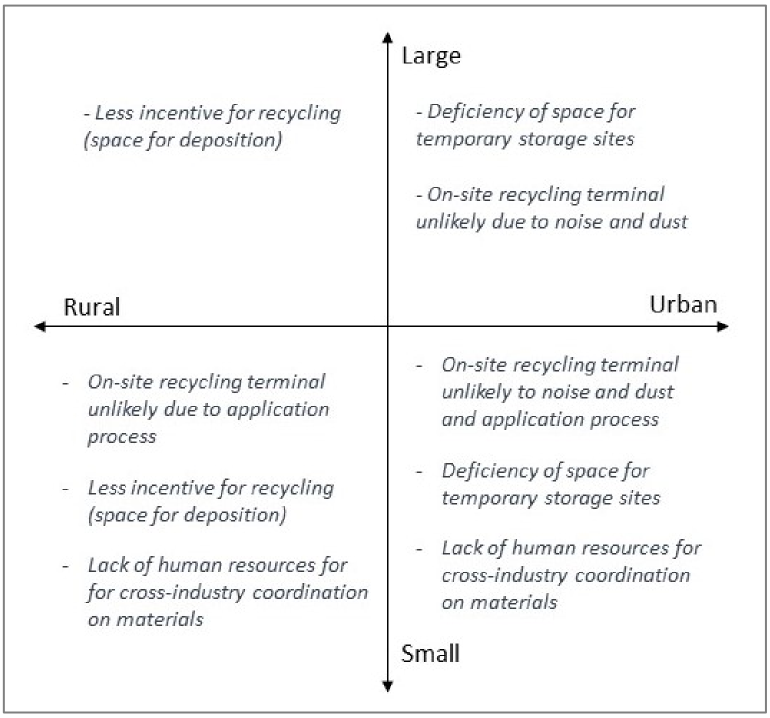

***Figure 4.2** Barrier dependency on project characteristics: size of a construction project and locality of a construction project to the barriers on temporary storage sites, recycling terminals and human resources.*

Transport cost and the lack of space are underlined as two main issues for improving the management of construction aggregates. Due to the low value of construction aggregates, transport costs often becomes the determining factor for where material is gained from and to where it is deposited. The lack of space is problematic, because it prevents initiatives such as temporary storage and recycling terminals, which could otherwise have supported the better utilization of material. If the lack of space prevents such solutions nearby, then most often material will be permanently deposited. Transport is also problematic because it causes other impacts such as CO_2 emissions, noise and dust, road damage etc. Research should be carried out on how transport cost and impacts could be reduced. This could include the electrification of trucks, reducing the size of individual trucks, etc. If this concurrently increases the transport distance, which is profitable, then the potential for measures such as temporary storage and recycling terminals increases.

For the interviews carried out in this thesis, industry stakeholders are overrepresented compared to public authorities, why the mentioned barriers and mitigation measures mainly regard the construction sites and incentives for contractors. This may understate potential conflicts in the public, legal, and regulatory systems in the shift for a better material management.

Still, to overcome any of these barriers, the importance of including industry stakeholders in developing measures is underlined, because contractors to secure that they work in practice. In addition, it was pointed out that any change in regulations and requirements should be long-lasting to provide security for contractors to adjust their businesses.

4.5 Further work

In this thesis, we have investigated the potentials for optimizing construction aggregates management in the road sector by the application of MFA methodology. We have developed a MFA system, which can help provide transparency on material flows and stocks in road infrastructure. When quantified, such a system allows us to understand current material management, and to identify in which areas mitigation measures should be applied to direct the system towards greater compliance with the circular economy mindset. Moreover, the system itself supports optimized material management as it allows quantifying supplies of and demands for material for all road projects prior to construction, supporting a coordination on material utilization across the construction industry.

Through the study, we identified especially four areas, which requires further investigation and development to form a better foundation for the use of the MFA system for the outlined purposes. These are:

1. Carry out a regional quantification of the MFA to thoroughly test the system definition and draw more robust conclusions on the current material management within the road sector.
2. Develop a system to organize and store data, and distribute the responsibility for data collection and management to public authorities. This additionally requires setting requirements to the content and format of the data, which will be collected.
3. Approach the current limitations in 3D software to comply with the suggested approach for better material management.
4. Model the current road infrastructure in 3D to provide models for the quantification of flows through stock comparison, and to support carrying out prospective dynamic MFAs.

In addition, in this thesis, we investigated what underlying barriers prohibit contractors from managing material in a way more compliant to the circular economy mindset. These barriers must also be approached, to really secure the possibility of optimizing material management on construction aggregates for road construction, and mitigate issues of environmental impacts, land-use conflicts, and resource scarcity from this sector.

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5.1 Personal communication

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APPENDIX A: Interview subjects

Interview subject	Association	Interview type	Date
Carlsen, B. and Vi-cario, A.	ÅF Engineering	Open	02.02.2018
Haugen, O.J.	Statens Vegvesen Region Midt	Open	06.02.2018
Johannessen, H.P.	Skanska Industrial Solutions	Open	07.02.2018
Vicario, A.	ÅF Engineering	Semi-structured	17.04.2018
Aakre, A.	EBA	Semi-structured	17.04.2018
Olsen, V.	Franzefoss Pukk	Open	18.04.2018
Åmodt, L.	NyeVeier	Semi-strutured	19.04.2018
Hedlund, J.	PEAB Anlegg	Open	24.04.2018
Johannessen, H.P.	Skanska Industrial Solution	Semi-structured	26.04.2018
Hartnik, T.	Miljødirektoratet	Open	04.05.2018

APPENDIX B: Interview guide

Interview performed by:

Date:

Information on interview subject

Names:	Position:
Organization:	Anonymous*:

*If you answer 'no' i.e. you are not anonymous, you may still indicate anonymity for specific questions.

Text in orange are words or sentences, which may be added if the interview subject does not mention these aspects on his or her own. However, they should not be provided before the question in black has been answered.

TEMA: Ressursbruk	
I din erfaring, hvordan håndteres utgravde masser/hvad brukes de til? Hvor i landet er din erfaring basert på?	
Når utgravde masser utnyttes i eget eller andre prosjekter, hvilke hensyn tas det generelt/hva tas det hensyn til? (timing, kvalitet, kvantitet) Hvilke hensyn tas til kvaliteten av massene? Må massene altid igjennem en form for resirkulering? (sortering, rensning annet?)	
Hvad skal det til, at du samarbejder med andre entrepenører om masse deling? Hvad understøtter at sådanne overførsler skjer? (skjer det bare ved tilfeldig prat og TippNett)	
Hvis du skulle kjøpe masser fra et annet prosjekt, hvilken informasjon er da nødvendig for deg å ha? (f.eks. kvantitet, kvalitet, transport avstande, timing, kostnad, annet?) Ville en høyere grad av informasjon gjøre det enklere å resirkulere materialer til høyere formål en backfilling?	
Utnyttes masser fra andre infrastruktur prosjekter? (f.eks. riving av et hus).	
Oplever dere noen krav fra myndigheter ift. hvordan ressurser utnyttes? Opplever dere noe press ellers i industrien til, hvordan masser utnyttes? (bergverkindustrien)	

Hvor alvorlig ser dere på trusselen med knapphet på byggeråstoffer i fremtiden? (problem for kommunen/udbyder eller dere?)	
Andre kommentarer til ressursbruken innen infrastruktur?	

TEMA: Metoder til økt ressursutnyttelse	
I hvor stor grad utnyttes masser innen samme prosjekt? Hvilke hensyn tas til materialets kvalitet?	
Hvor stor en andel av utgravde masser vurderer du kunne være utnyttet i andre prosjekter ? (egne vs. andre entrepenører?) Hvilke formål kunne de utnyttes til? Hvis back-filling, hvorfor ikke formål med høyere kvalitetskrav?	
Hvilke barrierer ser du for at flere masser utnyttes og ikke sendes på deponi? (mangel på data, lobbyisme fra transportvirksomhet, manglende opbevaring av masser/timing etc., logistikk, manglende kommunikasjon)	
Utgangspunktet i denne master oppgave er, at for å forbedre utnyttelsen av ressurser må vi øke gjennemsigtigheten innen ressursbruket. Hvad tenker du om denne antakelse? (fordele/ulepmer)	
En konsulent har uttalt, at etter etablering av NyeVeier, har det blitt mere vanlig med samarbejd mellom veiprosjekter. Kjenner du deg igjen i denne uttalelsen? Hvis ja, hvad har NyeVeier gjort som har ledt til økt samarbeid?	
Kjenner du noen andre initiativer, som ønsker å forbedre ressursutnyttelsen? (bruker dem gjennomsigtighet? F.eks. TippNett).	
Hvilke initiativer tror du må tas for at ressursutnyttelsen forbedres for systemet som helhet? Åpen marked ved gjennomsigtighet Optimalisering funksjon Legal instruments Benefits Kommunikasjon av fordele og ulemper for den enkelte (f.eks. manglende tilgang på ressurser)	
Hvis myndighetene skulle stille krav om økt resirkulering (så og så stor andel skal brukes til min. sådan formål), hvem ville	

det være meningsfuldt å sette sådan krav til? (konsulent, entrepenør..?)	
Hvad skal til for at dette er verdifult for konsulenter og entrepenører? What's in it for you?	

TEMA: Innrapportering av data	
Hvilke data innrapporterer dere til statistik myndigheter?	
Hvilke data innrapporterer dere til byggherre?	
Ser dere egne fordele/ulemper ved en større grad av innrapportering? (statistik å forholde seg til, virksomhetshemmeligheter..)	

TEMA: Tidsaspekt/timing *Ved «samordning av aspektene tid og ressurstilgjengelighet» henvises til det, at ressurser ikke nødvendigvis blir tilgjengelige akkurat når de skal brukes.*	
Hvordan samordner man aspektene tid og ressurstilgjengelig i planleggningen sin innen et prosjekt? (f.eks. på prosjektnivå – DynaRoad).	
Hvordan samordner man aspektene tid og ressurstilgjengelighet innen for virksomheten? Altså mellom prosjekter innen samme virksomhet? I hvor stor grad gjøres dette? Hvilke typer prosjekter?	
Ser dere ut mot andre virksomheter? Hvad er den lengste periode dere har samordner med andre virksomheter over?	
Hvilke barriere gir det, at ressurser ikke brukes med en gang de er tilgjengelig og omvendt? (f.eks. at man må opbevare materialer, at man ikke vet hvem som har det neste prosjektet om tre år, osv.).	
Hvad kan man gjøre for å imødegå disse barriere?	
Prosjektet Kortreist Stein foreslår, at man i udbudsdokumenter skal konkretisere, hvor store områder rundt byggeprosjektet man vil trenge f.eks. til midlertidig opbevaring eller resirkulering. Hvad tenker du om dette?	

TEMA: Software development	
I hvor stor grad er dere kjent med BIM/VDC? I hvor stor grad er bransjen generelt kjent med BIM/VDC?	

Hvilke 3D programtyper bruker du/dere? Hvad er funktional-iteten av dette program?	
Hvilke krav oplever dere at det stilles fra myndighetene ift. bruk av BIMV/VDC software?	
Hvilket nivå/level er dere på? Hvilke innrapporteringskrav stiller myndigheterne?	
Hvis myndighetene skulle stille strengere krav til innrapportering via 3D modeller, hvilke utfordringer ville dette gi?	
Måtte myndigheterne tage noen initiativer i tilleg til at stille krav, for at kravet kunne innfris? (f.eks. udbyde kurser, konkretisere format, opbygge egen infrastruktur etc.)	
Hvad tenker du om muligheten for en samlet BIM cloud for Norge? Regional BIM? Hvad er funktionaliteten? Hvad er utfordringene?	

Kan jeg kontakte deg igjen, hvis jeg trenger yderligere information? (Ja/Nei)
Kontaktopplysninger:

Takk for din deltakelse i dette intervju!

Med vennlig hilsen

Marie Katrine Rasch

Master student, Industrial Ecology, NTNU

APPENDIX C: Interview notes

The interview notes are listed chronologically in time, and correspond to the list of interview subjects given in Appendix A.

Carlsen and Vicario 2018 (open)

Interview performed by: Marie Katrine Rasch

Date: 02.02.2018

Information on interview subject

Names: Beth Carlsen and Adrian Vicario	Position:
Organization: ÅF Engineering	Anonymous*: No

*If you answer 'no' i.e. you are not anonymous, you may still indicate anonymity for specific questions.

Interview notes

Utgravde materialer. Disse mengder er godt kendt for det er her økonimien er. Disse tal fås idag fra BIM. Masserne estimeres på baggrund av "plukprøver"/stikprøver av Jorden, men dette fører til usikkerhed for pludselig måske andre masser, som ikke kan bruges til det samme.

Massene brukes enten I same prosjekt eller på deponi. Statens Vegvesen prøver å sammenkoble entrepenører hvis forskjellige entrepenører/totalentrepriser på samme stræk.

Englang 2011, konsept utvikles omkring ønsket samkjørring. Snakker om levels. NyeVeier ønsker nivå 3 (level 3). Ønsker dette implementeret til 2020.

VDC ← Dynaroad, miljø, økonomi. Disse ønskes samordet. Pt må disse koblinger gjøres manuelt.

Dynaroad ikke 3D. Viser hvordan masser flytter seg, hvordan kortest veg. Step 1, 2, 3.

Etter NyeVeier, samarbeide er blevet mye mere vanlig.

AutoCAD får ikke inn tid (så man kunne se et byggeprosjekt). Tror AutoCAD ryger ut i fremtiden fordi bare en database. BIM er bare en database.

<u>Haugen 2018 (open)</u>

Interview performed by: Marie Katrine Rasch

Date: 06.02.2018

Information on interview subject

Names: Odd Jostein Haugen	Position:
Organization: Statens Vegvesen Region Midt	Anonymous*: Not known

*If you answer 'no' i.e. you are <u>not</u> anonymous, you may still indicate anonymity for specific questions.

<u>Interview notes</u>

Nydalsbrua-prosjketet pilotprosjekt for BegLCA.

Data som fås fra entrepenører gemmes ikke i noen database. Erom, webmodeller. Ikke 3D. pdf som scannes. 3D modellen haven, men brukes I begrenset omfang.

Genutnyttelse av masser: nei, "ellers må man ha et annet prosjekt, og det har man aldrig».

Ikke samkooridnering, fordi det kan være «farlig» å forsinke en del. E6 ble ét prosjekt, fordi så lettere samkoordinering av utgravde vs. fylling.

PEAP, entrepenør bak E6.

Alle prosjekteringer i 3D, model gives til entrepenør. 3D modell beholdes av SVV.

Bliver for stort, for tung å jobbe med, hvis man samler flere modeller.

SVV modellgrunnlag. V770.

Tenker på masser kortreist og gjenbruk, fordi det er økonomi I det.

Deponi? Mellomlagring, ordnet nok plass til entrepenør ordner selv. Runt veien. Deponi, setter annonse i avisen, entrepenør kontakter.

Entrepenør bestemmer selv, hvorfra de får materialer fra, eller imot konkurrense.

Noen som jobber med å snu det sammen

Samarbeide mellom etaterne er veldig begrenset. Hver sin økonomi. Av og til prøver man å samarbeide. Ikke lov med tværfinansiering (f.eks. mellom SVV og miljødirektoratet).

Frihet i linieføring er stort set fraværende, gitt i reguleringsplan.

SVV region midt: Drift, brøyte og slik, Nytt bygg, Viltoppsyn

1000 ansatte i Region Midt.

Siden 2003 ikke ute å bli skitne på fingene, utlicitering.

Sporadisk kontakt mellem nytt bygg og drift i prosjektering.

Drift kan ha krav til detailløsninger.

Hovedoversikt over mengder.

Gamle materialer fra veien brukt i støyvoller, ingen viten førav. Har noen antakelser men ingen fast viten.

Revidering? Nok ikke revidering av 3D modell, men I tallene av utgravd material.

Johannessen 2018a (open)

Interview performed by: Marie Katrine Rasch

Date: 07.02.2018

Information on interview subject

Name: Hans Petter Johannessen	Position: District responsible
Organization: Skanska Industrial Solutions	Anonymous*: No

*If you answer 'no' i.e. you are not anonymous, you may still indicate anonymity for specific questions.

Interview notes

Göteborg student, solehelga plussby. Plusshus. Problem, jernbaneprojekt, deponere råstoffer som altid gjort, selvom bryter masseforvaltningsplaner. E16 og ringriksbanen i Bærum. Argument

Materialer i veien er kjent. Man kjenner byggetidspunkt, veien står i mapper. Så man vet hvad som er i. Yngre 40-50 år siden. Men ikke mange materialer uanset. Store prosjekter som har volumen. Både kjukk hvor forsterkningslag, hvordan dekke. Bra peiling på

Tre hovedkvaliteten i norge, til forsterk og bærelag. Og det som man trenger i veidekke.

70-80% det er godkjent for bruk i nye veier.

Mange som er imot resirkulering.

Kart som viser bergkvalitet fra NGU.

De masser som går til deponi fra byggeprojsekt i byen har man oversikt over by-produksjon, men på land betyder ikke noget.

Mangler arealer, mangler samarbeider mellom etater.

Nye standarder, du har lov å bruke i veg

Veidekke er begrenset til gjenbruk, 80% i EU. SVV er mere konservativ, 20-30%, tør ikke så mykje.

Masser ut til deponi, masser inn til produksjon.

Veldig dårlig samordning mellom prosjekt, bare tippnett. Mangler verktøyer, lasterbiler har kontakt og vet. Manuelle systemer. Bruker transportører. Transportører vil beholde den business. Avtaler til flere aktører. Ikke alle som vil bruke verktøy heller

Terminaler, mellomlagring, råstoffinnsamling. Kortreiste materialer. Store volumen.

Ikke involvert i kortreist stein.

Skanska har kanskje oversikt, men ikke altid. Lite kostnad, hvis små masser ikke økonomi, så tjekker ikke engang.

Veidekke har mange pukkverk, skanska har ingen pukkverk, men mange terminaler. S skal ha flere pukkverk, men alle

Mellomlagring/terminaler bliver solgt frit markedet.

Hvad brukes resirkulert til? Du bruker det til det som det er godkendt til. Forsterkningslag, støyvoller.

I TRD ikke samme behov for resirkulering, ift oslo og bergen hvor mere urgent.

Funksjon krav i stedet for materialekrav, kun i store prosjekter nå.

Gjenbruk mest mulig, resirkulering. Varierende praksis, ikke alle som har kompentense.

Kartlagt bare prosjekt over mange millioner. Noen prosjekt som har alle masser.

Bærum kommune. Mange byggeprosjekter. 15 mil m3 som skal flyttes over 10 år.

Norgebygges.no, alle statlige prosjekter på en gang. Abbonnement.

Prosjekteres over neste fem år.

Konsulentene ønsker ikke å svare på noen ting, før alt er ferdig. Løsmasser kan være forurenst. 70% er alle løsmasser er forurenset. Kan resirkuleres også.

Store næringsprosjekt, mykje på deponi, for skal ut veldig fort. Ikke nok terminaler. Blandet med materialer. Nabobyen, 5-6 mil til hønefoss ish, jord til bonde. Feil politikk. Fylkeskommune har ansvar for å se på det. Regionale planer for å se på det. Masseforvaltningsplaner, åben på nett. Kommune skal følge dette i fremtiden. Skjønner hvor utviklingen går.

Villfyllinger, redusert. Mere i TRD. Varierer med geografi. Deponi med med rene masser, og så mikser med forurensete masser. Ikke særlig store konsekvenser.

Vicario 2018 (semi-structured)

Interview performed by: Marie Katrine Rasch

Date: 17.04.2018

Information on interview subject

Name: Adrian Vicario	Position: projekteringsleder og BIM koordinator
Organization: ÅF Engineering	Anonymous*: No

*If you answer 'no' i.e. you are not anonymous, you may still indicate anonymity for specific questions.

Interview notes

TEMA: Ressursbruk	
I din erfaring, hvordan håndteres utgravde masser/hvad brukes de til? Hvor i landet er din erfaring basert på?	Filling, grøft. Drenering. Prøver å genbruke så mye av massen. Så balancen nermer seg nul ved avslutningen. Brukes langs samme veilinie. Håntere masse innen for veilinie. Noen masser er ikke brukbare. Kvaliteten, forurenset masser. Kvikkleira kan ikke brukes. Til deponi. Forurenset masser må testes, tilstandsklasse. Noen forurenset masser kan transporteres til deponi og så brukes på et annet dponi (klasse 2). Ikke barnehage men kanskje veiprosjekt. Konsulent bestemmer hvilke masser kan genbrukes. Konsulenten foreslår setder det skal stå, men entrepenørerne som bestemmer i siste ende. Konsulent siger materiale kan gjenbrukes, men entrepenører bestemmer precis hvor. Konsulent hjelper dem ved total entreprise prosjekter.
Når utgravde masser utnyttes i eget eller andre prosjekter, hvilke hensyn tas det generelt/hva tas det hensyn til? (timing, kvalitet, kvantitet)	Entrepenøren som tager hensyn til timing. DynaRoad for noen år siden. Brukte når sammen med entrepenør for å hjelpe dem. Men akkurat nå bare volum av masser.

Hvilke hensyn tas til kvaliteten av massene? Må massene altid igjennem en form for resirkulering? (sortering, rensning annet?)	Deponi behandler masser langs vei. Men entrepenøren som foreslår handlingsplan. Her foreslås konkrete arealer for deponi. Statens vegvesen anbudskonkurrence. Lov til å pr Konsulent prosjektere vei i deltajer, men noen ting de ikke kan fastsette, så kan entrepenører ikke konkurrere med noget. Enkel fremtidsplan for konsultent, priser. Men presis ved entrepenører. Entrepenører er setter pris under, og så finder de 10 millioner her og der ved å finne feil ved konsulent utkast. Diskvalifisering på veldig lav pris ses ikke i Norge. De bare gir oppgaven som om, når skal entrepenøren til at tabe penge, men entrepenørene er flinke. Diskvalifisering i Norge må ha veldig gode argumenter. Personlig følelse. Det må kontrolleres mere.
Hvad skal det til, at du samarbejder med andre entrepenører om masse deling? Hvad understøtter at sådanne overførsler skjer? (skjer det bare ved tilfeldig prat og TippNett)	To store prosjekter E6 s'r, og Ranheim. Begge hærer til NyeVeier. Kunden/byggherre må bestemme. Det skal ske organisert fra byggherre. Veiene må prsjekteres samtidig. Entrepenøren i anbudet kan spørre byggherren. Ikke lov å vite om et annet prosjekt. Men siden konsulent ikke bygge alle prosjekter, dem må ikke vide detaljer om andre prosjekter. Konsulenter kan være proaktive, men det er byggherrer som bestemmer for det er de som ejer masser. Neon gange kjøper entrepenør overskud av masser, fordi billigere hvis mange masser. Men ikke NyeVeier som skal betale for det ekstra, så da må entrepenører må selge.
Hvis du skulle kjøpe masser fra et annet prosjekt, hvilken informasjon er da	Ubehandlet masser fra et andet prosjekt, som må behandles før bruk. Fraksjoner, 22-63

nødvendig for deg å ha? (f.eks. kvantitet, kvalitet, transport avstande, timing, kostnad, annet?) Ville en høyere grad av informasjon gjøre det enklere å resirkulere materialer til høyere formål en backfilling?	(størrelser, mellem 22 og 63). Volumen, transportavstande (lokalitet). Dårlige masser, mineralsammensetning f.eks. Når prosjektering, tenker på total volum. Alle masser som ikke brukes i samme vei angives «går til godkendt deponi». Det er ikke lov for entrepenør at selge masser, hvis ikke statens vegvesen godkender det.
Utnyttes masser fra andre infrastruktur prosjekter? (f.eks. riving av et hus).	
Oplever dere noen krav fra myndigheter ift. hvordan ressurser utnyttes? Opplever dere noe press ellers i industrien til, hvordan masser utnyttes? (bergverkindustrien)	Det settes ikke krav til resirkulering. ÅF prøver, men det går litt på miljø. All produksjon må være utslipp nul, ikke noget overskud. Ikke kjøpe masser. Massevolumen kan kontrolleres i større prosjekter. Men ved små prosjekter kan det bli nødvendigt å kjæpe. Vei som har overskud, går til deponi. Så det kan gå til små prosjekter. Først ser på hvem som selger masser. F.eks. franzefoss har også deponi. De selger disse masser. Det som kjøpes fra deponi koster mere enn å sende til deponi. Deponien behandler masser, så som selges igjen.
Hvor alvorlig ser dere på trusselen med knapphet på byggeråstoffer i fremtiden? (problem for kommunen/udbyder eller dere?)	Stort sak nå. Ikke mye som man kan gjære i prosjekteringen. Det er entrepenør som bestemmer hvordan masser fjernes fra tunnel. Konsulent og byggherre er det ikke noe konsulenter tenker på. De finner ut om det er bruk for tunnel, men ikke noe med masserne.
Andre kommentarer til ressursbruken innen infrastruktur?	

TEMA: Metoder til økt ressursutnyttelse	
I hvor stor grad utnyttes masser innen samme prosjekt? Hvilke hensyn tas til materialets kvalitet?	
Hvor stor en andel av utgravde masser vurderer du kunne være utnyttet i andre prosjekter ? (egne vs. andre entrepenører?) Hvilke formål kunne de utnyttes til? Hvis back-filling, hvorfor ikke formål med høyere kvalitetskrav?	
Hvilke barrierer ser du for at flere masser utnyttes og ikke sendes på deponi? (mangel på data, lobbyisme fra transportvirksomhet, manglende opbevaring av masser/timing etc., logistikk, manglende kommunikasjon)	Lite fleksibilitet for konsulenter til at tenke utnyttelse i ressourser ut for prosjektt. TippNett er en kjempe god ide. Noen må kontrolleres av staten (byggherrer). To prosjekter tett ved hverandre, dem må samarbeide. Type applikasjon, men byggherre må godkjenne. Risiko for ellers det bare tjenes penge på masser. Det mangler noen veier for samarbeidet. Men det går
Utgangspunktet i denne master oppgave er, at for å forbedre utnyttelsen av ressurser må vi øke gjennemsigtigheten innen ressursbruket. Hvad tenker du om denne antakelse? (fordele/ulepmer)	Det går mest på entrepenører. Dette kan avslører hvordan entrepenører er sterke mot konkurrenter. Noe som ikke kan deles med andre. Mister konkurrenceevne. Noen ting må deles, NyeVeier kjøper arbeid av entrepenør, mye av det konnskap som må tilbakeføres til NyeVeier. NyeVeier ejer alt som skjer i prosjekter, inklusiv kunnskap. Workshop med andre som deles. «vi har lært, når man transportere masser». Alt kunnskap eies av

	nye veier. Deler kunnskap funnet i prosjektet men ikke rutiner. Kan levere alle BIM modeller. Møterutine ikke dele. Bedre med to tuneller end to bruer pga. massehåndtering. NyeVeier må presse på entrepenører "Vi må ha en workshop". Hvis de er involvert i prosjekt. NyeVeier må ha høy ekspertise til å bstemme. Det skulle være mere faglig ekspertise hos kunder/byggherrer. Ulempe for konsulenter fordi bygherre ikke altid forstår og bare avviser. Så større ekspertise vil vøre en fordel for entrepenøren/konsulenten. Konventioneller pga. Manglende kunnskap. Tre konsulenter var enige, men byggherre ville ikke har det. Men løsningen krevede ekstra penge i kostnader. Mistillid? Kunder er veldig administrative er veldig opptatt av penge. Men også må ha faglig ekspertise. NyeVeier har rammeavtale. Ikke ekspertise hos NyeVeier om hydrologi. Går via rammeavtale (byggherren har små prosjekter, når setter anbud på prosjekt koster for mye, rammeravtale på små prosjekter, så alle som er med i rammeavtale). Fordeler mellem entrepenører som er med i prosjekter. NyeVier har rammeavtale. Leier fra ÅF for å ha ekspertise. Det er vanskelig å få ingeniører til byggherrer, fordi dårligere lån
En konsulent har uttalt, at etter etablering av NyeVeier, har det blitt mere vanlig med samarbejd mellom veiprosjekter. Kjenner du	

deg igjen i denne uttalelsen? Hvis ja, hvad har NyeVeier gjort som har ledt til økt samarbeid?	
Kjenner du noen andre initiativer, som ønsker å forbedre ressursutnyttelsen? (bruker dem gjennomsigtighet? F.eks. TippNett).	
Hvilke initiativer tror du må tas for at ressursutnyttelsen forbedres for systemet som helhet? Åpen marked ved gjennomsigtighet Optimalisering funksjon Legal instruments Benefits Kommunikasjon av fordele og ulemper for den enkelte (f.eks. manglende tilgang på ressurser)	
Hvis myndighetene skulle stille krav om økt resirkulering (så og så stor andel skal brukes til min. sådan formål), hvem ville det være meningsfuldt å sette sådan krav til? (konsulent, entrepenør..?)	
Hvad skal til for at dette er verdifult for konsulenter og entrepenører? What's in it for you?	

TEMA: Innrapportering av data	
Hvilke data innrapporterer dere til statistik myndigheter?	
Hvilke data innrapporterer dere til byggherre?	

Ser dere egne fordele/ulemper ved en større grad av innrapportering? (statistik å forholde seg til, virksomhetshemmeligheter..)	

TEMA: Tidsaspekt/timing	
Hvordan samordner man aspektene tid og ressurstilgjengelig i planleggningen sin innen et prosjekt? (f.eks. på prosjektnivå – DynaRoad).	
Hvordan samordner man aspektene tid og ressurstilgjengelighet innen for virksomheten? Altså mellom prosjekter innen samme virksomhet? I hvor stor grad gjøres dette? Hvilke typer prosjekter?	
Ser dere ut mot andre virksomheter? Hvad er den lengste periode dere har samordner med andre virksomheter over?	
Hvilke barriere gir det, at ressurser ikke brukes med en gang de er tilgjengelig og omvendt? (f.eks. at man må opbevare materialer, at man ikke vet hvem som har det neste prosjektet om tre år, osv.).	
Hvad kan man gjøre for å imødegå disse barriere?	
Prosjektet Kortreist Stein foreslår, at man i udbudsdokumenter skal konkretisere, hvor store områder rundt byggeprosjektet man vil trenge f.eks. til midlertidig opbevaring eller resirkulering. Hvad tenker du om dette?	

TEMA: Software development	
I hvor stor grad er dere kjent med BIM/VDC? I hvor stor grad er bransjen generelt kjent med BIM/VDC?	Utbredt i bransjen i Norge. Mangler noe nytt i verden, mangler standarder f.eks. for format. Ikke konkretisert.
Hvilke 3D programtyper bruker du/dere? Hvad er funktionaliteten av dette program?	Programvare avhenger av prosjekt. Hovedsagelig Autodesk.
Hvilke krav oplever dere at det stilles fra myndighetene ift. bruk av BIMV/VDC software?	De største prosjekter, NyeVeier, stiller krav om BIM. Strengere krav til prosjekteret må kjøres på BIM. Nå skal BIM være sentrals. Men mindre byggherre, kommuner, bruker level 0. På papir (level 0). Store kommune level 1-2. 3D som visuelt. NyeVeier vil gjerne ha level 3 til nivå hvor mulig. I ÅF prosjektere uanset i 3D, altid i BIM. Men leverer som kunden vil ha. Kommer også an på detajlnivå, hvad kunden etterspørger. Ikke alle som betaler for at få det på 3D. Statens Vegvesen, noen prosjekter bare levert i 3D. Noen som ænsker 2D, 3D. Modelgrunnlag (statens vegvesen) krav til standarder. Veldig overordnet krav. Hvad betyer informasjon må standardiseres. Det er ikke gjort. Europa.
Hvilket nivå/level er dere på? Hvilke innrapporteringskrav stiller myndigheterne?	
Hvis myndighetene skulle stille strengere krav til innrapportering via 3D	

modeller, hvilke utfordringer ville dette gi?	
Måtte myndigheterne tage noen initiativer i tilleg til at stille krav, for at kravet kunne innfris? (f.eks. udbyde kurser, konkretisere format, opbygge egen infrastruktur etc.)	Sette i konkurrencegrunnlag. Alle konsulenter i Norge (untagen småbedrifter) har kunnskaper. Det kommer av seg selv med 3D bruk. Hvis småbedrifter må lære seg det. SVV udbyder kurser i 3D. Programvarer gir kurser. Det er også konkurrence hvem som er bedst til BIM. Denne kunnskap kan ikke deles.
Hvad tenker du om muligheten for en samlet BIM cloud for Norge? Regional BIM? Hvad er funktionaliteten? Hvad er utfordringene?	Det må gjøres! Ikke nødvendigvis en cloud for hele staten, men ser for seg NyeVeier/SVV, en kunde, må ha en database/cloud, hvodan man skal standardisere alle prosjekter. SIM City. Med mye mere detaljer. Kan støtte drift og vedlikehold. Må ha kunnskap til alt som skjer i bygget. «dør må skiftes ut om to år». Ikke bare model for å bygge den, men også model for å vedlikeholde den. Må standadiseres av en myndighet. Krav om miljø, ... så også krav om hvilken model som bygges. Ikke tilgjengelig for alle. Kun myndigheten. Det er myndigheten som kan dele det som de vil. Kan også være at SVV gir ut 3D model som kan være grunnlag for vurdering. F:eks. Hvad er i jorden. Det kan løses med sådan database. Verden hvor vi har alt data sentralisert en plass (ikke Norge, men i de enkelte enheter). Udfordringene for å oppnå dette: standardisering. Må bestemmes hvem skal bestemme. NyeVeier, hvem i NyeVeier som bestemmer hvordan det skal se ut. Må hente kunnskap fra entrepenørene. De skal ikke bestemme dette alene. Stor faglig kunnskap til bidra med.

Aakre 2018 (semi-structured)

Interview performed by: Marie Katrine Rasch

Date: 17.04.2018

Information on interview subject

Name: Arne Aakre	Position: Avdelingsleder Vei og Jernbane
Organization: EBA	Anonymous*: No

*If you answer 'no' i.e. you are not anonymous, you may still indicate anonymity for specific questions.

Interview notes

TEMA: Ressursbruk	
I din erfaring, hvordan håndteres utgravde masser/hvad brukes de til? Hvor i landet er din erfaring basert på?	Entrepenører, nøkkel til lønsomhet, masseballance, minst mulig håntering av transport. Brukes i prosjekt og så fort som mulig. Anlegg av veig vs. vedlikehold, asfaltering. Av og til masser av sådan kvalitet. Tviste-saker: stor uenighet i økonomi kan ofte handle om flytting av masser. Beskrivelsene av kvaliteten av massene. Massene er ikke av kvalitet som angitt. Besidder/byggherrer som skal beskrive materialene. Hånteres, knuses, renses på plassen. Ikke altid det gjøres på plassen. Store prosjekter. Sikring av arealer runt byggeprosjekt til resirkulering.
Når utgravde masser utnyttes i eget eller andre prosjekter, hvilke hensyn tas det generelt/hva tas det hensyn til? (timing, kvalitet, kvantitet) Hvilke hensyn tas til kvaliteten av massene? Må massene altid igjennem en form for resirkulering? (sortering, rensning annet?)	Mellem prosjekter: kvaliteten: kjøpe med antagelse at det er godt nok. Elers. Mölleverdien, mineralsammensetning i andre I store prosjekter har man asfaltanlegg på prosjektet, bruker masser utgravde. ENCC – kontakt.
Hvad skal det til, at du samarbejder med andre entrepenører om masse deling? Hvad understøtter at sådanne overførsler skjer? (skjer det bare ved tilfeldig prat og TippNett)	Mellom prosjekter: Looprocks Entrepenører at flytte masser er forretningside. Kjøpe opp, selge. Håkernes mashine.

Hvis du skulle kjøpe masser fra et annet prosjekt, hvilken informasjon er da nødvendig for deg å ha? (f.eks. kvantitet, kvalitet, transport avstande, timing, kostnad, annet?) Ville en høyere grad av informasjon gjøre det enklere å resirkulere materialer til høyere formål en backfilling?	
Utnyttes masser fra andre infrastruktur prosjekter? (f.eks. riving av et hus).	
Oplever dere noen krav fra myndigheter ift. hvordan ressurser utnyttes? Opplever dere noe press ellers i industrien til, hvordan masser utnyttes? (bergverkindustrien)	Nå begynner det å komme krav fra myndigheter. Transportere mindst mulig, mindst CO2. Kortreist stein. Kvaliteter, krav har vært det hele tiden. Downcycling tilladt.
Hvor alvorlig ser dere på trusselen med knapphet på byggeråstoffer i fremtiden? (problem for kommunen/udbyder eller dere?)	Knapphet – det vil altid være masser. Transport høy. Det er utfordringen, avstander, looprocks. Transport vil muligvis foregå utslippsfri (el-biler), men stadig slidt på veier.
Andre kommentarer til ressursbruken innen infrastruktur?	Transport. CO2 ikke noe problem i fremtiden. Støy, belaster miljø, veiene. Omkostninger vil fortsat være høye.

TEMA: Metoder til økt ressursutnyttelse	
I hvor stor grad utnyttes masser innen samme prosjekt? Hvilke hensyn tas til materialets kvalitet?	Deponi: enkelte masser som er forurenset. Tunnel, bunden av tunnel blir forurenset (diesel), pg.a. kjørringer, så dem må deponeres. Tror på anleggsprosjekter. Rensing er en ekstra prosess. Veldig små mengder. Tror anleggs der er andre løsninger.
Hvor stor en andel av utgravde masser vurderer du kunne være utnyttet i andre prosjekter ? (egne vs. andre entrepenører?) Hvilke formål kunne de utnyttes til? Hvis back-filling, hvorfor ikke formål med høyere kvalitetskrav?	

Hvilke barrierer ser du for at flere masser utnyttes og ikke sendes på deponi? (mangel på data, lobbyisme fra transportvirksomhet, manglende opbevaring av masser/timing etc., logistikk, manglende kommunikasjon)	
Utgangspunktet i denne master oppgave er, at for å forbedre utnyttelsen av ressurser må vi øke gjennemsigtigheten innen ressursbruket. Hvad tenker du om denne an-takelse? (fordele/ulepmer)	Kjempe fordel. Forutsetninger for bedre utnyttelse. Tror ikke entrepenører vil ha noe imot det. Har fokus på å fremstå miljømessig.
En konsulent har uttalt, at etter etablering av NyeVeier, har det blitt mere vanlig med samarbejd mellom veiprosjekter. Kjenner du deg igjen i denne uttalelsen? Hvis ja, hvad har NyeVeier gjort som har ledt til økt samarbeid?	Prosjekter i Telemark. NyeVeier som har begge. Felles kontorer for begge entrepenører. Prosjekter foreløper parallelt. Ryksett-dørbal, tunelreetablering Bamle tunnel og Høgen tunnel.
Kjenner du noen andre initiativer, som ønsker å forbedre ressursutnyttelsen? (bruker dem gjennomsigtighet? F.eks. TippNett).	
Hvilke initiativer tror du må tas for at ressursutnyttelsen forbedres for systemet som helhet? Åpen marked ved gjennomsigtighet Optimalisering funksjon Legal instruments Benefits Kommunikasjon av fordele og ulemper for den enkelte (f.eks. manglende tilgang på ressurser)	Langsiktighet, forutsigbarhet. Visse krav i kontrakten, disse krav gjelder alle kontrakter i fremtiden, så entrepenører kan bygge opp virksomheten for evnen og kunnskapen. Rigge virksomheten til. Nye krav må ikke bare skifte. Teste ut nytt, da gjøre mange gange, så entrepenører kan øve seg.
Hvis myndighetene skulle stille krav om økt resirkulering (så og så stor andel skal brukes til min. sådan formål), hvem ville det være meningsfuldt å sette sådan krav til? (konsu-lent, entrepenør..?)	Krav både til konsulent og entrepenører. Begge har berøring med dette. Avtaler kan være mellem byggherre og entrepenør. Dia-log mellem b. Og e. Er vigtig. E. Har over-sikt over hvad som er mulig. E. Bygger opp kapacitet, bare oppgaven er der.

	Byggherre er redd at skal stille så strenge krav at ikke konkurence nok i markedet. Men e. Ike redd for det, de tilpasser seg, så lenge langsigtighet.
Hvad skal til for at dette er verdifult for kon-sulenter og entrepenører? What's in it for you?	

TEMA: Innrapportering av data	
Hvilke data innrapporterer dere til statistik myndigheter?	Vet ikke. Ganske beskedent.
Hvilke data innrapporterer dere til byggherre?	Større grad av innrap. Kommer an på hvilken slags data. Ingen som ønsker mere byråkrati. Stiller du krav, må du følge opp.
Ser dere egne fordele/ulemper ved en større grad av innrapportering? (statistik å forholde seg til, virksomhetshemmeligheter..)	Nei, ikke motstand fra e.

TEMA: Tidsaspekt/timing	
Hvordan samordner man aspektene tid og ressurstilgjengelig i planleggningen sin innen et prosjekt? (f.eks. på prosjektnivå – DynaRoad).	Barrierer: lagringsplasser, forurensning-sproblemtik, kostnader.
Hvordan samordner man aspektene tid og ressurstilgjengelighet innen for virksomheten? Altså mellom prosjekter innen samme virksomhet? I hvor stor grad gjøres dette? Hvilke typer prosjekter?	
Ser dere ut mot andre virksomheter? Hvad er den lengste periode dere har samordner med andre virksomheter over?	
Hvilke barriere gir det, at ressurser ikke brukes med en gang de er tilgjengelig og omvendt?	

(f.eks. at man må opbevare materialer, at man ikke vet hvem som har det neste prosjektet om tre år, osv.).	
Hvad kan man gjøre for å imødegå disse barriere?	
Prosjektet Kortreist Stein foreslår, at man i udbudsdokumenter skal konkretisere, hvor store områder rundt byggeprosjektet man vil trenge f.eks. til midlertidig opbevaring eller resirkulering. Hvad tenker du om dette?	

TEMA: Software development	
I hvor stor grad er dere kjent med BIM/VDC? I hvor stor grad er bransjen generelt kjent med BIM/VDC?	Begynner å være ganske udbredt hos store entrepenører. Byggeherre veldig begrenset kompetence innen BIM. Mindre prosjekter der er ikke små entrepenører ikke relevant.
Hvilke 3D programtyper bruker du/dere? Hvad er funktionaliteten av dette program?	BIM er bra for å løse konflikter, transport. Sjanse for å gjøre alt rigtig Full kontrol ift. dokumentasjon Opstår feil underveis Vedlikehold, hvad er det som befinner sig. Mye lettere å genta ting. Finde de gode løsninger. Miljøopptimalisering.
Hvilke krav oplever dere at det stilles fra myndighetene ift. bruk av BIMV/VDC software?	Myndigheter ikke ekstra initiativ. Forudsigbarhet! Entreprenører er gode til å omstille seg. Myndighetene har lite kunnskap, vil ikke stille krav hvis ikke kunnskap.
Hvilket nivå/level er dere på? Hvilke innrapporteringskrav stiller myndigheterne?	
Hvis myndighetene skulle stille strengere krav til innrapportering via 3D modeller, hvilke utfordringer ville dette gi?	
Måtte myndigheterne tage noen initiativer i tilleg til at	

stille krav, for at kravet kunne innfris? (f.eks. udbyde kurser, konkretisere format, opbygge egen infrastruktur etc.)	
Hvad tenker du om muligheten for en samlet BIM cloud for Norge? Regional BIM? Hvad er funktionaliteten? Hvad er utfordringene?	

<u>Olsen 2018 (open)</u>

Interview performed by: Marie Katrine Rasch

Date: 18.04.2018

Information on interview subject

Name: Vegard Olsen	Position: Regionsleder Trønderlag
Organization: Franzefoss Pukk AS	Anonymous*: No

*If you answer 'no' i.e. you are <u>not</u> anonymous, you may still indicate anonymity for specific questions.

<u>Interview notes</u>

Masser fra gammel veg er "brukt". Knuses, … forurensning. De må igjennem resikurlering. De brukes som fyllmasse. Mere kostbart hvis skal brukes til veg. Fyllmasse ingen krav, men ikke forurenset. Dyrt å resikulere.

Massetip (rene masser, deponi typisk urene). Jord, leira, jordforbedring.

Franzefoss har deponi for forurenset masser. Kontrollert avrenning. Massetip har entrepenører, bønder. Ramlo sand, forsett gruss. Driver også med massetip. Franzefoss har hatt. Stoppet nå. Ser på mulighetene for å gjøre det igjen.

Hvis TRD beslutter det skal resirkuleres, så..

Asfalt kan freses. Den fresemassen kan brukes igjen. Makssetting.

Hvis tager imot på massetip for 30 kr/m3, da kan du resirkulere Fra massetip blir det altid behandlet før solgt.

Resirkulering for Franzefoss ikke noget problem. Franzefoss vil få resikuleringsprocess. Virgine masser. Økonomi ligger i at ..

Denne processen gjøres for asfalt.

100 nok/m3.

Tunnelmasser i haug. Røys springer ret, brukes å fylde ut bekkedal. Samme dynge, da bliver det blandingsprodukt. God kontrol kan man kanskje.

Mobilt knuseverk og sikkteerk. Leier av entrepenører. Flere stenbrud, hvor ikke faste.

Oslo er det hauge med gode stein. Bondkall pukkverk. Vinterbru.

Tomtutvikler samarbeid så FF kan gå inn som sprengningsekspert. Være de som går inn og arbeider. Tjener litt av det nå. Stjørdal, Foosbergan pukkverk lite marked.

Dyrt å transportere, rigge mobilt knuseverk. Derfor det samles.

500.000 t på Lia.

Tiller, Remol miljøpark, tar strøsel inn.

FF har kompetence i salg på markedet (derfor kan entrepenører ikke selge videre selv, mangler kompentencen).

Resirkulerte masser brukes ikke bærelag og asfalt, men oftes forsterkningslag.

FF noe av salg går til fyllmasser. S¨hvis der ikke finnes lavkvalitetsmaser. Først fra andre tomter og bygg.

Må vite det er et marked. Investeringsvillighet.

Velde pukkverk - resikulering asfalt og betong. Lønner seg med asfalt fordi høy verdi på asfalt.

Innrappotering

D. Mineralforvaltning.

Produsert og solgt

FF. Gjen. Deponi.

500 m – 7 km, lite forskjell, da er man ute by vs. land.

UBM (resikulering på byggeplass) begrenset fordi støy, støv, avrenning.

FF mineralloven, prosjekt plan og byggningsloven. Da andre konkurrencefordel. Større administration + infrastruktur for pukkverk.

Manglende dokumentering. Krav til byggemaerialer. Må gjennem en dokumentation på nytt.

SVV mere fleksibilitet. Fremdeles deklarering, men bare fleksibilitet ift. type.

Bransjeorg. Norsk bergindustri.

Hellere selge «deponi» masser end ny utspringing. Bare selgere som styre dete, ikke markedsføring.

Deponi, inntekskilde. Forurenset masser. Også massetipper som tjent penge på.

Inventiv fra myndigheter: avgift fra regjering på deponi. Lønsomt å gjenvinne.

Krevende å sortere, like gret med massetipp.

Miljøparker blir fremtiden. Ofte virgine masser nysprengt, ikke tidligere masser.

Åmodt 2018 (semi-structured)

Interview performed by: Marie Katrine Rasch

Date: 19.04.2018

Information on interview subject

Name: Lars Åmodt	Position: Manager Technology
Organization: Nye Veier AS	Anonymous*: No

*If you answer 'no' i.e. you are not anonymous, you may still indicate anonymity for specific questions.

Interview notes

TEMA: Ressursbruk	
I din erfaring, hvordan håndteres utgravde masser/hvad brukes de til? Hvor i landet er din erfaring basert på?	Ikke noe system for masser til andre prosjekter Handbøker, begrenser hvor materialer kan brukes, så deponi Transport er dyrt. Ikke noe serlig markedet for transport, så nermeste deponi.
Når utgravde masser utnyttes i eget eller andre prosjekter, hvilke hensyn tas det generelt/hva tas det hensyn til? (timing, kvalitet, kvantitet) Hvilke hensyn tas til kvaliteten av massene? Må massene altid igjennem en form for resirkulering? (sortering, rensning annet?)	Inngå avtaler med andre som har bruk for masser. Ja, byggherre som må sikre at overførsel av masser mellem prosjekter. Trøndelag: forsøg å sammenkjører masser. Flyplass og vegbygg. TN og LR til mindre skala.
Hvad skal det til, at du samarbejder med andre entrepenører om masse deling? Hvad understøtter at sådanne overførsler skjer? (skjer det bare ved tilfeldig prat og TippNett)	Hvordan vet man om andre prosjekter? Det vet man ikke, initiatv til byggherre. Samarbeidsfora, men ikke brugt til å se på hvordan masser kan håndteres. Kommunen er involvert i planleggningen. Hvis ikke midler, ikke finansering til transport Hvorfor ikke i budgettet? Man vil gøre det billigst muligt. Det er entrepenøren som vil vinde anbud. Derfor ikke transport i budget. Tidligere gikk overskudsmasser til entrepenøren. Litt mere fleksibilitet. Hvorfor gikk man vekk fra dette? Hvis ikke ent. Klarte å bruke masse uten kostnad, så det ble ekstra

	kostnad for ent. Hvis ikke alternativ bruksom-råder. Deponier i reguleringsplan.
Hvis du skulle kjøpe masser fra et annet prosjekt, hvilken informasjon er da nødvendig for deg å ha? (f.eks. kvantitet, kvalitet, transport avstande, timing, kostnad, annet?) Ville en høyere grad av informasjon gjøre det enklere å resirkulere materialer til høyere formål en backfilling?	Kontrol av masser. Hvis ikke goe nok, vekk. Fylling da treng man ikke teste kvaliteten. Krav til hvordan komprimeres over tid. Går på håndtering av masserne. Timing, fleksibilitet: (bruk en plass, ut annen plass Entrepenørens planlegging. Klarer å få massealance på nul. Kortest transport. NyeVeier skal få entrepenøren til å optimalisere hvordan utnytte masser.
Utnyttes masser fra andre infrastruktur prosjekter? (f.eks. riving av et hus).	
Oplever dere noen krav fra myndigheter ift. hvordan ressurser utnyttes? Opplever dere noe press ellers i industrien til, hvordan masser utnyttes? (bergverkindustrien)	
Hvor alvorlig ser dere på trusselen med knapphet på byggeråstoffer i fremtiden? (problem for kommunen/udbyder eller dere?)	Større grad kunne bruke masser i vegbyggning. Håndbøker med litt lavere kvalitet kan brukes. Vegdirektoratet må grovknuses for å kunnes brukes i vegen. Fraksjoner. For noe år siden, mange veier skadet pga. Tiene. Pga. Ikke sortert masser i vegbygging → skjerper kravene. Grunn til, Svv mener det må vøre robusthet i håndbøker. Kompliserer materialhåntering.
Andre kommentarer til ressursbruken innen infrastruktur?	

TEMA: Metoder til økt ressursutnyttelse	
I hvor stor grad utnyttes masser innen samme prosjekt? Hvilke hensyn tas til mate-rialets kvalitet?	
Hvor stor en andel av utgravde masser vurderer du kunne være utnyttet i andre prosjekter ? (egne vs. andre entrepenører?)	

Hvilke formål kunne de utnyttes til? Hvis back-filling, hvorfor ikke formål med høyere kvalitetskrav?	
Hvilke barrierer ser du for at flere masser utnyttes og ikke sendes på deponi? (mangel på data, lobbyisme fra transportvirksomhet, manglende opbevaring av masser/timing etc., logistikk, manglende kommunikasjon)	
Utgangspunktet i denne master oppgave er, at for å forbedre utnyttelsen av ressurser må vi øke gjennemsigtigheten innen ressursbruket. Hvad tenker du om denne an-takelse? (fordele/ulepmer)	Ikke vitendeling direkte mellem konsulenter. Nyttiggjørelse vil ha innspil fra entrepenører. Ikke noe system for det endda. Men jobber på det. Hente inn informasjon innover i organisationen. NyeVeier.
En konsulent har uttalt, at etter etablering av NyeVeier, har det blitt mere vanlig med samarbejd mellom veiprosjekter. Kjenner du deg igjen i denne uttalelsen? Hvis ja, hvad har NyeVeier gjort som har ledt til økt samarbeid?	
Kjenner du noen andre initiativer, som ønsker å forbedre ressursutnyttelsen? (bruker dem gjennomsigtighet? F.eks. TippNett).	
Hvilke initiativer tror du må tas for at ressursutnyttelsen forbedres for systemet som helhet? Åpen marked ved gjennomsigtighet Optimalisering funksjon Legal instruments Benefits Kommunikasjon av fordele og ulemper for den enkelte (f.eks. manglende tilgang på ressurser)	Transportkostnader Restriktioner i håndbøker Mindre prosjekter ikke kontrol på massebalance innen prosjekt Optimalisere veglinier ikke innen små prosjekter Større prosjekter større sammenheng. Massebalance.
Hvis myndighetene skulle stille krav om økt resirkulering (så og så stor andel skal brukes til min. sådan formål), hvem ville det være meningsfuldt å sette sådan krav til? (konsu-lent, entrepenør..?)	Samarbeide: Store prosjekter må ha samarbeide på tvers. Ikke noe bevist valg. Initiativer:

	Legge mere vekt på klimagasutslip i anbud. Konsekvenser ved forskjellige valg. Klimaperspektiv hos NyeVeier. 40% innen 2030 ent. Må følge opp. Angi hvor mye de klarer å få til. Hvordan få ned CO2? Veidekke i Hamar, alternativ fyring av asfaltverk, alt. Energikilder
Hvad skal til for at dette er verdifult for konsulenter og entrepenører? What's in it for you?	

TEMA: Innrapportering av data	
Hvilke data innrapporterer dere til statistik myndigheter?	
Hvilke data innrapporterer dere til byggherre?	Ikke konkrete krav Dokumenteres alt i BIM, dokumentere alt de gjør skal inn i modellen. Ike specifikke krav. Ikke alle som klarer å implementere dette. Hvor dumper lass. Hvad bruker dere det til? Muligheter for ent. Og oss. Set det innenfor bygg. Sett en del feil. BIM aspekter i driftsfasen. Opdaterer modellen ved drift. Dette må fremdeles utvikles. Håper 2019.
Ser dere egne fordele/ulemper ved en større grad av innrapportering? (statistik å forholde seg til, virksomhetshemmeligheter..)	

TEMA: Tidsaspekt/timing	
Hvordan samordner man aspektene tid og ressurstilgjengelig i planleggningen sin innen et prosjekt? (f.eks. på prosjektnivå – DynaRoad).	Når vet man om kvalitet? Ofte for lite undersøkelser, må gjøres tidligere så man vet hvad masser kan brukes til. Masser man hellere kan bruke. Usikker på om man for dette til. Har ikke nok informasjon. Når først angitt at det skal gå til deponi:

	Endring man blir enig med entrepenøren om. Nye prosjekter lager handlingsplaner i samarbeide med kommune og dere. Underveis i planlegningen. Da må man vite noe om kvalitet. Gjøre undersøkelser, og så får man utnytte på best mulig måte.
Hvordan samordner man aspektene tid og ressurstilgjengelighet innen for virksomheten? Altså mellom prosjekter innen samme virksomhet? I hvor stor grad gjøres dette? Hvilke typer prosjekter?	
Ser dere ut mot andre virksomheter? Hvad er den lengste periode dere har samordner med andre virksomheter over?	
Hvilke barriere gir det, at ressurser ikke brukes med en gang de er tilgjengelig og omvendt? (f.eks. at man må opbevare materialer, at man ikke vet hvem som har det neste prosjektet om tre år, osv.).	
Hvad kan man gjøre for å imødegå disse barriere?	
Prosjektet Kortreist Stein foreslår, at man i udbudsdokumenter skal konkretisere, hvor store områder rundt byggeprosjektet man vil trenge f.eks. til midlertidig opbevaring eller resirkulering. Hvad tenker du om dette?	

TEMA: Software develop-ment	
I hvor stor grad er dere kjent med BIM/VDC? I hvor stor grad er bransjen generelt kjent med BIM/VDC?	Utvikling av BIM: Strenge krav i kontrakten ikke mulig, så ent. Kan utvikle løsning mens de jobber. Parallelt med BaneNor, SVV. Jobber med hvordan bransjen bygger løsninger. (→ flere fora «bygningssmart» «nordisk byggeherre BIM», utvikle i bransjen, →bransjen: autodesk med ent. → også entrepenører, konsulenter)

Hvilke 3D programtyper bruker du/dere? Hvad er funktionaliteten av dette program?	
Hvilke krav oplever dere at det stilles fra myndighetene ift. bruk av BIMV/VDC software?	Integrering i én modell. 500 km motervei. Entreprise BIM (EBIM) eller AssetsBIM (ABIM) ABIM finnes i Storbrittania. I januar så de. Ikke helt overførbart. Softwareutvikler ukendt. Noe som starter med nå. Tung materia. Både teknisk. Hvordan skal vi bruge det. Hvordan teknisk løsning. Fora, utviklingsprosjekter. Søke forskningsmidler.
Hvilket nivå/level er dere på? Hvilke innrapporteringskrav stiller myndigheterne?	
Hvis myndighetene skulle stille strengere krav til innrapportering via 3D modeller, hvilke utfordringer ville dette gi?	
Måtte myndigheterne tage noen initiativer i tilleg til at stille krav, for at kravet kunne innfris? (f.eks. udbyde kurser, konkretisere format, opbygge egen infrastruktur etc.)	Langsigtighet? Noen gange sagt entrepenør må kunne på plass med system. Noen krav, plan hvordan komme frem til. 4 underskrevet kontrakter, bedre og bedre for hver gang. Ingen kurser Format: ingen krav inntil nå. Det må ses på ABIM. Igang med dette.
Hvad tenker du om muligheten for en samlet BIM cloud for Norge? Regional BIM? Hvad er funktionaliteten? Hvad er utfordringene?	
Ekstra:	Ent på å finne gode løsninger: 25% er pris 75% er den gode løsning. Optimalisere hvordan man bygger: overordnet kostnad og utslip. Vise hvordan ting gjøres bedre, støy etc. Initiativ for kreativitet for god løsning.

Hedlund, J. 2018 (open)

Interview performed by: Marie Katrine Rasch

Date: 24.04.2018

Information on interview subject

Name: Johans Hedlund	Position: National Category Manager
Organization: PEAB	Anonymous*: No

*If you answer 'no' i.e. you are not anonymous, you may still indicate anonymity for specific questions.

Interview notes

100.000 – 50.000 leira til deponi. Bønder til masrker. Bønder som allerede har deponiavtale. Gebyr.

Vegvesenet har ikke set på sammenkjøring.

Gamle vegmasser: 100.000 asfalt, gjenbruk 50% (bærelag, betales pr. Ton (BA gjenbygging). Asfalt legges på lager på byggeplassen, knuser kommer til anlegget når nok materiale. Lagringsplass.

Franzefoss, nyspreng materiale.

Hvis vejen er gammel, mest sand. Brugt som fylling (anleggsveier). Problem timing. Man ved ikke hvor mye som kommer. Gammel veg – hvis skal fjernes ser man ikke hvad var under.

Bruger ikke Dynaroad. Store fyllinger kan planlegges, men mindre fyllinger, der er så mange parametre som spiller inn. Mindre fyllinger måske 30%, da går hele billedet.

Justere ikke 3D modellen, når man har endret plan. Økonomisk regulering foregår på siden. Gemini.

Byggeavsnit: 2-3 m øverst → bekk som skulle heves, 25.000 m3 (den nermest).

Kalkstøtte til å stabilisere. 2 mnd hærdning.

3-12 m enten il bek, 45.000 m3 opfylling (lengre borte) eller til bønder 80.000 m3. Beslutning underveis.

Materiale til frostsikringslag fås fra Franzefoss.

Materiale til forsterkningslag fås fra Ramlo.

PEAB asfalt. Havn i Trondheim. 10-15% gjenbruk. PEAB industry.

Johannessen 2018b (semi-structured)

Interview performed by: Marie Katrine Rasch

Date: 26.04.2018

Information on interview subject

Name: Hans Petter Johannessen	Position: District responbile
Organization: Skanska Industrial Solutions	Anonymous*: No

*If you answer 'no' i.e. you are not anonymous, you may still indicate anonymity for specific questions.

Interview notes

TEMA: Ressursbruk	
I din erfaring, hvordan håndteres utgravde masser/hvad brukes de til? Hvor i landet er din erfaring basert på?	Overskudsmasser. Deponering. Nei, 80% er deponering. Oslo- stor-Oslo. Det samme i hele landet. I byer.
Når utgravde masser utnyttes i eget eller andre prosjekter, hvilke hensyn tas det generelt/hva tas det hensyn til? (timing, kvalitet, kvantitet) Hvilke hensyn tas til kvaliteten av massene? Må massene altid igjennem en form for resirkulering? (sortering, rensning annet?)	Planlegge i forkant, mellom prosjekt. Må planlegge for gjenbruk. Det blir ikke gjort. TippNett og Looprocks, blir ikke brukt av mange nok. Gir ikke noe bidra. Barrierer? Markedet er ikke modent, for mange som tjener penge på deponering. 70-80% til permanent deponering. Egnet for gjenbruk. Ingen mulighet i dag. Ikke tilrettelagt arealer runt byen til lagring for resirkulering. 30% går gjenbruk, til ombruk i en eller anden form. Både direkte og resirkuleringsprocesser. Mest til ombruk, for eksempel slalombakke eller rideanlegg. Eller støyvoller. Deponi, permanent deponi. Slutdeponi. Da blir det liggende. Forskjellige recipienter. Transporterer, kommunen. Franzefoss tar imot bare masser dem skal som dem skal resirkulere. Skanska. AS gruppene. Først og fremst de tre som driver med resirkulering.

	Skanska tager imod masser fra andre entrepenører også.
Hvad skal det til, at du samarbejder med andre entrepenører om masse deling? Hvad understøtter at sådanne overførsler skjer? (skjer det bare ved tilfeldig prat og TippNett)	Slipper å betale dyr transport. Slipper de-poniavgift. 4-5 gange så mye for transport end deponiavgift. Resirkuleringsanlegg planlagt i byen og runt byen.
Hvis du skulle kjøpe masser fra et annet prosjekt, hvilken informasjon er da nødvendig for deg å ha? (f.eks. kvantitet, kvalitet, transport avstande, timing, kostnad, annet?) Ville en høyere grad av informasjon gjøre det enklere å resirkulere materialer til høyere formål en backfilling?	Ja, skanska kjøper fra leverandører, masseuttak. Ikke mellem prosjekt. Ikke så ofte, for det må passe i tid og type prosjekt. Myndigheter gjør ingenting for å time prosjekter. Myndighetene er skikkelig dårlige på det. Ikke fokus med reduksjon av transport. Startet med litt fokus. Enkelte kommune. Bærum, Oslo ikke så langt, er på vei men veldig lite fokus det. Da information pris og kvalitet. Det koster litt penge å få deklaration, men ikke vanskelig å få prøver. Sikre steinkvaliteten. Størrelse? Mellem prosjekt ikke fordeling. Kan ikke brukes i vegkroppen med mindre Myndgiheter vil ikke ha sådan maskiner på plassen. Vanskelig å få gjenbruk pga. regelsæt. Gravemaksine krever ikke tillatele, men det gjør resirkuleringsmaskiner. Vanskelig å få tilladelse, tidskrevende. Regelverk hjelper ikke. Ikke tilpasset det samfund vi lever i nå. Alt må sendes til fylkesmann, dokumentasjon for masser. Utslip av støv og støy. Maskiner bråker ikke mer enn lastebil. Samme for alle. Resirkuleringsmaskiner, det er en del som gjør det ulovlig. Og så pga. regelverk er vanskelig. Noen få prosjekter som søker mens dem utvikler prosjekt. Noen søker etter hvert.

	Hvis det er stort prosjekt er det enklere. Hvis det er prosjekt uten for by er det enklere. Verst med små prosjekter innen by.
Utnyttes masser fra andre infrastruktur prosjekter? (f.eks. riving av et hus).	Ja, men ikke direkte, da er de innenom en resikuleringsområde hos Skanska, AS eller Fransefoss. Kvalitetssikres og bearbeides. Ellers deponi.
Oplever dere noen krav fra myndigheter ift. hvordan ressurser utnyttes? Opplever dere noe press ellers i industrien til, hvordan masser utnyttes? (bergverkindustrien)	Veldig lite krav, men anbefaler. Du får litt ekstra ros i anbud. Hadde det vært krav hadde regelverket også blitt skiftet. Nei. Opplever bare de som tjener penge på deponi tjener mindre penge. På vei til å bli et større fokus fra fylkesmand og miljødepart. At alle forsøker å gjenvinner masser før de kjører det til deponi. En del fylke som er fremme og lage planer. Kommuner må lage planer som viser de lever opp til fylkeskommuner. Oslo vil ikke være med, for de har så lite arealer, og alle kommuner runt mottar søppel. Vil ikke være med isamarbeide fordi dem vet problemer. Vært med som tilhører.
Hvor alvorlig ser dere på trusselen med knapphet på byggeråstoffer i fremtiden? (problem for kommunen/udbyder eller dere?)	Norge består jo bare å fjell. Knapphet i nerheten av byer. Lang transport, kostnader, miljø. Fremtiden: transport grøn, bare kostnader. Tager mange år før vi er der.
Andre kommentarer til ressursbruken innen infrastruktur?	Hvis stein er sterk nok og vært gjennom 70% er sterke nok til å bli gjenbrukt. Stein vs. grus og sand og leire. Grus brukes ofte i betong, ofte god kvalitet. Rein. Naturlig fordeling. Sand får vi ikke noe mer av. Grunnvannet er avhengig av dette. Leire, kan bare brukes i matjord, ellers må det ombrukes direkte. Tildekke grøftanlegg, veiskråning. Vannet lagret i leire til å skabe grønt anlegg.

TEMA: Metoder til økt ressursutnyttelse	
I hvor stor grad utnyttes masser innen samme prosjekt? Hvilke hensyn tas til materialets kvalitet?	
Hvor stor en andel av utgravde masser vurderer du kunne være utnyttet i andre prosjekter ? (egne vs. andre entrepenører?) Hvilke formål kunne de utnyttes til? Hvis back-filling, hvorfor ikke formål med høyere kvalitetskrav?	70-80% av deponi, mye kunne være blitt brukt, ca. fort 40%. Mye stein som føres til deponi. Brukes både i veikrop, grøfter, under næringsbygg. Skille mellem: Tre hovedkvaliter: veikrop (mellem kvalitet), veigrøft, nøringsbygg, asphalt (høy kvalitet). Når det er store plasser og har resikuleringsmaskine, da skiller dem mellem materialetyper. Man får bedre betalt for gode kvaliteter. Da skille også kvaliteter ved hvis veien. Stein til asfalt gjøres til produksjonsanlegg. Samme med til betong. 70-80% er fra Ristone?? De driver å se på dette. Skandale. Plus erfaring. Alt blir kjørt til permanent deponi. Behovet er mye større end det som deponeres. Gravemasser, ut av bakken, ser vi som ubrukelig. Masser penge på å produsere nye masser.
Hvilke barrierer ser du for at flere masser utnyttes og ikke sendes på deponi? (mangel på data, lobbyisme fra transportvirksomhet, manglende opbevaring av masser/timing etc., logistikk, manglende kommunikasjon)	Plass for mellomlagring Timing Regelverk, plan og byggloven, miljødepartment, fylkesmand tilladelse. Forbedre forskriften. Tydelig tilladelse. Deponi tager også langt tid å søke. Men når man først har det varer det mye lengere, ca. 10 år. Skanska har ikke egne deponiplasser.

Utgangspunktet i denne master oppgave er, at for å forbedre utnyttelsen av ressurser må vi øke gjennemsigtigheten innen ressursbruket. Hvad tenker du om denne an-takelse? (fordele/ulepmer)	Hver og en passer sine prosjekt. For lite samarbeid. For dårlige å arbeide over kommunegrenser. Deponere noe som nabokommune treng. Bærum k. siger hvis vi har deponi og resikulering, så skal det bare være for vår kommune. Hele pointen er at grenser skal elimineres. Bedre med større kommuner. Fordele: Samarbeid. Ferre ulovlovlighet, billigere prosjekt, lavere kostnader. Ulempe: nei.
En konsulent har uttalt, at etter etablering av NyeVeier, har det blitt mere vanlig med samarbejd mellom veiprosjekter. Kjenner du deg igjen i denne uttalelsen? Hvis ja, hvad har NyeVeier gjort som har ledt til økt samarbeid?	
Kjenner du noen andre initiativer, som ønsker å forbedre ressursutnyttelsen? (bruker dem gjennomsigtighet? F.eks. TippNett).	
Hvilke initiativer tror du må tas for at ressursutnyttelsen forbedres for systemet som helhet? Åpen marked ved gjennomsigtighet Optimalisering funksjon Legal instruments Benefits Kommunikasjon av fordele og ulemper for den enkelte (f.eks. manglende tilgang på ressurser)	Hvordan får man økt gjennomsigtighet: NGU lager rapporter som sir hvor vi transporter på grus og pukk. Ingen som lager rapport på løsmasser, gravermasser. En eller anden burde tage ansvar for dette. Ansvaret er ikke hos noen. NGU eller miljødepartementet. Hver fylkeskommune, må da ha ansvar for å kartlegge utslipp fra unødvendig transport av løsmasser. Samferdselsdepartementet bør etterspøre dette. Da når vi ikke klimamålet fra klimaavtalen. Da begynner dem å sette krav til alle som bygger. Må komme fra departementet! Klima og miljødepartementet. Hvis vi ikke kartlegger ting, så da vet vi ikke hvor det er.

	Fylkeskommune har ingen myndighet, gjør bare det de får besked på. Hvor mye CO2 slipper selskapene på pr NOK, du blir rater på CO2 utslipp om noen år. Du må være miljøvenlig nok. Men først begynne måle. Skanska VegLCA, bruker den. Bare en opskrift på hvordan du skal måle det. Må sette krav vejvesenet!
Hvis myndighetene skulle stille krav om økt resirkulering (så og så stor andel skal brukes til min. sådan formål), hvem ville det være meningsfuldt å sette sådan krav til? (konsu-lent, entrepenør..?)	Når de setter ting ut på anbud, alle de store, stille krav i anbud, entrepenørene skal gjenbruke så mange andeler.
Hvad skal til for at dette er verdifult for kon-sulenter og entrepenører? What's in it for you?	Sikrer ved å stille krav. Hvis du ikke opfylder det, så får du skår og trekk. Konkurrere på krav som stilles. Ikke bare konkurrere på pris.

TEMA: Innrapportering av data	
Hvilke data innrapporterer dere til statistik myndigheter?	Innrapporter til kunden, og det er vegvesenet. Og så også innrapportering til Skanska.
Hvilke data innrapporterer dere til byggherre?	Vegvesent forbruk, CO2 utslipp. Privatutbygger så ingenting. Innrapporter forbruk av diesel og olje. Al innrapport hvor brugt og sådan. Lagt i lager. Alt som kjøres ut av anlegget. Masser som flyttes innen anlegget må ikke. Må spesifere hvor det har gått til deponi. rapporteres må det ikke rapporteres.
Ser dere egne fordele/ulemper ved en større grad av innrapportering? (statistik å forholde seg til, virksomhetshemmeligheter..)	Nei Tager tid å rapporter. Ingen gider rapportere hva det ikke brukes. I dag brukes det ikke til noen. Skanska synes det er greit p

	rapporeere likevel, fordi de vet dårlige blir luker vekk.

TEMA: Tidsaspekt/timing	
Hvordan samordner man aspektene tid og ressurstilgjengelig i planleggningen sin innen et prosjekt? (f.eks. på prosjektnivå – DynaRoad).	Bruker mye tid på planlegningen. Bruker software, DynaRoad.
Hvordan samordner man aspektene tid og ressurstilgjengelighet innen for virksomheten? Altså mellom prosjekter innen samme virksomhet? I hvor stor grad gjøres dette? Hvilke typer prosjekter?	
Ser dere ut mot andre virksomheter? Hvad er den lengste periode dere har samordner med andre virksomheter over?	
Hvilke barriere gir det, at ressurser ikke brukes med en gang de er tilgjengelig og omvendt? (f.eks. at man må opbevare materialer, at man ikke vet hvem som har det neste prosjektet om tre år, osv.).	
Hvad kan man gjøre for å imødegå disse barriere?	
Prosjektet Kortreist Stein foreslår, at man i udbudsdokumenter skal konkretisere, hvor store områder rundt byggeprosjektet man vil trenge f.eks. til midlertidig opbevaring eller resirkulering. Hvad tenker du om dette?	Helt enig. Arealer er ofte problemet. Ikke tidlig nok. Bare tenker Det løser entrepenøren.

TEMA: Software develop-ment	
I hvor stor grad er dere kjent med BIM/VDC? I hvor stor grad er bransjen generelt kjent med BIM/VDC?	Bruker det veldig mye. Visulisere mykje. Resirkuleringsterminaler i BIM. Seperat.

	Tror det kommer til å planlegges i software, men software er ikke komplet endda. Ulike møter, hvor man finner optimaleløsninger. Delta i fora, hvor det blir diskutert: nei. Alt legges inn i modellen. Drift og vedlikehold for bygg. Optimalisert, alt dokumentasjon. Det er nå på gang. Men ikke hørt om det, når det gjelder masser.
Hvilke 3D programtyper bruker du/dere? Hvad er funk-tionaliteten av dette program?	
Hvilke krav oplever dere at det stilles fra myndighetene ift. bruk av BIMV/VDC software?	Ja, det er økene krav. Skanska har været pådriver for soft-ware. Samordning på tvers av faggrupper.
Hvilket nivå/level er dere på? Hvilke innrapporteringskrav stiller myndigheterne?	
Hvis myndighetene skulle stille strengere krav til innrapportering via 3D modeller, hvilke utfordringer ville dette gi?	Flere må ansøttes som er flinke på software. Unge er flinke på IT og digitale verktøy. Større og større avdelinger, så ikke noe vanskelig. Mange som har lyst å jobbe med.
Måtte myndigheterne tage noen initiativer i tilleg til at stille krav, for at kravet kunne innfris? (f.eks. udbyde kurser, konkretisere format, opbygge egen infrastruktur etc.)	Utfordringen er at myndighetene ikke tilegner seg kompetensen. Private utvikler seg mye raskere end myndighetene. Så da får man det ikke til å gå fort nok. Ikke så mange som har lyst til å jobbe i kommune eller i vegvesenet. Kommune eller vegvesenet må bli mere attraktiv. Fornyer seg, så blir det mere spennende. Lønsnivå er ikke så vigtig. Men hvor interessant det er å arbeide på arbeidsplassen, veldig konservative idag.
Hvad tenker du om muligheten for en samlet BIM cloud for Norge? Regional BIM? Hvad er funktionaliteten? Hvad er utfordringene?	

Hartvig 2018 (open)

Interview performed by: Marie Katrine Rasch

Date: 04.05.2018

Information on interview subject

Name: Thomas Hartvig	Position: Seksjonsleder
Organization: Miljødirektoratet, seksjon for avfall og grunnforurensning	Anonymous*: No

*If you answer 'no' i.e. you are not anonymous, you may still indicate anonymity for specific questions.

Interview notes

Rene naturlige masser.

Innrapportering: nei

Vanligvis ikke til deponi (godkjent)

Ifm. Infrastruktur, overskudsmasser. Helst gjenvindes. Ofte ikke brukt.

Enkelte saker. Utarbeider faktaark til entrepenører. Forvaltning. Begynt å gi tilladelse til å opprette slike deponier. Normalt bare etter avtale med deponi.

Vegvesenet trodde bare spørre kommunen. Utgangspunkt må ha tilladelse av miljødirektoratet §29 i forurensningsloven.

2 år på mellomlagring, herefter tilladelse efter §29. Enkeltstående deponi samtykke.

System på innsamling? Ikke markedet for rene masser. Mellomlager: vegvesenet bygger en veg, så har avtale med lokale entrepenører. Hvordan skaper man et system som understøtte dette?

Masseforvaltning: Akershus, Rogaland. Intentioner men ingenting forplikter.

Mest mulig materialgjenvinning. Hvis ikke forurenset til nyttig formål.

EØS strengere forståelse av gjenvinning enn vi ellers forstår. E.g. skal erstatte primærmasser. Noe du hadde gjort UANSET!

Miljødirektoratet: samtykke til annen disponering (det er ikke gjenvinning, men annen disponering. Ikke tillat). Hvis samfunnsnytten er veldig stor. F.eks. anlegg av forboldbane.

Vegvesenet bygger ut i Buskerud, store mengder overskuddsmasser. Plassert i nærheten. Men hvis miljødirektoratet fått søknad, så nok tenke seg godt om, da man vet, at det er behov for masser ved Gildhus bugt. Fylde ut bugt for å bygge hus. 40 km fra vegprosjektet. Koste mere, men måten er bedre bruk.

Ikke mottat søknad.

Til nå legger ved siden av prosjektet, men bare uten tilladelse. Før bare spurt kommunen, fordi uvitende om regel om søknad til miljødirektoratet. Avfall, men ikke krav at de skal på godkendt deponi. Regelen har altså vært det hele tiden om søknad til miljødirektoratet, men folk har ikke vist om det.

Nå skal miljødirektoratet utvikle faktaark.

APPENDIX D: Display analysis

Interview subject	Mass management and planning	Accounting and reporting	Barriers and initi-atives	3D software
Contractors	**Johannessen, 2018a:** Tre hovedkvaliteter i Norge. Det som brukes i forsterkningslag, bærelag, og veidekke. 70-80% godkjent for bruk i nye veier. Mellomlagring/terminaler, blir solgt frit på markedet. Hvad brukes resirkulert til? Det som det er godkjent til. Forstkerningslag, støyvoller Villfyllinger, redusert. Mere i TRD. Varierer med geografi. Deponi med rene masser, og så mikser med forurensete masser. Ikke serlig stor konsekvens. **Hedlund, 2018:** 100.000 – 50.000 leira til deponi på marker. Til bønder som allerede har deponiavtale. Gebyr. Bønder var flinke å søke deponiavtale, da prosjektet først omtalt.	**Johannessen, 2018a:** Materialer I veien er kjent. Man kjenner byggetidspunkt, veien står i mapper. Så man vet hvad som er i for veier yngre enn 40-50 år. Men ikke mange material i eldre veier uanset. Store prosjekter som har volumen. Bra peiling på nyere, store prosjekter. Konsulentene ønsker ikke å svare på noen ting, før alt er ferdig. Løsmasser kan være forurenset. 70% av alle løsmasser er forurenset. Kan resirkuleres også. **Johannessen, 2018b:** Innrapportere til kunden, og det er vegvesenet. Og så også innrapportering til Skanska. Vegvesenet forbruk, Co2	**Johannessen, 2018a:** Mange som er imot resirkulering. De masser som går til deponi fra byggeprosjekt i byen har man oversikt over, men på land betyder det ikke noget. Mangler arealer. Mangler samarbeide mellom etaterne. Ny standarder, du har lov å bruke i veg. Veidekke er begrenset til gjenbruk, 80% i EU. SVV mere konservativ, 20-30 %. Veldig dårlig samordning mellom prosjekter, bare tippnett. Mangler verktøy, lastebiler har kontakt og vet. Manuelle systemer. Bruker transportører. Transportører vil beholde den business. Avtaler til flere aktører.	**Hedlund, 2018:** Justere ikke 3D modellen, når man har endret plan. Økonomisk regularing foregår på siden. Gemini. **Johannessen, 2018b:** Bruker BIM software veldig mye. Resirkuleringsterminaler i BIM. Seperat. Tror det kommer til å planlegges i software, men software er ikke komplet endda. Ulike møter, hvor man finner optimale løsninger. Delta ikke i fora, hvor det blir diskutert. Alt legges inn i modelles. Drift og vedlikehold for bygg. Optimalisert, alt dokumentasjon Det er nå på gang. Men ikke hørt om det, når det gjelder masser.

	Vegvesenet har ikke set på sammenkjørring. Transport til bønder, 50% er gebyr, 50% er transport, så man kunne ha kjørt dobbelt så langt = til Soknedal. Gamle vegmasser: 100.000 asfalt, gjenbruk 50% (bærelag, betales pr. Ton (BA gjenbygging). Asfalt legges på lager på byggeplassen, knuser kommer til anlegget, når nok materiale. Lagringsplass. Hvis vejen er gammel, mes sand. Brugt som fylling (anleggsveier). Problem timing. Man ved ikke hvor mye som kommer. Bruger ikke Dynaroad. Store fyllinger planlegges, men mindre fyllinger, der er så mange parametre som spiller inn. Mindre fyllinger måske 30%, da går hele billedet. **Johannessen, 2018b:** Overskudsmasser. 80% er til deponering. Oslo – stor-Olso. Det samme i hele landet. I byer.	utslipp. Privatudbygger, ingenting. Innrapportere forbruk av olje og diesel. All innrapport hvor brug og sådan. Lagt i lager. Alt som kjøres ut av anlegget. Masser som flyttes innen anlegget må ikke. Må spesifisere, hvor det har gått til deponi.	Skanske har kanskje oversikt over utgravde masser innen virksomheten, men ikke altid. Lite kostnad, hvad små masser ikke økonomi, så tjekker ikke engang. I TRD ikke samme behov for resirkulering, ift. oslo og bergen hvor meget urgent. Store næringsprosjekt, mykje på deponi, for skal ut veldig fort. Ikke nok terminaler. Blandet med materialer. Blir brag til nabobyen 5-6 mil til hønefoss, jord til bonde. Feil politikk. Fylkeskommune har ansvar for å se på det. Regionale planer for å se på det. Masseforvaltningsplaner, åben på nett. Kommune skal følge dette i fremtiden. **Hedlund, 2018:** Problem timing. Man ved ikke hvor mye som kommer av sand. **Johannessen, 2018b:** Må planlegge for gjenbruk. Det blir ikke gjort.	Økende krav fra myndigheter. Skanska har vært pådriver for software. Samordning på tvers av faggrupper. Flere må ansettes som er flinke på software. Unge er flinke på IT og digitale verktøy. Større og større avdelinger, så ikke noe vanskelig. Mange som har lyst å jobbe med. Utfordringen er, at myndighetene ikke tilegner seg kompentencen. Private utvikler seg mye raskere end myndighetene. Så da får man det ikke til å gå fort nok. Ikke så mange, som har lyst å jobbe i kommune eller i vegvesenet.

	30% går til gjenbruk, til ombruk i en eller anden form. Både direkte og resikuleringsprocesser. Mest til ombruk, for eksempel slalombakker eller rideanlegg. Eller støyvoller. Franzefoss tager bare imot masser til resirkulering. Skanska. AS gruppene. Først og fremst de tre som driver med resikulering. Skanska tager imot masser fra andre entrepenører. Hvis masser fra annet prosjekt, så information om pris og kvalitet. Det koster litt penge å få deklaration, men ikke vanskelig å få prøver. Sikre steinkvaliteten. Størrelse? Mellem prosjekt ikke fordeling. Kan ikke brukes i veikroppen med mindre. Unyttes masser fra annen infrastruktur: ja, men ikke direkte, da er de innenom resirkuleringsområde hos Skanska, AS eller Franzefoss. Kvalitetssikres og bearbeides. Ellers deponi.		Markedet er ikke modent for bruk av Looprocks og tippnett, for mange som tjener penge på deponering. 70-80% til permanent deponering. Egnet for gjenbruk. Ingen mulighet i dag. Ikke tilrettelagt arealer runt byen til lagring for resikulering. Samarbeide: slipper å betale dyr transport. Slipper deponiavgift. 4-5 gange så mye for transport end deponiavgift. Resikuleringsanlegg planlagt i ben og runt byen. Ikke så ofte kjøp mellem prosjekter, fordi ikke passer i tid og type. Myndighetene gjør ignenting for å time prosjekter. Myndighetene er skikkelig dårlige på det. Ikke fokus med reduksjon i transport. Enkelte kommune. Bærum. Olso ikke så langt. Myndighetene vil ikke ha maskiner på plassen. Vanskelig å få gjenbruk pga. Regelset.	

	Stein vs. grus, sand og leira. Grus brukes ofte i betong, ofte god kvalitet. Rein. Natrulig fordeling. Sand får vi ikke noe mer av. Grunnvannet er avhengig av dette. Leire kan bare brukes i matjord, ellers må det ombrukes direkte tildekke grøftanleg, veiskråning. Vannet lagret i leire til å skape grønt anlegg. Skille mellem tre hovedkvaliteter: veikrop (mellem kvalitet), veigrøft, afalt (høy kvalitet). Når det er store plasser og har resikuleringsmaskine, da skiller dem mellem materialertyper. Man får bedre betalt for gode kvaliteter. Behovet er mye større enn det som deponeres. Gravemasser, ut av bakken, ser vi som ubrukelig. Masser penge på å produsere nyemasser. Bruker mye tid på planleggingen. Bruker software, dynaroad.		Gravemaskiner krever ikke tillatelse, men det gjør resirkuleringsmaskine r. Vanskelig å få tillatelse, tidskrevende. Regelverk hjelper ikke. Ikke tilpasset det samfund vi lever i nå. Alt må sendes til fylkesmann, dokumentasjon for masser. Utslip av støv og støy. Maskiner bråker mer ikke mer enn lastebil. Resirkuleringsmaksin er, der er en del, som gjør det ulovlig. Også fordi regelverk er vanskelig. Noen få prosjekter som søker mens dem utvikler prosjekt. Noen søker etter hvert. Hvis det er stort prosjekt er det enklere. Hvis der er prosjekt uten for by er det enklere. Verst med små prosjekter innen by. Krav fra myndigheter? Veldig lite krav, men anbefaler. Du får litt ekstra ros i anbud. Hadde det vært krav hadde regelverket også blitt skiftet. Oplever de som tjerner penge på deponi, tjner mindre	

			penge. På vei til å bli et større fokus fra fylkesmand og miljødep. At alle forsøker å gjenvinne masser før de kjører det til deponi. En del fylke som er fremme og lager planer. Kommuner må lager planer, som viser de lever opp til fylkeskommuner. Oslo vil ikke våre med, for de har så lite arealer og alle kommuner runt motta søppel. Knapphet? Norge består jo bare av fjell, men lang transport, kostnader. - Plass for mellomlagring. - Timing - Regelverk, plan og byggloven, miljødep., fylkesmand tillatelse. Deponi tager også tid å søke, men den har man i mye lengere tid. Hver og en passer sine prosjekt. For lite samarbeid. For dårlige å arbeide over kommunegrenser. Deponere noe som nabokommune treng.	

			Bærum k. Siger hvis vi har deponi og resikulering, så skal det bare vær vår kommune. Hele pointen er at grenser skal elimineres. Bedre med større kommuner. Fordele: samarbeid. Ferre ulovligheter, billigere prosjekter, lavere kostnader. Økt gjennomsigtighet: Ingen lager rapporter om løsmasser og utgravde masser. En eller anden burde ta ansvar for å kartlegge utslipp fra unødvendig transport av løsmasser. En eller anden bær tage ansvar for dette. NGU eller miljødept.Samferdels departement bør etterspørre dette. Eller når vi ikke klimamålet. Må komme fra deparmentet. Hvis ikke kartlege ting, så da vet vi ikke hvor det er. Fylkeskommune har ingen myndighet, gjør bare det de får besked på. Du må være miljøvenlig nok, men først begynne å måle.	

			Bør inkluderes som krav i anbud. Da gjøres det også attraktivt for entrepenør, ellers får du skår og trekk. Tager tid å innrapportere. Ingen gider rapportere, hvis det ikke brukes. I dag brukes det ikke til noe. Skanska syns det er greit å rapportere likevel, fordi de vet dårlige blir luker vek. Arealer er ofte problemet. Ikke tidlig nok. Kommuner eller vegvesenet må bli mere attraktiv. Fornye seg, så blir mere spennende. Lønsnivå ikke så vigtig. Men hvor interessant det er å arbeide på arbeidsplassen. Veldig konservative idag.	
Consultants	**Carlsen og Virario, 2018:** Massene brukes enten i samme prosjekt eller til deponi. Dynaroad ikke 3D. Viser hvordan masser flytter seg, hvordan kortest veg. Step 1, 2, 3. **Virario, 2018:**	**Carlsen og Virario, 2018:** Utgravde masser. Disse mengder er god kendt for det er her økonomien er. Disse tal får idag fra BIM. Masserne estimeres på baggrund av plukprøver/stikprø ver av jorden, men dette fører til usikkerhed for	**Virario, 2018:** Diskvalifisering på veldig lav pris ses ikke i Norge. Diskvalifisering i Norge må ha veldig gode argementer. Vare gir oppgaven til lavest pris, entrepenør muligvis taper penge, men entrepenører er flink	**Carlsen og Virario, 2018:** England 2011, koncept utviklet omkring ønsket sammenkjørring av programmer. Snakker om levels. NyeVeier ønsker nivå 3. Ønsker dette implementeret til 2020.

	Utgravde masser brukes til grøft, filling, drenering. Prøver å gjenbruke masser, så interne balance nermer seg nul ved avslutningen. Bruker langs samme veilinie. Håndterer masser inne for samme veilinier (ikke andre prosjekter). Noen masser er ikke brukare: kvaliteten, fourenset masser. Kvikkleira kan ikke brukes. Til deponi. Forurenset masser må testes tilstandsklasse. Hvis forurenset ikke barnehage, men kanskje veiprosjekt. Konsultent bestemmer hvilke masser kan gjenbrukes. Konsulenten foreslår hvor det skal gjenbrukes, men i siste ende entrepenøren som bestemmer precis hvor. Entrepenøren som tager hensyn til timing. Entrepenøren foreslår handlingsplan. Her foreslås konkrete arealer for deponi. Konsulent prosjekterer vei i detaljer, men noen ting de ikke kan fastsette, så kan entrepenører ikke	pludselig måske andre masser, som ikke kan bruges til det samme. **Virario, 2018:** Kan leverer alle BIM modeller til byggherre. Kommuner bruker level 0 (papir format). Store kommuner level 1-2. 3D som visuelt. NyeVeier vil gjerne ha level 3. I ÅF.E. prosjekterer altid i 3D, altid i BIM. Men leverer som kunden vil ha. Kommer også an på detajlnivå, hvad kunder etterspørger. Ikke alle som betaler for å få det på 3D. Statens vegvesen, noen prosjekter bare levert som 3D, andre ønsker 2D og 3D.	til å argumenterer imot. Massedeling skal være organisert av byggherre. Entrepenøren kan spørre byggherren. Konsulentene kender ikke detaljene i andre prosjekter, fordi disse er hemmeligstemplet. Det settes ikke krav til resirkulering. All produksjon må være utslipp nul, ikke noget overskud. Lite fleksibilitet for konsulenter til at tenke på utnyttelse i ressourcer ut for prosjekt. Gjennomsigtighet: dette kan avslører, hvordan entrepenører er sterke mot konkurrenter. Mister konkurrenceevne. NyeVeier kjøper arbeid av entrepenører, mye av det kunnskap burde tilbakeføres til NyeVeier. NyeVeier ejer alt som skjer i prosjekter, inklusiv kunnskap. Kunnskap kan deles men ikke rutiner.	VDC ← dynaroad, miljø, økonomi. Disse ønsket samordnet. Pt. må disse koblinger gjøres manuelt. AutoCAD får ikke inn tid (så man kunne se et byggeprosjekt). Tror AutoCAD ryger ut i fremtiden, fordi bare en database. BIM er bare en database. **Virario, 2018:** BIM modellering er utbredt i bransjen i Norge. Mangler standarder, f.eks. format. Ikke konkretisert. Forholder seg til standarder i modellgrunnlaget . Veldig overordnet krav. Hva betyr informasjonen må standardiseres? Programvare avhenger av prosjekt. Hovedsagelig autodesk. Til de største prosjekter stiller NyeVeier krav om BIM. Alle konsulenter i Norgen (untagen småbedrifter) har kunnskaper. Det kommer av seg selv med 3D. Hvis småbedrifter vil være med, så lærer de seg det.

	konkurrere med noget. Enkel fremtidsplan for konsulent, priser. Men presis ved entrepenører. Ubehandlet masser fra et andet prosjekt. Må behandles før bruk. Fraksjoner. Dårlige masser, mineralsammensetning. Lokalitet må vites og volumen.		NyeVeier må ha høy ekspertise til å bestemme. Det skulle være mere faglig ekspertise hos kunder/byggherrer. Ulempe for konsulenter ikke altid forstår og avviser. Konventioneller pga. Manglende kunnskap. Det er vanskeligere å få ingeniører til byggherrer, fordi dårligere løn.	Det er også konkurrence, hvem som er best til BIM. Denne kunnskap kan ikke deles. SVV udbyder kur-ser i 3D. Programvare gir kurser. BIM cloud: Det må gjøres! Ikke nødvendigvis for hele staten, men hver byggherrer må ha en database. Kan støtte drift og vedlikehold. Ikke bare model for å bygge den, men også model for å vedlikeholde den. Krav om miljø.., så også krav om hvilken model som bygges. Ikke tilgjengelig for alle. Kun myndigheten. Kan også være SVV gir ut 3D model som kan være grunnlag for vurdering, f.eks. hvad er i jorden. Det kan løses med sådan database. Største utfording: standadisering. NyeVeier skal bestemme hvordan skal se ut, men må hente kunnskap fra entrepenørene. De skal ikke bestemme dette alene. Stor faglig

				kunnskap til bidrar med.
Industry organization	**Aakre, 2018:** Massebalance er nøkkel til lønsomhet, minst mulig håntering av transport. Brukes i prosjekt og så fort som mulig. Håndteres, knuses, renses på plassen. Ikke altid det gjøres på plassen. Store prosjekter. Sikring av arealer runt byggeprosjekt til resirkulering. Kjøpe masser fra annet prosjekt: kjøpe med antakelse om at det er godt nok. Ellers mölleverdi, mineralsammensetning. Krav fra myndigheter: transporter minst mulig, minst CO_2. Kortreist stein. Downcycling er tillat. Knapphet: det vil altid være masser. Det er transport som er utfordringen. Støy, belaster miljø, slid på veiene.	**Aakre, 2018:** Ganske beskeden innrapportering til statistik. Større grad av innrapportering til byggherre. Kommer an på hvilken slags data. Ønsker ikke mere byråkrati. Hvis stiller krav, så må du følge op. Ingen motstand fra e. Til større grad av innrapportering.	**Aakre, 2018:** Stor uenighet i økonomi kan ofte handle om flytting av masser. Beskrivelsene av kvaiteten av masser. Massene er ikke av kvalitet som angitt. Krav fra myndigheter: transporter minst mulig, minst CO_2. Kortreist stein. Downcycling er tillat. Enkelte masser som er forurenset, bunden av tunnel forurenset (diesel) pga. Kjørringer, så de må deponeres. Da ikke skjille bunker. Gjennomsigtighet: kjempe fordel! Forutsetninger for bedre utnyttelse. Tror ikke entrepenører vil ha noe imot det. Har fokus på å fremstå miljømessige. Langsiktighet, forudsigbarhet. Visse krav i kontrakten, disse krav gjelder alle kontrakter i fremtiden, så entrepenører kan bygge opp virksomheten for evnen og kunnskapen. Nye krav	**Aakre, 2018:** Begynner å være ganske udbredt hos store entrepenører. Byggherre veldig begrenset kompetence innen BIM. Så vil ikke stille krav, de ikke selv kjenner til. BIM er bra for å løse konflikter: - Sjanse for å gjøre alt rigtig. - Full kontrol ift. dokumentasjon. - Oppstår feil underveis - Vedlikeholde, hvad er det som befinner seg. - Mye lettere å gjentating. Finde gode løsninger. - Miljøopptimalisering.

			må ikke bare skifte. Teste ut nytt, da gjøre mange gange, så entrepenør kan øve seg. Krav til økt resirkulering: Dialog mellem byggherre og entrepenør. E. Har oversikt over hvad som er mulig. Byggherre skal ikke være redd å stille for strenge krav, E. Tilpasser seg, så lenge det er langsigtighet. Barrierer: lagringsplasser, forurensningsproblematik, kostnader.	
Mining industry	**Olsen, 2018:** Masser fra gammel veg er «brukt». De må igjennem resirkulering. De brukes som fyllmasse. Mere kostbart hvis skal brukes til veg. Fyllmasse ingen krav, men ikke forurenset. Dyrt å resirkulere. Asfald kan freses. Den fresemassen kan brukes igjen. Hvis tager imot på massetip for 30 kr/m3, da kan resirkulere. Fra massetip blir det altid behandlet før solgt.	**Olsen, 2018:** Direktoratet for mineralforvaltning Produsert og solgt FF. Gjen. Deponi.	**Olsen, 2018:** FF mineralloven, prosjekt er plan og byggningsloven. Da andre konkurrencefordele. Større adminstration + infrastruktur for pukkverk. Manglende dokumentering. Krav til byggematerialer. Må igjennem dokumentering på nytt. SVV mere fleksibilitet, men krever fremdeles deklaring, fleksibilitet ift. type.	

	Tunnelmasser i haug. Brukes å fylle ut bekkedal. Samme dynge, da bliver det blandingsprodukt. Mobilt knuseverk og sikteverk. Leier av entrepenører. Flere stenbrud hvor ikke faste. Tomtutvikler samareid så FF kan gå inn som sprengningsekspert. Dyrt å transportere og rigge mobilt knuseverk. Derfor samles masser en plass. FF har kompetence i salg på markedet (derfor kan entrepenører ikke selge videre selv, mangler kompetencen). Resirkulerte masser brukes ikke i bærelag og asfalt, men oftest i forsterkningslag. Noe salg går til fyllmasser, hvis ikke lavkvalitetsprodukter finns. Resirkulering av betong og asfalt lønner seg, fordi høy verdi. 500 m vs. 7 km, lite forskjell i kostnad, da er man ute av byen.		Incentiv fra myndighetene: avgift fra regjering på deponi. Lønsomt å gjenvinne. Krevende å sortere, da like greit med massetipp.	

	Hellere selge deponimasser enn sprenge ut på nytt.			
Road authorities	**Haugen, 2018:** Genutnyttelse av masser: nei, «ellers må man ha et annet projekt, og det har man aldrig». Tenker på masser kortreist og gjenbruk, fordi det er økonomi i det. Mellomlagring, ordnet nok plass til entrepenør, ordner selv. Runt veien. Deponi, setter annonse i avisen, entrepenør kontakter. Entrepenør bestemmer selv, hvorfra de får materialer, ellers imot konkurrencegrunnlag. Sporadisk kontakt mellom nytt bygg og drift i prosjekteringen. Drift kan ha krav til detailløsninger. Gamle materialer fra veien brukes i støyvoller. **Åmodt, 2018:** Byggeherrer som må sikrer masseoverførsel mellem prosjekter.	**Haugen, 2018:** Data som fås fra entrepenører gemmes ikke i noen samlet database. pdf som scannes. 3D modellen haves, men brukes I begrenset omfang. Alle prosjekteringer i 3D, model gives til entrepenør. 3D modell beholdes av SVV. SVV har hovedoversikt over mengder. **Åmodt, 2018:** Klimaperspektiv hos NyeVeier, 40% innen 2030. Entre. Må følge opp. Angi hvor me de klarer å få til. Hvordan få ned CO2? Veidekker i Hamar, alternativ fyring av asfaltverk, alt. Energikilder. Innrapport til byggherre, ingen specifikke krav. Dokumenteres alt i BIM. Ikke specfikke krav, fordi det er	**Haugen, 2018:** Samarbeide mellom etaterne er veldig begrenset. Hver sin økonomi. Av og til prøver man å samarbeide. Ikke lov med tværfinansiering (f.eks. mellom SVV og miljødirektoratet). Ikke samkoordinering, fordi det kan være «farlig» å forsinke en del. E6 ble ét prosjekt, fordi så lettere samkoordinering av utgrave vs. fylling. **Åmodt, 2018:** Ikke noe system for masser til andre prosjekter. Håndbøker begrenser, hvor material kan brukes, så deponi. Transport er dyrt. Ikke noe serlig markedet for transport, så nermeste deponi. Man vet ikke om andre prosjekter. Det må være på initiativ til byggherrer. Samarbeidsfora, men	**Haugen, 2018:** Bliver for stort, for tung å jobbe med, hvis man samler flere modeller (til en database). SVV modellgrunnlag. V770. Nok ikke revidering av 3D modell ift. endringer i løpet av byggefasen, men i tallene av utgravd materiale. **Åmodt, 2018:** Muligheter for ent. Og oss. Set det innenfor bygg. Sett en del feil. BIM aspekter I driftsfasen. Opdaterer modellen ved drift. Dette må fremdeles utvikles. Håper 2019. Utvikling av BIM: - Strenger e krav I kontrakt en ikke mulig, så ent. Kan

	Trøndelag: forsøg å sammenkjærer masser. Flyplass og vegbygg. Tidligere gikk overskudsmasser til entrepenør. Litt mere fleksibilitet. Hvis ikke e. Klarte å bruke masser uten kostnad, så ble ekstra kostnad for e. Hvis ikke alternativ bruksområde, mindske viltfyllinger. Til annet prosjekt: kontrol av masser. Hvis ikke goe nok, vekk. Fylling, da treng man ikke teste kvaliteten. Krav til hvordan komprimeres over tid. Går på håntering av massene.	ikke alle, som klarer å implementere dette. Hvor dumper lass.	ikke brukt til å se på hvordan masser kan håndteres. Kommunen er involvert i planleggningen. Ikke budgettert med midler til transport. Entrepenør vil vinde anbud. Større grad kunne bruke masser i begbyging. Håndbøker med litt lavere kvalitet kan brukes. Vegdirektoratet må grovknuses for å kunne brukes i vegen, så både stor og små. Fraksjoner. For noen år siden, manger veier skadet pga. Tiene pga. Ikke sortert masser i vegbyggingen → skjerper kravene. Grunn til SVV mere robusthet i håndbøker. Komplisere massehåndtering. Ift. nyttiggjørelse vil NV ha innspil fra entrepenører. Ikke noe system for det endda, men jobber på det. Hente informasjon innover i organisationen. Barrierer:	utvikle løsninger mens de jobber. - Parallelt med BaneNor, SVV. Jobber med hvordan bransjen bygger løsninger Integrering i én modell. 500 km motervei. Entreprise BIM (EBIM) eller Assets BIM (ABIM). ABIM i Strobrittania. Så på det I Januar, men var ikke helt overførbart. Softwareutvikler ukendt. Noe som starter med nå. Tung materia. Både teknisk og hvordan skal vi bruke det. Hvordan teknisk løsning finnes ved for a, utviklingsprosjekt er. Søke forskningsmidler. Format: ingen krav inntil nå. Da må ses på ABIM. Igang med dette.

			- Transport - Restriktioner i håndbøker - Mindre prosjekter ikke kontrol på massebalance innen prosjekt. - Optimalisere veglinier ikke innen små prosjekter - Større prosjekter må ha større sammenheng. Legge mere vekt på klimautslipp i anbud. Legge vekt på forskjellige valg. Når vet man om kvalitet: ofte for liteundersøkelser, må gjøres tidligere så man vet, hvad masser kan brukes til. Usikker på om man for dette til. Har ikke nok informasjon. Når først angitt at det skal gå til deponi? Endring man blir enig med entrepenøren om. Nye prosjekter lager handlingsplaner i samarbejde med kommunen og dere? Da må man vite noe om kvalitet. Gjøre	Langsigtighet: 4 underskrevet kontrakter, bedre gang for gang.

			undersøkelser. Her er det en konflikt i tid. Ent på a finne gode løsninger: 25% pris, 75% den gode løsning. Optimalisere hvordan man bygger: overordnet kostnad og utslip. Vise hvordan ting gjøres bedre: støy, initiativ for kreativ løsning.	
Other au-thorities	**Hartvik, 2018:** Vanligvis ikke til godkjent deponi. Ifm. Infrastruktur, overskudsmasser. Helst gjenvinnes. Ofte ikkr brukt. 2 år på mellomlagring, herefter tilladelse efter §29. Enkeltstående deponi samtykke. EØS strengere forståelse av gjenvinning enn vi ellers forstår. E.g. skal erstatte primærmasser. Noe du hadde gjort UANSET. Miljødirektoratet: samtykke til annen disponering (ikke gjenvinning, men annen disponering. Ikke tillat). Hvis samfunnsnytten er veldig stor. F.eks. anlegg av fodballbane.	**Hartvik, 2018:** Ikke innrapportering av rene naturlig masser.	**Hartvik, 2018:** Vegvesenet trodde bare skulle spørre kommunen. Utgangspunkt må ha tilltalse av miljødirektoratet §29 i foreurensningsloven. Buskerud utbygging: ikke mottat søknad. Til nå ligger ved siden av prosjektet, men bare uten tilladelse. Før bare spurt kommunen, fordi uvitende om regel om søknad til miljødirektoratet. Avfall, men ikke krav at de skal på godkendt deponi. Regelen har altså vært der hele tiden om søknad til miljødirektoratet, men folk har ikke vist om det. Nå skal miljødirektoratet utvikle faktaark.	

	Vegvesenet bygger ut i Buskerud, store mengder overskudsmasser. Plasert i nærheten. Men hvis miljødirektoratet fått søknad, så nok tenkte seg godt om, da man vet, at det er behov for masser ved Gildhus bugt. Fylde ut bugt for å bgge hus. 40 km fra vegprosjektet. Koste mere, men måten er bedre bruk.			