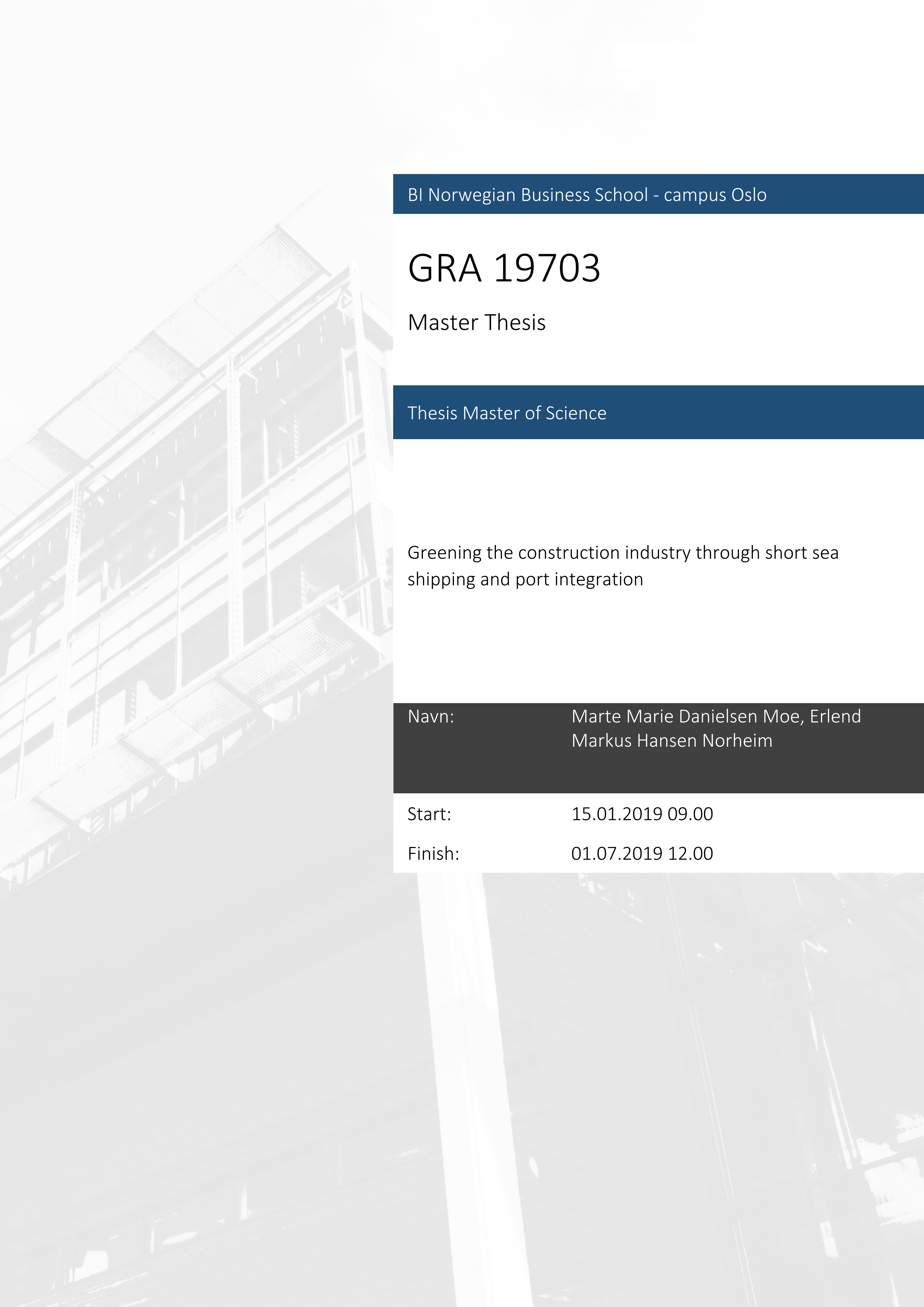

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Greening the construction industry through short sea shipping and port integration

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Abstract

HeidelbergCement has enhanced their sustainable strategy and developed the Sustainable Commitments 2030 as a response to the UN Sustainable Development Goals. In order to reach their sustainability goals, HeidelbergCement seeks to reduce their environmental footprint and to create long-term value for stakeholders and society. This involves consolidation of volumes and modernisation of their logistic system through the Sjursøya terminal in the Port of Oslo. Therefore, the objective of this thesis is to investigate how HeidelbergCement, as a construction material supplier, can contribute to the *Green Shift* in the construction industry by modernising their distribution system through port integration. The research question was the following: *How can a construction material supplier contribute to the Green Shift in the construction industry by changing its logistical distribution system through port integration?*

To examine this problem, different types of analytical methods are included. This thesis has a mixed method strategy. Data was obtained through multiple in-depth interviews with HeidelbergCement, NorBetong and the Port of Oslo. Furthermore, a case study is used to identify and explain the resources that makes up the current and potential future distribution systems. The effects of modernisation is quantified and discussed in terms of economic, social and environmental sustainability.

Our findings indicate that the modernisation of distribution system contributes to the economic, socio-political and environmental dimensions. In particular, the modernisation has the potential to yield a reduction in emission of CO2 with 52 %, NOx with 49 % and SO2 with 70 %. The study can be used as an example to showcase how sea transportation and port integration can contribute to greening the construction industry. Furthermore, our findings illuminate the role and function of a port in a supply chain where long-term relation can facilitate for reducing environmental footprint and sustainable securement of raw materials.

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1.0. Introduction

1.1. Background

1.1.1. The Green Shift

In 2015, the United Nations published 17 overall measures including several sub goals for sustainable development towards the year 2030 (United Nations, 2015). In general, these measures aim to eliminate poverty, achieve equality and tackle the *climate change*. Shortly after publication, the *Green Shift* quickly became a widely used buzzword and adapted to politics in multiple countries. Even though the exact meaning of the term Green Shift is somewhat unclear, it can be understood as a transition towards achieving sustainable societies, mainly with regards to climate issues. Consequently, organisations now incorporate and report on climate measures, and other sustainability measures, as part of their core business values in order to develop sustainable business models.

The construction industry constitutes an important role in the continuous development of cities. However, this industry also contributes heavily to environmental emissions. Over the years, emissions related to on-site activities has received the majority of attention. In other words, the suppliers to the construction industry has received limited attention. Moreover, it seems as the limited attention has focused on greening the production of construction materials, such as cement and aggregates (dry bulk products). This implies that other important parts of the supply chain with regards to dry bulk, e.g. the distribution of cement and concrete, has to some extent been overlooked. Transportation of building materials and construction machinery to the construction site represent 25 % of all heavy-duty vehicles greenhouse gas emissions in Norway, and of these, 56 % is generated from transportation of construction masses to/from construction sites (Bygg21, 2018). In other words, activities linked to supplying the construction industry represent a large portion of the total greenhouse gas emissions.

1.1.2. HeidelbergCement Group

HeidelbergCement Group is one of the world’s leading supplier of building materials. The organisation operates in 60 countries and in 5 continents with nearly 60 000 employees. The annual revenue in 2017 was over 17 000 million euros

(HeidelbergCement, 2017a). In HeidelbergCement’s sustainability report from 2017 it is stated that they aim to create long-term value for stakeholders and to society at large (HeidelbergCement, 2017b). As a response to the UN Sustainable Development Goals, HeidelbergCement has enhanced their sustainability strategy and developed the “Sustainable Commitments 2030” (HeidelbergCement, 2017c). In this way, HeidelbergCement is actively seeking to fulfill their share “of the global responsibility to tackle the world’s most pressing social, economic, and environmental challenges” and reduce their environmental footprint (HeidelbergCement, 2017c).

In Norway, HeidelbergCement operates through six subsidiaries, in which the three most relevant for this study are Norcem, NorStone and NorBetong. Norcem is the only cement producer in Norway with factories located in Brevik and Kjøpsvik. The company produce various types of cement, including cement used in concrete production. NorStone own and run multiple quarries, including Jelsa, Tau and Grenland. NorBetong is among Norway’s leading producers of wet concrete with a revenue of over 4 billion NOK in 2017. The company distributes concrete to both private use and to large construction companies. Among the factories located in and around Oslo, the factory at Sjursøya in the Port of Oslo (see Appendix 1) is one of the main factories serving the Oslo market. In 2018, the factory produced around 220 000 tons (92 500 m3) of wet concrete.

1.1.3. The Port of Oslo

The Port of Oslo is the largest public owned port in Norway. The port has two main docking areas; Byhavna and Sydhavna. Byhavna mostly handles local and international ferries and cruise ships, while Sydahvna is designed to handle cargo such as containers and bulk products. Each year the Port of Oslo handles approximately 6 million tons of goods, evenly distributed between dry bulk and unit cargo, wet bulk, and container cargo (Norheim & Moe, 2018). The Port of Oslo acts as a landlord meaning that the port administration rents out areas to private terminal operators. Today, there are about 25-30 operative terminals in the port. Each terminal is connected to multiple owners of goods that is further part of many value chains. Thus, the port interacts with many stakeholders with different perspectives, each with different criteria demanded from the port.

The Port of Oslo has a strategic advantage in its location and role as a city port. Half of the Norwegian population lives within a three-hour drive and the southbound and northbound highway and railway are reached in a short distance. For dry bulk products, sea transportation and production in a port located close to the market is a favorable alternative to road transportation. This is due to the characteristics of dry bulk, where the value compared to volume is low. However, the closeness to city also brings with it some challenges; it requires that production and movement of goods needs to be as silent and "invisible" as possible, not to cause noise and disruptions to nearby residents. Moreover, port activities contribute to local emissions in the city, which means that the port authorities are responsible to make sure the terminal users operate as sustainable as possible.

1.2. Motivation and Purpose of the Study

The construction industry in Norway is of great importance in order to reach the environmental goals at the national level (Bygg21, 2018). As HeidelbergCement is a major supplier of aggregates, cement and concrete in Norway it is natural to assume that they also contribute heavily to the environmental emissions in this industry. In order for HeidelbergCement to reach their sustainability goals with regards to local and global emissions, they seek to modernise their distribution set-up, particularly in the Oslo market which is their biggest market in Norway. In short, HeidelbergCement is planning to consolidate the production of concrete by moving their facilities around Oslo to Sjursøya in the Port of Oslo. This requires a modernisation of inbound logistics and port operations.

The connection between the Port of Oslo and HeidelbergCement is a crucial element in the concrete distribution system; as the primary concrete factory serving the Oslo market is located in the port, it is where the inbound logistic systems meet the outbound logistic systems. The cement terminal and the concrete production facility at Sjursøya is positioned close to HeidelbergCement's biggest market; Oslo. In addition, there are several aspects of production in port and transportation by sea that are of strategic importance to HeidelbergCement. The availability of raw material extraction sites close to Oslo is limited. Having a production facility in the port and transporting raw materials by sea enables HeidelbergCement to access and source raw materials from a wider area. Hence, it is possible to source from quarries with the required quality, even though they are located far from the production facility. A large resource pool of raw materials contributes to a sustainable management of minerals which in turn mean that the concrete used in construction in Oslo is made of resources sourced in the most sustainable way.

HeidelbergCement has chosen a distribution system for the Oslo market that includes sea transportation and terminal in the port to secure sustainable sourcing of raw materials, production and delivery of products. As their primary concrete factory is located in the port the Port of Oslo can either prevent or enable HeidelbergCement to modernise and develop their value chain in a more sustainable direction. Thus, the Sjursøya facility/Port of Oslo case can be used as an example to showcase how HeidelbergCement can improve and green their value chain.

1.3. Research Question

The potential for developing long-term stability for future investments lies with how HeidelbergCement's resources are connected to each other. These connections are crucial in order to secure sustainable long-term supply of raw materials. Given how the production and distribution set-up is today, it is necessary to look into the connection between the Port of Oslo and HeidelbergCement. This allows us to analyse how they communicate and share views on further development to understand how the network of resources can be developed. The scope of the study comprises of analysing how stable long-term business relations can secure sustainable sourcing of raw materials and enable modernisation of the concrete value chain by exploring;

- transportation of raw materials by sea,
- consolidation of production volumes, and
- a distribution set-up which facilitates for development towards zero-emission operations.

Based on the background information and purpose presented above, the following research question is derived:

How can a construction material supplier contribute
to the Green Shift in the construction industry by changing its logistical
distribution system through port integration?

By using the Industrial Network Approach and the ARA model we investigate how HeidelbergCement can modernise their logistics system to secure sustainable sourcing of raw materials, focusing on the relational nature between HeidelbergCement and the Port of Oslo. A thorough case description is presented to show the current logistic system and the changes that follow, to achieve a desirable future scenario for HeidelbergCement and the Sjursøya terminal. The study analyses the effects of modernising inbound and outbound logistic systems and highlight the changes that are necessary to reduce the environmental footprint. By calculating the environmental emissions, i.e. carbon dioxide (CO2), nitrogen oxide (NOx) and sulphur dioxide (SO2), and logistics costs from inbound transportation, the current logistics system is compared against two potential distribution systems. In addition, CO2 emissions generated from operations in the Sjursøya terminal is analysed and presented along with potential measures to reduce emission levels. From this, the study showcase how modernisation contributes to the Green Shift in the construction industry.

2.0. Relevant Theory and Academic Literature

This chapter consists of four main parts. The first part presents a theoretical framework that sets the academic context for developing and analysing the case. Because of the relational nature in the problem statement we use the Industrial Network Approach to explain the background for relationship development. This approach also enables to approach ports from different angles and investigate the port's role in its industrial context. The core of the thesis is based on the complex interplay between resources and the long-term relational nature of securing a sustainable sourcing of raw materials. Hence, the ARA model enables studying the dyadic relationship between HeidelbergCement and the Port of Oslo to explore how they adapt to new market situations in the industrial network. The port can be understood as both an actor (port authority) and a resource (port). In this thesis, the Port of Oslo is treated as a resource functioning as an enabler or disabler for HeidelbergCement to perform certain activities. In light of this, we extend the discussion in the resource dimension in the ARA model and elaborate on resource interdependencies, both physical and organisational, to identify what resources that make up HeidelbergCement's logistic system. This section forms the basis for analysing the changes in resource interfaces when altering the distribution system.

In part two, we present relevant literature about the role of ports and underlying factors for integration. It is necessary to explore the role and function of the port in supply chains to understand how the port can create value and contribute to modernisation. To our knowledge, there exists little academic literature directly concerning the distribution of dry bulk products by sea and its resulting impact on the construction industry. In light of this, the third section presents sustainable considerations of sea transportation and sustainability measures in terms of economic, social and environmental sustainability. These measures provide the baseline for analysing the quantitative data.

The last part of this chapter consists of background information to set the case context. This section ties the practical case context to the theory and academic literature presented. It also provides practical information about the context in which we develop and analyse the case between HeidelbergCement and the Port of Oslo.

2.1. Industrial Networks and the ARA model

The constant changing market conditions is altering the way firms operate: from firm vs. firm to supply chain vs. supply chain (Christopher, 2016). In order to survive, actors in value chains need to constantly seek ways to adapt to new market conditions. Market developments put pressure on organisations to modernise, improve mobility and reduce carbon footprint. The Industrial Network Approach and the ARA model provides a framework for understanding business relationships in the context of resources and how they are developed.

2.1.1. Industrial Network Approach

The concept of industrial networks can be applied to provide an understanding of how market changes take place and how firms adapt. The industrial network approach allows us to explore and analyse operating firms in the context of interconnected business relationships. The framework is derived from a large number of empirical studies where results have shown that business relationships can have important economic functions (Håkansson & Ingemansson, 2013). The basic point of departure for this approach is that firms as actors operate in the context of interconnected business relationships. Hence, the dyadic relationship between two firms are connected to other relationships. These relationships affect the outcome of the actor's actions and are sources of efficiency and effectiveness (Gadde, Huemer & Håkansson, 2003). For example, a port may have a given set of resources, e.g. infrastructural location, that enables another actor to use the port as a node in its transportation network. Hence, the interaction between the port and the actor is important for the port to facilitate for effective and efficient use of the port. Moreover, this dyadic relationship is connected to e.g. the customers and is shaped based on their requirements. If the customer demands products that are more environmentally friendly it would be in the supplier and the port's interest to accommodate this requirement. In this way, dyadic relationships are connected to other relationships and shape the type of activities that are carried out.

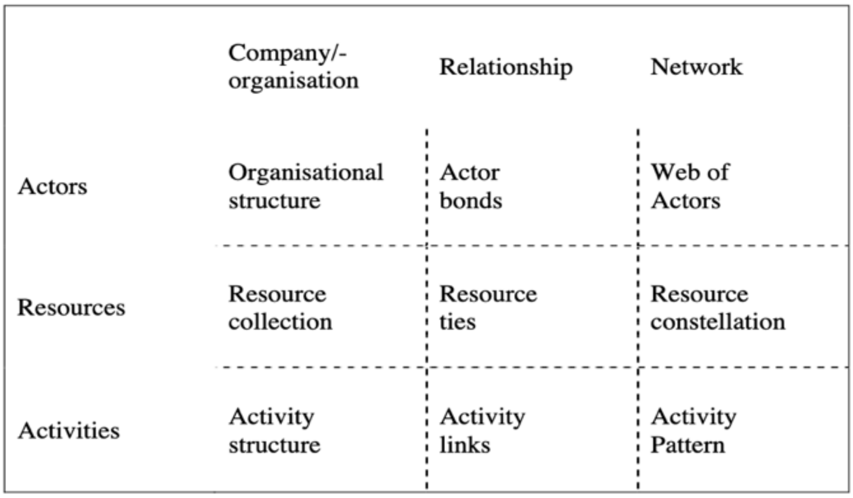
From the aforementioned example, one can say that actors in the industrial network are defined in terms of their identity in relation to other actors, acquired through interaction (Snehota & Håkansson, 1995). This means that exchange in one relationship is contingent upon the exchange in another relationship. The feature of these relationships is developed based on level of investment, involvement and adaptations. In this way, actors are defined by others in terms of the importance of what type of activities performed and resources utilised. Over time, actors adapt to each other by directing their respective activities and resources towards the corresponding counterpart (Hatteland, 2010). In other words, supply chain events constitute of actors performing activities based on their resources.

From a resource perspective, one can argue that a resource alone does not have any given quality or value. However, combining a resource with other resources creates this quality (Huemer, 2012). For example, when investigating aggregates alone they have no given value. The value of aggregates is dependent upon how they are used and/or combined with other resources. In the production of concrete, aggregates are of high value as they are the core ingredient to producing the finished product. In this way, the use of resources creates links to other resources which results in interdependencies according to how they are utilised. As actors use resources to perform activities, they also develop interdependencies with other actors through repeated exchanges. Furthermore, these dyadic relationships have important connections to third parties (Håkansson & Ingemansson, 2013). Hence, relationships are embedded into a network of relationships.

2.1.2. The ARA Model

The ARA framework developed by Snehota and Håkansson (1995) is a conceptual model that can be used for analysing functions and substance of distinct business relationships. This model establishes a foundation for studying the role of actors and their influences in the industrial development process. The model considers actors to be part of open systems that is influenced by other actors in the network in which they operate. Through different forms of interaction, actors gain access to external resources owned by others in the industrial network; for example, when using a port as part of a distribution system, you also gain access and are linked to the resources at the port of origin. In this sense, the ARA model can be applied as a framework for analysing the structure of interrelationship between actors that engage with each other and form interdependencies through utilising resources.

The model consists of three layers in which business units are connected: actors, activities and resources (Snehota & Håkansson, 1995). These variables are mutually related in the network structure, as shown in figure 2.1. More specifically, actors are defined according to what type of activities they perform and what resources they control (Håkansson & Johanson, 1992). The activities performed by one company is built on those carried out by others which in turn is built upon activities from yet others. These activities are carried out based on the available combination of resources, such as terminal equipment, quays and type of vessels. Actors control some resources and have access to others but may also create new resources by working with other actors which implies that activities are altered when actors combine and use resources (Lenney & Easton, 2009).



	Company/-organisation	Relationship	Network
Actors	Organisational structure	Actor bonds	Web of Actors
Resources	Resource collection	Resource ties	Resource constellation
Activities	Activity structure	Activity links	Activity Pattern

Figure 2.1: Actors - Resources - Activity framework from Snehota and Håkansson (1995)

One can say that activities are dependent on each other and thus activities performed by one actor takes place in response to how activities are conducted by other actors (De Martino, Morvillo & Marasco, 2008). If the port authority is initiating new methods for unloading bulk vessels it will generate new types of activities on the vessel as well as at the terminal. Likewise, if the supplier charter bigger vessels in their distribution system, it may require different equipment at the port to manage the process of unloading the vessel. Consequently, resources are required to perform activities and is defined through the type of interaction - how they are used.

The ARA model is abstract which allows one to apply it to study a phenomenon by relating relevant elements to each other in a logical manner to explain events (Lenney & Easton, 2009). In order to explain events, it is necessary to outline who are the actors, what are the activities and what are the resources utilized. By doing so, one provides a bridge between the theoretical and empirical elements which makes the ARA model operational (Lenney & Easton, 2009). In this sense, depending on the perspective, the port can be understood as either an actor or a resource. From a user of the port point of view, it can be logical to define the port as a resource enabling the user to perform certain activities. In this way, the locational and other relevant infrastructural elements (as resources) is key to improve the performance of the users. However, from a port point of view it could be defined as an actor pooling interdependencies through combining heterogeneous features of resources (Hatteland, 2010). In this way, port authorities may attempt to change the features of the resources to accommodate the user as an effort to align mutual goals. One way to do this is to facilitate for sharing of equipment, such as cranes and wheel loaders, across terminals in the port, making port activities more efficient overall. In this sense, the port is an important actor in many different supply chains as it creates additional value. Another way could be to facilitate for the use of more specialised equipment for terminals handling e.g. gas, petroleum and dry bulk. For each of these terminals, the port authority needs to facilitate for adaptation as these resources have features that are essential for the necessary operations to be carried out.

To sum up, this section has explained how the ARA model can be used as a tool to analyse how industrial behaviour takes place by linking actors, activities and resources to together. As the port can be viewed as an actor (port authority) or a resource (port), depending on the perspective, it is necessary to position the port as to how it will be analysed. The perspective of this thesis is based on HeidelbergCement whereas the port is viewed as a resource enabling modernisation of their distribution system. This perspective allows us to systematically explore the relation between resources and how they are organised in their industrial context.

2.1.3. Extended ARA Model: The Resource Dimension

In this section, we extend the discussion of the ARA model in the resource dimension which forms the basis for the outlined case description in chapter 4. The efficiency and effectiveness in logistics is largely a result from combining resources (Jahre, Gadde, Håkansson, Harrison & Persson, 2006). HeidelbergCement has chosen a distribution system for the Oslo market that includes sea transportation and is now seeking to modernise this set-up to secure long-term sustainable sourcing of raw materials and reduce their environmental footprint. When altering a distribution system, it is necessary to look into what type of logistical changes that are needed. As resources are necessary for the undertaking of activities, we provide a thorough explanation of their characteristics by presenting four resource dimensions. From this, we elaborate on how the interplay between resources change when altering the feature of a resource.

2.1.3.1. Physical and Organisational Resources

Håkansson, Tunisini and Waluszewski (2002) classified resources in terms of physical (facility and product) and organisational (business unit and business relationship). This classification of resources forms the basis for the NETLOG 4R-framework (Jahre et al., 2006). The first type of physical resource, *facility*, are most commonly identified as infrastructure of society, such as roads, railways and *ports* (Håkansson et al., 2002; Jahre et al., 2006). According to Heskett, Ivie and Glaskowsky (1964) this type of resource is then identified through two key elements in logistic systems - a set of *fixed points* connected by a *transportation network*. These fixed points can be understood as facilities, as they can be terminals, warehouses, or production sites. The transportation network also includes facility resources, such as vehicles moving goods between the fixed points and equipment used for moving, storing and handling goods. The second type included in physical resources are *products* that are manufactured, distributed and used in the facilities. Products can be both inputs in production and finished goods sold to customers. Occasionally, products can also be location specific. This means that the geographical location of facilities can be an important variable for some of the inputs in the final product. For example, a production facility located in the port enables transportation of input materials from locations far away and thereby enabling access to raw materials that may not be possible to transport over the same distance by road.

Resource combinations and interfaces between them evolve and is shaped during interaction between firms which means that the resource dimension includes organisational content. The interaction process is considered between *business units* (a firm, part of a firm or several firms) that possess certain resources and experience. The essence of business units is focused around cooperation derived from capabilities and social abilities. In other words, business units are critical as they form what type of resources that can be used by others. Closely linked is the *business relationship* that provides access for other actors to the resources of a given firm (Jahre et al., 2006); it connects the products and facilities. Importantly, the relationship between two firms is affected by the connection to other relationships and business units. Consequently, the dyadic relationship connectedness to other relationships can enable or constrain value generation in the particular dyadic relationship. Therefore, a business relationship is important as it provides the bridge to mobilise, combine and use resources (Håkansson et al., 2002). The relationship between the Port of Oslo and HeidelbergCement is important for accessing and securing sustainable resources. The particular relationship is what creates the interdependence between raw materials, production facility, vessels, distribution trucks and other resources.

In light of the aforementioned resource dimensions it is evident that logistics management is a resource-intensive task that evolves around managing effective handling and utilisation of the resources at hand. Logistics decisions regarding fixed point facilities are based on location and capacity, while for transportation facilities it focuses on selection of modes, routes and networks. These decisions are enabled based on what type of business units that are involved and the characteristics of relationship among them. In this way, the utilisation of resource constellations, classified according to physical and organisational resources, forms logistics systems. Therefore, logistics management is to a large extent about making the best use of the existing logistic resources (Jahre et al., 2006).

2.1.3.2. Resource development

What constitutes the best use of existing logistic resources is constantly changing along with the development of new market conditions. In this sense, *changeability* becomes an important feature of the resource element (Shapiro, 2001). Changeability differ according to the type of resource; a port’s infrastructural location remains almost the same over time, while unloading equipment is easier to change. When a resource is altered it also changes its feature and thereby its interface with other connected resources. For example, if a storage facility for aggregates is expanded in a terminal it requires a larger share of the space. This may result in the need to change location and/or structure of other facilities in the terminal that are connected to the storage facility and thus altering logistics operations between these facilities. Therefore, an important part in logistics management constitutes of coordinating the resource setting at hand (Jahre et al., 2006).

Jahre et al. (2006) state that the available resources form the basis for what type of activities that can be conducted. Usage of a resource is linked to the usage of others and combined they are interconnected and form the set of resources. The resulting resource constellation forms the activities carried out in the logistic system. So, to modernise a distribution system it is necessary to look into how the interfaces between resources change and what is required from them to enable the change. In light of this, one can argue that resources are the foundation that form the organisation’s network of interconnected relationships. Consequently, these relationships vary according to how the existing resources are organised.

This section has extended the ARA model in the resource dimension and classified them according to four types; facilities, products, business units and business relationships. In doing so, we have provided a framework that can be used for mapping resources in a distribution system and explain the interplay among them. We ended this section by explaining the importance of resource changeability and coordination when altering a system. This provides the bridge to the next chapter where collaboration is a key element for enabling change.

2.2. The Role of Port and Port Integration in Supply Chains

There exists a general notion in the literature that more integration leads to better performance of the supply chain (Bagchi, Chun Ha, Skjoett-Larsen & Boege Soerensen, 2005; Fabbe-Costes & Jahre, 2008; Kim & Schoenherr, 2018). Fabbe-Costes and Jahre (2008) conducted an extensive review of academic articles that study the link between supply chain integration (SCI) and performance. Findings show that there is a conceptual vagueness regarding SCI and performance. Since studies are using unclear and fragmented definitions of SCI, there is no consistent criteria or variables which make the findings compatible. In addition, performance is a complex concept because it depends on specific goal definitions of the unique situation. As a result, there are significant variations in the literature regarding what is used as unit of measure (e.g. net profit margins, return on assets, competitive position, etc). Therefore, it is difficult to draw conclusions on the link between SCI and performance (Fabbe-Costes & Jahre, 2008). In order to understand how a port may contribute to increased performance in supply chains, and if a higher level of integration is the key, it is necessary to outline the port's role in its network.

2.2.1. View of Supply Chain Integration and Ports

The constant changing environment among supply chains is affecting how ports operate as they are key constituents in many supply chains (Notteboom & Winkelmans, 2001). Traditionally, ports have been recognised as an interface between land and sea with main focus on activities such as transhipment and intermediate storage of goods (Carbone & Martino, 2003; Pettit & Beresford, 2009). However, the recognition of competition between supply chains, rather than as individual organisations, has raised the importance of business integration and formation of partnerships between the members of the shared supply chain (Snehota & Håkansson, 1995). Consequently, the supply chain view today includes inter-organisational interfaces between supply chain partners throughout the chain, increasing the significance of logistics operations (Jahre et al., 2006, p. 33). Hence, as the acknowledgement of SCI has increased, the port's role in supply chain is given higher attention (Franc & Van der Horst, 2010; Notteboom & Rodrigue, 2005; Pettit & Beresford, 2009).

2.2.2. The Role and Function of Ports

Mangan, Lalwani and Fynes (2008) argue that the port's role varies from acting as a simple transshipment hub to important logistic nodes. In other words, whether the port is viewed as having a function or playing a role depends on the perspective; the port's *role* is connected to the administrative characteristics of the Port Administration and the port as an actor, while the port's *function* is related to the view of the port as a resource (Hatteland, 2010). Consequently, the role depends heavily on the port users' supply chain strategies and products (e.g. minerals, containers, petroleum). As the port's role is dependent on the particular industry requirements and different types of supply chains linked to the port, it results in that ports offer a wide range of services (Demirbas, Flint & Bennett, 2014). However, it is evident that transport services that links supply chains and physical infrastructure (i.e. fixed points) are key elements in creating efficient logistics systems (Mangan et al., 2008). Consequently, ports can be understood as fixed points that enables certain distribution systems.

To fully understand the function of a port (as a resource) it is necessary to look into the port authorities (as actor), whereof ports can be distinguished as public or private ports. Hatteland (2010) outlines three differences that impacts the port's relation with its users. First of all, a public port has both local and national interests incorporated into their strategy. Therefore, public ports are subjects to both local and national laws and regulations (see part 2.4.2). Secondly, public ports offer a combination of transparency and discretion in contrast to private ports. This means that any given user or relationship can not prioritised over others because a public port can not discriminate between the port users. In other words, ties between a port and other resources are not designed to hinder particular organisations. Lastly, profit maximisation is not a sole objective of a public port as opposed to a commercial port. Instead, there exists a balance between securing effective and rational port operations and ensuring environmentally sustainable operations.

2.2.3. Underlying Factors for Port Integration

Ports operate as bi-directional logistics systems that facilitates the flow of goods and services and thus port activities require high level of coordination. Therefore, ports can be described as being used by firms that is involved in the management of flow of goods (Hatteland, 2010). To some extent, this assumes that port users and authorities coincide. Importantly, regarding the intertwined connection between resources and activities, the port authority constitutes an crucial *role* (see previous section) because they determine what type of resources that is allowed in the port and the resulting activities that can be carried out (De Martino et al., 2008). In this way, collaboration with port authorities is important for supply chains with specific needs, e.g. equipment and/or facilities, in the terminal. The level of integration varies according to the type of user and location of the port. Therefore, the underlying factors for integration is dependent on the industry in which the user operate because it yields specific needs. Indeed, there are also difficulties with allocating the best use of port infrastructure as terminals are scarce resources and require close collaboration between the user and the port for it to be successful (De Martino et al., 2008; Notteboom & Winkelmans, 2001).

A study by Panayides and Song (2009), investigation terminal operating companies and customers, suggest that the level of terminal integration in a supply chain is affected by several determinants, such as adaptability to changing market environment, terminal performance and process differentiation. Underpinning these factors is the extent to which the terminal has established systems and processes to offer functions that are relevant in order to becoming an integrated part in a supply chain, opposed to being a traditional transhipment terminal. The importance of the adaptability concept is supported by Robinson (2002) and Notteboom and Winkelmans (2001) suggesting that the port should be considered as an element that captures value both for the value-driven system it is a part of, and for itself.

2.2.4. Generating Value Through Integration

As the port is a node in a bi-directional logistic system, Panayides and Song (2008) argues that a port's primary activities should facilitate value creation in both inbound and outbound logistics for the supply chain as a whole. This could include facilitating for flow of goods for return transport by sea. In addition, port authorities should be understood as more than just a simple facilitator. This is because ports can play an important role in the development of value-added activities, information systems and intermodality (Panayides & Song, 2008). Therefore, the value delivered from the port is connected to the level of integration. For example, if a terminal operator has a long-term perspective to use the port it is easier for the port to facilitate for modernising equipment to improve efficiency and effectiveness of operations. Moreover, port authorities can contribute to provide public acceptance if the change in the port is unpopular by the public authorities. This is because it is in the port authorities' interest to secure long-term sustainable usage of the port.

A port creates *logistical value* through its resource constellation, and it is the physical location that brings supply chain members together (Bichou & Gray, 2004). The port facilitates for activities to be carried out which is the impetus for SCI as collaboration can create additional value to these activities (Pettit & Beresford, 2009). The view that resources do not have any predetermined feature, e.g. features of sustainability, rather their feature is a result of how they are combined with other resources (Jahre et al., 2006), indicates that the interaction process is crucial to understand change and how resources are designed. Therefore, interaction between resources is a key issue as it develops and form how resources are designed. Business relationships (as a resource) are, in this perspective, a result of interaction with other resources (facilities, products, business units and other relationships) (Jahre et al., 2006). In this way, business relationships and integration are important for value creation as it provides a bridge for change process to how resources are developed, e.g. combining and recombining of resources. An example of this is how the relationship between HeidelbergCement and the Port of Oslo enabled the establishment of the concrete production facility at the Sjursøya terminal (see section 4.3.3).

This subchapter has presented the role and function of ports and how port integration can contribute to value creation in supply chains. As a port's infrastructure is unique and not owned by private companies it can be secured through investments in resource combinations. The resource setting and its belonging interfaces provides the baseline for interaction between companies and gives opportunities to recombine them to increase their value. This is the essence of port integration as it describes how closer relationships through collaboration can create value to throughout the supply chain.

2.3. Supply Chain Sustainability

This subchapter address issues of sustainability and its connection to sea transportation. A key part is concerned with how to measure sustainability, which work as a base to analyse how economic, social and environmental sustainability is affected according to the modernisation of HeidelbergCement's logistics system.

In 1994, John Elkington introduced the concept of a triple bottom line stressing that organisations should start managing environmental and social aspects of their business equally to the economic perspective (Elkington, 1994). As stated in the introduction chapter, both national authorities and private organisations have increasingly incorporated sustainability into their strategies. As firms operate in a network and is affected by the actions of others, there has been a rising number of academic research investigating how to make supply chains more sustainable as a whole (Seuring & Müller, 2008). Through partnerships, firms access a bigger pool of resources, and the resources the company use in building effective relationships is the precondition for successful environmental and social collaborations in supply chains (Gold, Seuring & Beske, 2010). In other words, effective and long-term partnerships are is understood as important during the sustainability transition (Elkington, 1998). Hence, the relational nature, and its related resource pool, between HeidelbergCement and the Port of Oslo is a fundamental factor for HeidelbergCement to improve their logistics systems (reduce their environmental footprint) to and from the Sjursøya facility.

As stated in the introduction, the focus of greening the construction industry has evolved around the production of more sustainable products (e.g. environmentally friendly cement) and emissions generated at construction sites. However, other industrial activities, in particular transportation of goods, are major contributors to greenhouse emissions in supply chains (Christopher, 2016). Thus, organisations ought to review their transportation options as different transportation modes generate different levels of greenhouse gas emissions (Christopher, 2016). Therefore, alternative transportation modes are important to consider when renewing the logistics system. HeidelbergCement is looking to increase the use of transportation of aggregates by sea in the future logistics set-up. Next, we describe the sustainable aspects of sea transportation and how to quantify sustainability measures with regards to sea and road transportation.

2.3.1. Sustainability and Sea Transportation

The topic on making transport modes more environmentally friendly has been widely discussed in the literature (Bacallan, 2000; Elhedhli & Merrick, 2012; Pan, Ballot & Fontane, 2013; Vallejo-Pinto, Garcia-Alonso, Fernández & Mateo-Mantecón, 2019). However, to our knowledge, there exists little literature directly concerning sustainability of short sea shipping in the dry bulk segment. In recent years, moving cargo transport from road to sea has gained popularity and attention from European authorities and EU transport policy papers (Vallejo-Pinto et al., 2019). It is commonly accepted that maritime transport is an environmentally friendly mode of transport in terms of CO2 emissions (Hjelle & Fridell, 2012). However, this is not so clear when it comes to short sea shipping (Hjelle & Fridell, 2012; Vallejo-Pinto et al., 2019). Short sea shipping and environmental impact is explored in a study by DNV GL (2019) which investigates the green competitiveness of short sea shipping for dry bulk. The study challenges the academic literature by exploring exactly *when* short sea shipping is more environmentally friendly compared to transportation by road. The results of the DNV GL report is further discussed in part 2.4.4.

Although research show that freight by sea generally generate lower CO2 emissions than road transportation, this may not always be the case when it comes to sulphur dioxide (SO2) and nitrogen oxide (NOx) (Hjelle & Fridell, 2012). The legal emissions of SO2 and NOx are higher for sea transportation than road transportation which has slowed the modernisation of vessel engines compared to truck engines. The SECA directive was established in 2012 as a measure to regulate sulphur oxide emissions from maritime fuel in limited geographical areas (European Maritime Safety Agency, n.d.). The majority of diesel fuel in vessels today contain about 3,5% SO2. The future requirements in 2020 only allows 0,5% (European Maritime Safety Agency, n.d.; Regjeringen, 2016), which implies that shipowners need to look for other alternative fuel sources, such as LNG (Grønland, 2018).

When measuring emission levels from sea transportation as part of a logistics system we must also consider emissions related to terminal activities from unloading vessels. Regarding on-shore power supply, Gibbs, Rigot-Muller, Mangan, and Lalwani (2014) shows that this can contribute to the reduction of SOx and NOx emission levels from vessel at berth since it eliminates the need for the vessel to generate electricity by keeping the motor running. Onshore power supply enables emission-free docking and contributes to cleaner air, less noise pollution and a reduction of greenhouse gases when green power is used (Port of Oslo, 2012). However, there has been controversy in terms of the actual effect of CO2 emissions because it is dependent on how the electricity is generated. Measures such as the SECA directive and on-shore power supply show that there is an increased focus on making sea transportation more sustainable to strengthen its attractiveness as an alternative transportation mode to road transportation.

2.3.2. Measuring Sustainability

When measuring sustainability in a distribution system which include a port one can distinguish between inbound transportation (sea), terminal operations and outbound transportation. Consequently, elements within sustainability measures is given different impact level according to where in the distribution system it takes place (Rødseth, Wangsness & Klæboe, 2017). Transportation and port activities in urban areas where population density is high is directly affecting those residing in the affected area. For a change in distribution system to be sustainable it must be economically viable, contribute to better living conditions for those affected by it and decrease the environmental damage, i.e. reduce environmental emissions.

Sustainability measurement can be categorised into three dimensions; economic, environmental and social sustainability (Elkington, 1994). Since many indicators can be used to measure sustainability, each with different purpose and goal, one need to consider relevant measures for the particular situation. In this thesis, we define the economic and social sustainability in terms of profitability of business (efficiency) and living conditions (society), while environmental sustainability concerns greenhouse gas emissions (Christopher, 2016; Elkington, 1994; Gimenez, Sierra & Rodon, 2012).

It is challenging to compare distribution systems that features different set-up of transport modes. A vessel is consuming more fuel than a truck, but at the same time it has a carrying capacity far greater. These two transport modes also have different preconditions when transporting input materials to the production of concrete as these masses are generally transported in high volumes to the factory. In this sense, a comparison of the distribution systems must be made from the total emissions levels and costs. Therefore, the system analysis in this study compares inbound transportation costs and environmental emissions, with a primary focus on CO2 emissions, from the current and potential system based on the measurements discussed below. Moreover, we will analyse the CO2 emissions from port activities separately to investigate the effects of modernisation of the Sjursøya terminal. Below, we present elements in the economic, social and environmental sustainability that we consider when analysing the total effect from modernising distribution system.

2.3.2.1. Economic Sustainability

Economic sustainability includes measures such as trip length, utilisation, delivery time, and time spent on loading and unloading (Russo & Comi, 2012). In city distribution, the economic sustainability can be improved by optimising the flow of vehicles to reduce working hours and fuel consumption. In doing so, the traffic congestion can be reduced if the reduction in number of vehicles is significant and thus contribute to increased mobility inside the city (Russo & Comi, 2012). Increasing utilisation of transportation vehicles is also contributing to reducing the flow of vehicles and cost per trip, however, this is not possible to achieve with concrete as these are already delivering with full capacity. The port can contribute to economic sustainability by e.g. facilitating for infrastructure that allows for efficient unloading of goods from vessels including transfer of goods to storage. This can in return reduce time spent on unloading and related activities, which in turn will decrease cost of employing vessels and fuel usage. For HeidelbergCement to alter the distribution system in Oslo, it is important that the new system is economically viable and improves the competitiveness. That is, the investment costs need to be justified by cost savings from consolidating production volumes.

2.3.2.2. Social Sustainability

Social sustainability is understood as the reduction of conflict between the business and human beings that is affected by the industrial operations, i.e. impact on community or city (Russo & Comi, 2012). Thus, to improve the social sustainability it is necessary to know which actors and stakeholders that are affected by the business. When conduction industrial activities in populated areas, it is necessary to gain political acceptance from public authorities. Because the Port of Oslo is a city port and the port operations affect the nearby area, the Public authorities has interests in the port and can to a large extent determine what type of operations that is allowed to be carried out (further explained in 2.4.2).

One way of considering social sustainability is increased liveability in the city in terms of reducing road traffic. To achieve this, it is necessary to expand storage and production capacity in the port as this enables to transfer volumes from road to sea. However, a concern is noise resulting from activities in port that normally increase with higher level of production as a result from increasing activities. On the other hand, road transportation is considered to be one of the most significant contributors to noise (Russo & Comi, 2012). Another concern is the infrastructural scarcity in ports which often makes it challenging to expand facilities in the width dimension. When terminal operators are considering expanding facilities, they often need to build facilities higher. Consequently, expansions of facilities at terminals located in cities can have a negative impact on how the port and the port user is perceived by the local community. Building a huge silo park in the port might result in negative externalities to the nearby private residents. Therefore, the facility layout ought to be designed with this in mind.

Improving air quality is a big concern as it can be damaging to citizens and reduce quality of life. A report by Institute of Transport Economics show that there are considerable external costs related to handling of goods in port (Rødseth, Wangsness & Klæboe, 2017). These costs increase in urban areas where population density is high, as is the case with city ports. When including these costs in the calculation of total external costs in sea transportation it leads to a considerable increase, reducing the socio-economic profitability. However, when comparing external costs from sea transportation to rail and road, this study shows that transportation by sea still has the lowest external socio-economic costs.

2.3.2.3. Environmental Sustainability

The environmental sustainability can be understood as the outcome of the two sustainability measures above and can be improved by reducing the environmental footprint in the distribution system. The modernisation of HeidelbergCement's distribution system needs to contribute to improve the environmental emissions, air pollution and noise in the city and in the port surroundings.

Greenhouse gas emissions, especially CO2, emitted from transportation of goods is contributing to the global warming (National Transport Plan, 2018). CO2 stays in the atmosphere over 100 years and can move to other areas during this period, which means that the consequences from CO2 emissions is not determined by where the emission takes place (Rødseth, Wangsness & Klæboe, 2017). Therefore, when calculating CO2 emissions from sea and road transportation it is the sum of emission levels that are important. With regards to NOx and SO2, they are considered as local environmental emissions (Rødseth, Wangsness & Klæboe, 2017). This means that emission of NOx and SO2 is damaging the quality of the where the emission takes place. Therefore, in urban areas, high concentrations of NOx and SO2 is damaging to the people the frequents in the area (Rødseth, Wangsness & Klæboe, 2017). In the case of road transportation one can eliminate the CO2, NOx and SO2 emissions by using electric vehicles for city distribution. For sea transportation the development of electric vessels is still in the starting phase.

It is important to consider how consolidation of production volumes to the port results in more port activities and vessels transporting goods. Therefore, when evaluating the environmental sustainability regarding the transfer of goods from road to sea it is also necessary to look into the significance of emissions from port operations. This issue can be related to reducing the time spent on unloading and/or loading the vessels by improving time spent on goods handling (Rødseth, Wangsness & Klæboe, 2017). This could be done by using more efficient unloading equipment, such as conveyor belts instead of trucks moving aggregates from vessel to storage. While the vessels are docking the auxiliary engine is running to generate electricity. Consequently, the ship generates emissions while docking affecting the environment and society in the area. One way to improve this is by introducing onshore power supply to vessels to supply the needed electricity without the need for using auxiliary engine for this purpose.

The three aforementioned measurements of sustainability are closely related and improvement in one element often has positive effect on the outcome of the two others. The presented methods for measuring sustainability is used to analyse the effects of modernising HeidelbergCement's distribution system.

2.4. Case Context

The focus in port literature is typically concerned with the understanding of the various dimensions of the port rather than the context it is a part of, which is unique for every case. This thesis focusses on the distribution of concrete by using the Port of Oslo and it is therefore necessary to provide a context around the unique case. The following section explains the specific conditions and context of the HeidelbergCement-Port of Oslo case, in terms of both national and local environmental strategies, the role of the Port of Oslo and dry bulk shipping in Norway.

2.4.1. Sustainability Strategies and Goals: National and Local

The Norwegian Government's overall climate and environmental goal within the transportation sector is to reduce the greenhouse gas emission in line with the conversion to a low-emission society (National Transport Plan, 2018). The goal of the strategy is to offer effective, available, safe and environmentally friendly transport systems that covers societies demand and enables regional development (Fiskeri- og Kystdepartementet, 2013). Thus, it is important to develop a transportation system that promotes value creation in the society.

The Municipality of Oslo´s vision is a greener city facilitating for diversity and growth with room for everyone (Oslo Kommune, 2018b). There is steady increase in Oslo´s population and as a result local authority strive to create a more social, socio-economical and environmentally sustainable society (Oslo Kommune, 2018b). This includes facilitating for developing a sustainable city featuring several initiatives such as developing the urban area, creating easily accessible social and cultural arenas and improving traffic congestion and air quality. In terms of environment, the Municipality of Oslo has developed an ambitious plan called the Climate and Energy Strategy (Klimaetaten, 2016). Their main goals are to reduce greenhouse gas emission levels in Oslo by 36 % within 2020 and 95 % within 2030, compared to 1990-levels. The transportation sector accounts for 61 % of the emission levels in Oslo. As road transportation is expected to increase in the future, the the city of Oslo is working together with national authorities and the transportation industry to transfer as much freight as possible from heavy duty vehicles over to rail and sea.

The central location to the Port of Oslo makes it an important actor to the city of Oslo, both in terms of industry and society. Therefore, the Port Authorities (Oslo Havn KF) has developed zero-emission plan in cooperation with the municipality of Oslo including a number of measures to reduce emissions from transport associated with port activities (Oslo Kommune, 2018a). This includes stimulating for transferring volumes from road to sea, emission free activities in port and reduce transportation of goods connected to the port. Urban areas where population density is high, face comprehensive emission levels due to the large number of transport vehicles circulating to meet the required demand. However, sea transportation offers, potentially, low levels of energy usage and greenhouse gas emission per tonne-kilometres (Hjelle & Fridell, 2012).

2.4.2. The Port of Oslo

The Port of Oslo Authority is a municipal enterprise, which is accountable to the Municipality of Oslo. The Port of Oslo is a subject to the Port and Fairway act which implies that they are aligned with national interests, and to the Harbor Act which communicates the Government's interests. In addition, the Port of Oslo is a subject to the Planning and Building Act. The Harbor Act and the Planning and Building Act has contradictory definitions concerning the port’s role; the Harbor Act states that it is the needs from the sea transportation sector that should lay the foundation when defining the port’s role and what activities the port can carry out. However, the Municipality’s interpretation of the Planning and Building Act is that port activities should not include industrial activities such as processing of materials or production, which means that one has to go politically to make changes. This indicates that there exist contradictive understandings of the port's role and importance in their industrial network by the authorities.

The municipality's interpretation of the Planning and Building Act may hinder the Port of Oslo to facilitate for increased use of sea transportation. An example of this, is the recent case of establishing a construction mass terminal in the port. The purpose is to handle the surplus construction masses in Oslo (Borgestrand, 2019). Today, all of these masses are transported to disposals or landfill sites by road. However, a great amount of the masses can be categorised as lightly polluted and can be re-used in the construction market after it is cleaned and processed. When the sorting and cleaning is done, the remaining masses that are too polluted to be reused can then be transported by sea to landfill sites. Hence, this type of terminal creates volumes for dry bulk vessels to ship on their return. These return transports will increase the utilisation of the vessels and exploit more of the potential of sea transportation. Also, re-using construction masses will contribute to more sustainable use of materials. Hence, the municipality of Oslo's interpretation of what activities that can be carried out in the port may hinder the modernisation and exploitation of the of sea transportation.

2.4.3. Dry Bulk Transportation and The Port of Oslo

The Norwegian Government has historically focused on container and unit loads when obtaining information about the flow of units transshipped in the Port of Oslo (DNV GL, 2019; National Transport Plan, 2018). It seems as if there is a lack of knowledge concerning the scope of the dry bulk segment, even though dry bulk represent about ⅓ of the total volume of goods handled in the port (see section 1.1.3). In addition, the existing academic literature about a port's role in supply chains is mainly focused towards container cargo and units loads, and there is little research about the potentials from using short sea shipping in the dry bulk segment.

In the autumn of 2018, a study of dry bulk volumes in the Port of Oslo was conducted by this thesis' authors during an internship at the port. This internship study gathered insight and mapped the flow of goods in the Port of Oslo as a contribution to develop a short sea shipping strategy for the dry bulk segment. Some of the results from the study were quite interesting. Even though the Port of Oslo handles the biggest amount of container cargo in Norway, it is bulk products that represent the largest share in the port (Norheim & Moe, 2018). Furthermore, domestic short sea shipping for the Port of Oslo is heavily dominated by aggregates, stone and cement. Even more interesting is the fact that during the last decade, dry bulk cargo handling in the port has increased by 800 000 tons. In fact, dry bulk make up almost half of the volumes shipped from Norwegian ports to the Port of Oslo (Norheim & Moe, 2018). The increase in dry bulk cargo can be linked directly to the increase in construction activities in the city of Oslo; 60 % of the concrete marked in Oslo is supplied from production facilities located in Sydhavna (DNV GL, 2019).

In addition to this study, the Port of Oslo has engaged in several environmental studies directly related to the construction industry, such as distribution of asphalt, concrete, and development of a terminal for handling surplus masses from construction industry, as mentioned earlier. Given the role and implications of the dry bulk volumes, it is evident that without proper knowledge of this segment it will be difficult for the port as an enabler to facilitate for sustainable distribution systems.

2.4.3.1. Directional Imbalance in Transportation

The Port of Oslo is characterised by inbound flow of goods, which implies that there is a directional imbalance caused by low utilisation of return transportation (DNV GL, 2019; Norheim & Moe, 2018). One of the main reasons is due to the high level of construction activities in Oslo demanding frequent deliveries of concrete. The available capacity on sea transportation yields low socio-economic exploitation. The expected increase in demand of dry bulk products in Oslo makes it important to balance the imbalance in sea transportation. Construction activities generates big masses of waste, i.e. entrepreneurial masses and landfill- and recycling masses that is mainly transported and stored as landfill sites. However, some of these masses are perfectly suitable to be transported by bulk vessels (DNV GL 2019; Norheim & Moe, 2018). Therefore, there exists a great potential to increase the utilisation of sea transportation by including these flows of goods on outbound shipments from the port. Proper waste management can contribute to increase resource utilisation and thereby decreasing the climate impact. In addition, higher utilisation of sea transportation contributes to lower the unit costs per ton per shipment. To achieve this, it is necessary with collaboration between shipowner, port and construction industry.

2.4.3.2. The Port of Oslo as a Facilitator and Enabler

Many of the dry bulk extraction sites are located in relative proximity to the coastal line with quays able to dock (smaller) vessels, which facilitates for dry bulk transportation by sea. Interestingly, the closer the domestic short sea shipping is, in terms of geographical area to the Port of Oslo, the more dominating is dry bulk in sea transportation (Norheim & Moe, 2018). There can be several reasons for this, such as higher market demand in Oslo (than other cities) and the location of extractions sites and quays. The latter is very interesting as it gives insight into the resource perspective. The close location of extraction sites in regard to quays make sea transportation a natural choice. Furthermore, as the Port of Oslo is subject to public regulations (as explained in part 2.4.2), they play a key role in communicating to the public authorities to enable necessary operations for handling dry bulk products. Therefore, the Port of Oslo can be understood as a *facilitator* and *enabler* that makes it possible to exploit the advantages of sea transportation, with its strategic location and production facilities in the terminal (Norheim & Moe, 2018).

2.4.3.3. Competitiveness of Sea Transportation in the Dry Bulk Segment

The close location of extraction sites to the Oslo market makes road transportation competitive to sea transportation. A report by DNV GL (2019) derived two interesting conclusions based on the competitiveness of sea transportation of dry bulk. The first is that sea transportation above 500 km can compete with road transport below 20 km, with approximately equal socio-economic costs. The second is that sea transportation around 65 km can compete with road transportation on half the distance and still contribute to society gains. These conclusions highlight that sea transportation can compete with road transportation within the dry bulk segment over both short and long distances. Dry bulk products are characterised as low value goods and road transportation around 20-30 km often costs more than the product itself (DNV GL, 2019; Wolden, 2014). Thus, there exists strong interdependencies between dry bulk products and sea transportation, as one can exploit the advantages of capacity and volume of the vessels. The Sjursøya facility enables HeidelbergCement to exploit this interdependence. In addition, production of concrete needs to be located close to the market it serves as wet concrete will start to harden if it is transported over longer distances. The location of the Port of Oslo thus contributes to the competitiveness of sea transportation of dry bulk products.

2.4.4. A Case Study of Concrete Distribution in the City of Oslo

The case study below is an example of how different utilisation of resource constellations in logistics systems give very different results with regards to emissions, even though both systems produce the same product. This showcase the nature of resource interdependencies. Furthermore, this case shows the benefits of sea transportation underpinning that HeidelbergCement ought to modernise their distribution system through the Port of Oslo.

In 2016, the Port of Oslo conducted an internal case study of concrete distribution and production in the port (quality checked and revised by DNV GL in 2017) (DNV GL, 2019). The purpose of this study was to gain more knowledge about the environmental effects of moving inputs to the production of concrete from road to sea transportation and the last mile delivery from two different production sites. The study compares two different distribution systems of concrete; system 0 (road transportation) and system 1 (sea transportation + last mile delivery on road).

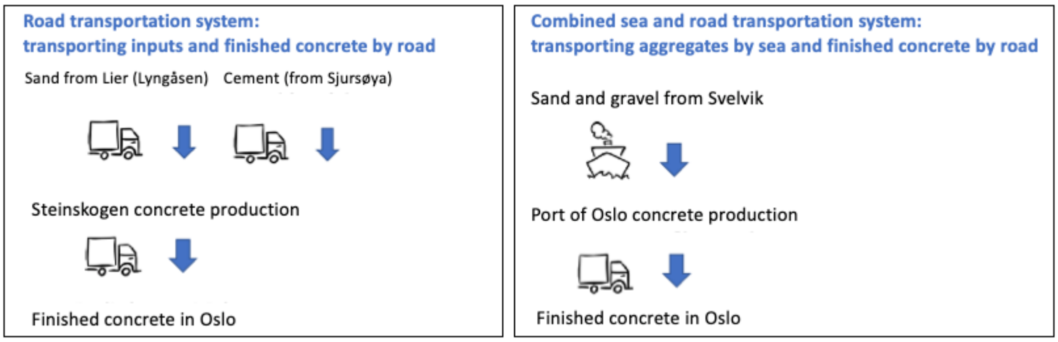


Figure 2.2: Case study for concrete distribution in the Port of Oslo

System 0: sand and cement are transported by road from Lyngås and Sjursøya, to the production site at Steinskogen. As the production site is located in the quarry, there is no transportation of gravel. Distribution of concrete to end customers at Økern.

System 1: sand and gravel are transported directly from the extraction site at Svelvik by sea to production site at Sjursøya. Cement is used from Norcem's facility located at Sjursøya. Distribution of concrete to end customer at Økern.

For a yearly volume of 625 500 tons concrete delivered to Økern it is estimated a yearly total reduction in CO2-emission of 1 345 tons (48 % reduction) when changing from only road transportation to a mix of sea and road transportation (DNV GL, 2019). However, the study finds that emissions of NOx and SO2 is higher with sea transportation than road. The increased emission levels can be considered as a tradeoff between emissions at sea or local emissions in Oslo where population density is high. Moreover, if the same volume was transported according to system 0, it would require ca. 16 000 trucks for inbound transportation of inputs to production site. System 1 eliminates the inbound road transportation as well as transportation of cement to and from Sjursøya – Steinskogen, through the city of Oslo. This means that system 1 also reduces the traffic load and empty driving through Oslo. Therefore, system 1 where production of concrete is carried out in the port is the best alternative in this study in terms of CO2 emission and as it removes 16 000 trucks from the road.

This study showcases that even though the production unit and volume is the same for both systems the distribution set-up is determined based on how these resources are utilised and combined, which in turn give two very different results. In light of this, the Port of Oslo constitutes as an enabler to system 1 as it is not possible to achieve this without having the necessary facilities in the port terminal. Hence, as system 1 yields better results in terms of social impact, the results of this case study underpins that HeidelbergCement ought to continue and develop their distribution through the Port of Oslo.

The case context subchapter has provided a situational context with relevant background information for HeidelbergCement's Sjursøya terminal and the Port of Oslo. Norwegian Authorities are working together to transfer volumes from road to sea, but their focus has been on container and unit loads. Therefore, we have addressed the general lack of knowledge regarding dry bulk and outlined the scope of dry bulk in the Port of Oslo. It is crucial to acknowledge that since the Port of Oslo is a subject to public regulations it may be difficult to make considerable changes in the port.

3.0. Research Methodology

This section describes the methodology of the thesis and the reasoning behind the research strategy and design. Planning and structuring how to conduct the research is important in order to make sure we are provided with sufficient data that can be analysed to produce relevant results. Therefore, we explain how the primary and secondary data was collected and analysed to answer the research question. Furthermore, a discussion on the reliability, replicability and validity of this thesis is provided. The extensive scope and the nature of the research question makes this thesis exceed the standard limit of maximum page numbers. However, in correspondence with our supervisor we have been permitted to exceed this limit.

3.1. Research Strategy

According to Bryman and Bell (2015), a research strategy is a general orientation to the quantitative and qualitative research. Quantitative research has a deductive approach to the relationship between research and theory and emphasises quantification in the collection and analysis of data. As a contrast, qualitative research has an inductive approach between research and theory which emphasise words rather than quantification in the collection and analysis of data (Bryman & Bell 2015). The relational nature in the research question can to a large extent be analysed in terms of a qualitative approach. However, this can lead to difficulty in defining an analytical path due to the richness of available data (Bryman & Bell, 2015). A quantitative approach can be used supplement the qualitative research by defining a clear path and enhancing the significance of the study. Therefore, we have applied a mixed method research strategy meaning that both qualitative and quantitative research methods are used.

3.1.1 Qualitative method

Qualitative research method is commonly used in case studies investigating business relations and non-numerical connections between actors (Bryman & Bell, 2015). Because of the relational nature in the research question, we applied the ARA model as a framework for studying the dyadic relationship between HeidelbergCement and the Port of Oslo. This approach enabled us to investigate how stable long-term relationship affects the modernisation of HeidelbergCement's distribution system through the Port of Oslo. In other words, the ARA framework has allowed us to study the interaction between firms and how interaction connects resources and activities of those firms in the context of the distribution system. In light of this, our case study is conducted by applying the NETLOG 4R-framework presented in Jahre et al. (2006). The NETLOG 4R-framework extends the ARA model in the resource dimension and has enabled us to outline and explain external and internal resource interfaces connected to the Sjursøya terminal in the business relationship between HeidelbergCement and the Port of Oslo. This framework includes four main dimensions: (1) description of the focal resource in the context of business relationships, (2) the interface with resources of the same type in the context of relationship vs. other relationships, (3) interfaces with other resources and (4) a summary with the most important findings from the analysis in 1-3 (see figure 3.1). The NETLOG 4R-framework is used to outline important resource connections in HeidelbergCement's current distribution system and how they may change by modernising the logistics system.

Since the future distribution system features consolidation of all production volumes from Steinskogen and Alnabru to the Sjursøya terminal, we have chosen Sjursøya terminal as the focal resource when analysing the changes in interfaces. The figure below gives a visual representation of the framework and the resource dimensions connected to the focal resource (the Sjursøya terminal).

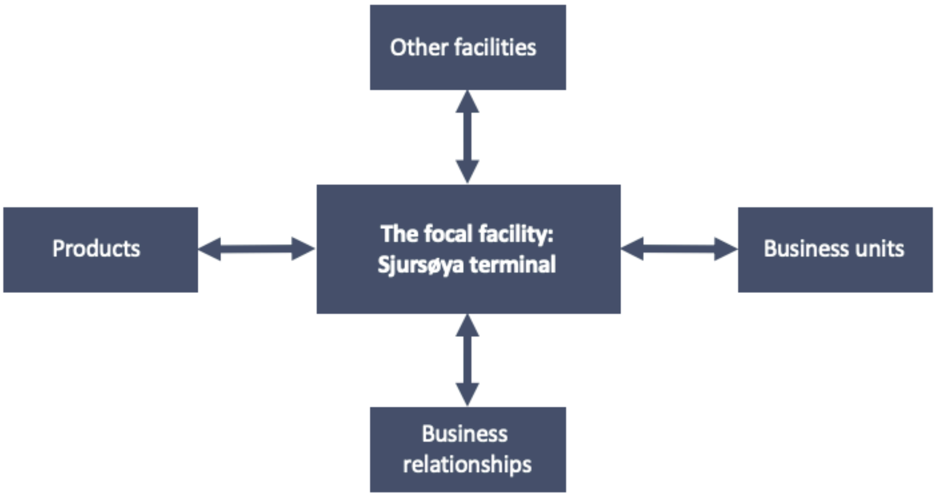


Figure 3.1: The NETLOG 4R-framework

3.1.2 Quantitative method

The quantitative research is different from qualitative research in that it consists of employing measurements and numerical data (Bryman & Bell, 2015). The quantitative part of the study contains numerical data and analysis of how HeidelbergCement can contribute to greening the construction industry by modernising their distribution system. Environmental emissions (CO2, NOx and SO2) of the current and the future logistics systems are calculated and compared to evaluate the environmental effect of change in the logistics system. Moreover, we have calculated CO2 emissions at the Sjursøya terminal separately to be able to analyse the specific effects of modernisation in the terminal. As the future system also needs to be economically viable, we have calculated and compared inbound transportation costs from the current and future scenarios. These calculations are derived and based on the developed case description.

Measuring the effects of changing distribution system involve collecting numerical inputs that is used to calculate the outcome. The data was collected from meetings, multiple interviews and phone conferences with HeidelbergCement, NorBetong and the Port of Oslo. However, some data proved difficult to obtain and as a result the quantitative analysis includes some approximations. Issues related to the numerical data will be discussed in the data collection and analysis section.

3.2. Research Design

A research design is used to provide a framework in order to collect and analyse data (Bryman & Bell, 2015). Based on our choice of business research, it is believed that a case study is the most appropriate research design. Yin (2003) defines a case study as "… an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (...) it relies on multiple sources of evidence" (Yin, 2003, p. 10). Furthermore, a case study design "focuses on understanding the dynamics present within a single setting" (Eisenhardt, 1989, p. 534). In sum, a case study facilitates for analysing a unique situation in its specific context. We believe that a case study design is applicable because of (1) the relational nature of the research question, (2) because of unique logistics systems and (3) the dyadic relationship between HeidelbergCement and the Port of Oslo. A case study typically combines data collection methods and data that is either qualitative, quantitative or *both* (Eisenhardt, 1989), where the latter is appropriate in our study.

The outline of the HeidelbergCement-Port of Oslo case was presented as a current issue of interest by the Port of Oslo during our internship in 2018. In our internship report we analysed the dry bulk segment and short sea shipping in Norway and suggested a short sea shipping strategy the Port of Oslo. We found the topic of dry bulk and short sea shipping very interesting, and it was the foundation for developing the research question in thesis. The case outline was developed in meetings with the Port of Oslo and HeidelbergCement as the specific logistics systems for analysis needed to be agreed upon. Furthermore, by visiting the Sjursøya terminal we got a visual perspective of how activities are carried out and how facilities are structured in a port. This general orientation enhanced our understanding about limitations and possibilities regarding modernisation of the terminal.

This thesis aims to explore how modernisation of HeidelbergCement's distribution system through the Port of Oslo can contribute to a greener construction industry. In this sense, the relational nature between HeidelbergCement and the Port of Oslo is interesting as the port, as subject to public regulations and being a city port, can either enable or prevent this development. Therefore, acceptance from stakeholders affected by this change is important to consider in order to implement the necessary changes. We believe that a case study research design which analyses the interaction and relationships by using the ARA model will provide a great level of learning and understanding of the business context that is undertaken. In addition, as there is limited literature focusing on the distribution of dry bulk the use of case study enables to gather in-depth knowledge to the field of study.

Stake (1995) differentiates between three types of case studies; intrinsic, instrumental and collective cases. An intrinsic case study is conducted to provide insight into the particularities of a certain situation (Bryman & Bell, 2015). The HeidelbergCement-Port of Oslo case represent a unique business relation and a particular situation, which makes an intrinsic case study appropriate. It is also important to identify and make clear the level of analysis that is being undertaken.

Bryman and Bell (2015) suggests the SOGI-model which entails societies, organisations, groups and individuals, where it is common to distinguish between what is the primary unit of measurement and analysis. This thesis aims to improve HeidelbergCement's distribution system in terms of economic, social and environmental sustainability. In this sense, this case study is considered a multi-perspectival analysis and thus is including organisational and societal levels (Bryman & Bell, 2015).

3.3. Data Collection

The appropriate methods for collecting data depends on the research question at hand and the level of data accessibility (Bryman & Bell, 2015). The case description in this thesis contains both qualitative and quantitative data, and the data has been derived from three main sources; visual observations of the Sjursøya terminal at the Port of Oslo, semi-structured interviews and secondary materials. In this subchapter we explain how we have gathered the necessary data to develop and analyse the case.

As HeidelbergCement's future distribution system involves consolidation of concrete production to the Sjursøya terminal we found it necessary to get a comprehensive understanding of the structure, activities and operations at the terminal. Visiting the terminal allowed us to explore what type of information that was needed in order to develop a good case. Following, we arranged meetings with HeidelbergCement and the Port of Oslo to determine how the case should be structured with the potential future distribution systems involved. This approach allowed us to identify what quantitative data which was necessary for measuring the effects of changing the distribution system. After designing the case and determining the layout of the future logistics systems we conducted multiple semi-structured interviews with HeidelbergCement, NorBetong and the Port of Oslo. Through the interviews we collected additional information to analyse the effects on inbound transportation costs and the environmental emissions from HeidelbergCement's change in distribution system.

3.3.1. Secondary Data

Bryman and Bell (2015) defines secondary data as data which already has been collected. The collection of data can often be a lengthy process, and by analysing secondary data the researcher can dedicate more of his or her time to the analysis (Bryman & Bell, 2015). Our secondary data consists of numerical data, organisational documents, internal studies and other case contextual documents.

3.3.1.1. Numerical data

The numerical data in the case description provided by HeidelbergCement, NorBetong and the Port of Oslo are actual numbers from suppliers and is used internally. Hence, we consider the numerical analysis and results to give a realistic presentation of the CO2 emissions and transportation costs. The data was collected through in-depth interviews, phone conferences and mail correspondence. The different companies provided different data. HeidelbergCement has provided key figures concerning inbound logistics, such as costs of road and sea transportation of aggregates, fuel use of vessels on the respective distances, time spent on unloading activities in port and details of vessel size and volumes shipped. NorBetong has provided information about fuel use related to road transportation, and volumes of concrete delivered to customers (production volumes). The Port of Oslo has provided information about terminal activities, and volumes in different flow of goods passing through the terminal. Other relevant key figures, such as NOx and SO2 are based on average estimates per ton-km for heavy trucks and vessels provided by our thesis supervisor. We were not able to obtain fuel use for aggregate and cement trucks. Hence, we use CO2 emissions from EURO 6 engines as emission factors. These were derived from internal documents at the Port of Oslo.

The numerical data has provided valuable information in constructing the case and in the analysis of the logistic systems. It was important to collect this data as it created a comprehensive image and display of the logistical flows, as well as how the inbound and outbound logistics systems are connected.

3.3.1.2. Organisational documents

Internal and external reports were essential to collect in the construction of the HeidelbergCement-Port of Oslo case. As the Port of Oslo is a public port and subject to local authorities, organisational documents, such as public regulations, were necessary in order to build an understanding of port activities and structures. In addition, as there exists limited publication regarding the distribution of dry bulk products it was necessary to collect internal reports on important characteristics of sea transportation within the dry bulk segment. These documents were valuable in the analysis of how HeidelbergCement can use their relation to the port in order to modernise their logistics systems.

3.3.2. Primary data

The primary data was collected using two distinct data collection methods; field observation and semi-structured interviews. These two methods combined gave us a comprehensive understanding of essential elements to build and analyse the case.

3.3.2.1. Field observation

The first part of the primary data was collected through field observations in the Sjursøya terminal. By observing activities and operations at the terminal we gathered information about the activities related to handling of inputs to the production of concrete. Also, by initiating the data collection process with observations, we had a better starting point to understand the practical setting before conducting the interviews. These observations also provided the foundation to understand the potential challenges when altering the logistics systems and structures in the port with aim to modernise the terminal.

3.3.2.2. Semi-structured interviews

The second method we used was in-depth, semi-structured interviews with HeidelbergCement, NorBetong and Port of Oslo. In-depth interviews are described as one of the more common ways of collecting data as it can be quite flexible (Bryman & Bell, 2015). Bryman and Bell (2015) differentiates between structured, semi-structured and unstructured interviews, based on the degree of leeway during the interview. That is, to what extent the interviewer can explore concepts or statements as the interview takes place. The purpose of conducting semi-structured interviews was to obtain a complete understanding of the business relationship between HeidelbergCement and the Port of Oslo in the industrial network setting.

The interviews provided us with a better understanding and enhanced our ability to recognise the coherences and context of the numerical data. It allowed us to explore topics we wanted to discuss through the interview, rather than a strict order of questions which aim to provide very specific data (Bryman & Bell, 2015). It was important that the questions were formulated in a manner which would provide data that actually contributed to answering the research question. For each of the interviews, we developed different set of questions based on what kind of information that was needed at the given time and the expertise of the respondent. Some of the topics that were discussed during the interviews addressed the following measures; *general questions (elements defining relationships, mapping of resources), terminal activities, volume delivered, number and type of shipment, storage capacity, volume and consolidation, distances, and specific cost and emission elements.* It is natural to assume that by making summary of notes after the interviews has strengthened our dataset and our understanding of it, as well as provided us with a better foundation for data analysis.

3.4. Data analysis

This section explains the methods used for analysing the data. The quantitative data is analysed with regards to the environmental and economic sustainability, that is, analysis of the environmental emissions and inbound transportation costs. The qualitative data is analysed in terms of the social sustainability and by using the ARA model to investigate the resource interfaces that make up the distribution system and the relationship between HeidelbergCement and the Port of Oslo. Furthermore, we analysed changes in resource interfaces connected to the Sjursøya terminal as a result of modernising the distribution system.

As the concrete value chain is complex, we have limited the quantitative analysis to the following logistics layout:

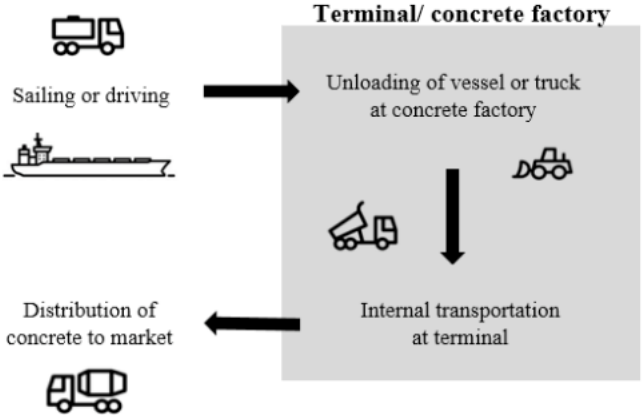


Figure 3.2: Logistics layout for analysis

The vessel and truck sails/drives to the concrete factory. There, it unloads the inputs. Next, the aggregates are transported internally at the factory, e.g. from the vessel to storage, and from storage to production. Finally, the finished wet concrete is distributed to the market in Oslo.

3.4.1. Quantitative data analysis

As discussed in subchapter 2.3. there are numerous ways of measuring environmental sustainability. To measure and analyse the economic and environmental sustainability aspects of the case, we use different types of quantitative data; CO2, NOx and SO2 emissions, and inbound transportation cost. Moreover, we separate the analysis of HeidelbergCement's current logistics systems from the analysis of the potential future systems. To be able to compare the systems, we use data from 2018 regarding volumes of inputs (both cement and aggregates) and finished concrete transported. Hence, the consolidation of volumes to Sjursøya terminal in the future systems is based on aggregated volumes from 2018 at Steinskogen, Alnabru and Sjursøya. By doing so, we gained valuable information from the comparison of each system without considering other factors that may affect the data, such as change in prices for raw materials and fluctuations in demand for concrete.

3.4.1.1. CO2 emission analysis

We have calculated the CO2 emissions for the current and future logistic system in three separate parts; inbound transportation, port operations and outbound transportation.

Inbound transportation

For aggregate and cement trucks, we have used standard EURO 6 engine emission levels to calculate CO2 emission per km driving. As the CO2 emissions per km driven is dependent on the load factor of the truck, we have included full load for deliveries and empty loads for return transportation. Also, we have estimated emission levels based on observations on time spent in queue driving and motorway driving; ⅓ of the distance is affected by queue driving, while ⅔ are estimated as motorway driving. Hence, the total emissions for one trip is calculated based on delivery with full capacity and returning to quarry empty, including the effect of queue driving. For inbound sea transportation, we calculate CO2 emissions based on fuel use for each trip provided HeidelbergCement. The conversion factor used is 2,68 kg CO2 per liter diesel.

Terminal operations

The Sjursøya terminal is the only production facility in the future system. Thus, we have calculated CO2 emissions from port activities in the current and future systems to analyse the effects of modernising terminal operations. The CO2 emission calculations from port activities are based on the fuel use of the different vessels when unloading, and the internal transportation by aggregate trucks and the wheel loader. Emissions from the aggregate trucks are calculated similar to the inbound aggregate trucks, however, only assuming queue driving emission factors. The CO2 emissions from the wheel loader is based on a diesel use of 17 litres per hour which was provided by HeidelbergCement. From this, we calculated the emissions based on estimated operating hours in one year. Since the CO2 emissions is dependent on the aggregate volumes unloaded from the vessels, we have conducted a sensitivity analysis to showcase how operating hours affect the emission levels (see part 5.1.1).

Outbound transportation

Fuel use related to outbound transportation was provided by NorBetong. The average diesel use for the concrete trucks are 5,8 liter per km. This factor includes elements of load factor and queue driving. From this, we calculated CO2 emission per truck trip, using the same emission factor as for sea transportation.

3.4.1.2. NOx and SO2 emission analysis

In order to capture the local environmental effects of altering HeidelbergCement's logistics system, we include the calculation of NOx and SO2 emissions (Rødseth, Wangsness & Klæboe, 2017). Emission levels related to SO2 and NOx for sea transportation depends on the machinery of the individual vessel. As were not able to obtain the necessary data from HeidelbergCement, the NOx and SO2 emission calculation are not as detailed as the CO2 emissions. The emission factors were provided by the thesis supervisor and are based on average estimates develop by the Institute of Transport Economics. The emission factors are, however, expressed in a general notion of *heavy trucks* and *other vessels* (not container vessels). Hence, we were not able to separate the emissions based on the vessel type (cement and dry bulk vessel) or size or differentiate between aggregate and concrete trucks. The emission factors are expressed in emission per ton-km. That is, the total volume in tons transported over the average distance.

3.4.1.3. Transportation cost analysis

The economic sustainability of the current and future logistics systems is analysed in terms of inbound transportation costs for all systems, and handling costs and goods charges in the Sjursøya terminal. The cost data received from HeidelbergCement for sea transportation comprise of three elements; transportation cost per ton, handling costs and goods charges in terminal. However, we were unable to obtain the inbound transportation costs from sea transportation of cement, as this data was too sensitive for HeidelbergCement to share. Hence, we only consider the inbound transportation costs by sea for aggregates.

We have not been able to collect information regarding production costs at each facility nor the investment costs from expanding facilities in Sjursøya terminal due to confidentiality. However, we discuss these aspects with regards to economy of scale from consolidation of production volumes and free up capital from closing production facilities in the current distribution system.

3.4.2. Qualitative data analysis

The social aspect of sustainability has proven difficult to quantify. Hence, we provide a qualitative discussion on political and social acceptance in terms of the effects from modernising the distribution system. The analysis looks into the resource constellation in Sjursøya today and a recombination to achieve the future distribution system. In this sense, we provide a qualitative discussion based on the outlined case and environmental emissions in the terminal and city and its impact on social sustainability.

3.5. Quality of the Research

To ensure that the quality of the research in this study is of high standard we have considered different quality measures. Three prominent criteria in quantitative research are reliability, replicability and validity (Bryman & Bell, 2015). The following part will explain our approach to secure quality.

3.5.1. Reliability and Replicability

Reliability is about whether a measurement is stable or not (Bryman & Bell, 2015). It refers to if the results from a study are consistent and repeatable. As a part of the case study, we have calculated inbound transportation costs for aggregates and the environmental emissions in the current and the future system. The numerical secondary data is collected from HeidelbergCement, NorBetong and the Port of Oslo. Regarding the transportation costs, it is reasonable to assume that the findings are stable over time as these are company specific for HeidelbergCement and NorBetong (disregarding price discounts from renegotiations). However, in terms of the environmental emissions there exists many different calculation methods which may give different results. Even so, in the big picture, the differences will only show small deviations, and the results will be representable for the study.

Another concern that undermines the reliability of the data is the approximations and proxies used in our calculations. With regards to emission levels of NOx and SO2 from sea transportation our calculations are likely to generate higher numbers than what is the actual case. This is because we use general NOx and SO2 estimates based on much bigger vessels than in our case. However, the emission levels still showcase the magnitude from modernising the distribution system. We use EURO 6 engine emission levels to calculate CO2 emissions from inbound road transportation. It is highly likely that that all trucks in the system are not equipped with engines certified according EURO 6 standard. However, we consider the assumption as reliable and to give a good indication of CO2 emissions. Lastly, as queue driving is estimated based on personal observations it is likely that they deviate to some extent. However, the inclusion of queue driving gives a more accurate picture of the situation. This issue is further investigated in a sensitivity analysis (see section 5.1.1).

Replicability is concerned with if the procedure employed in a study is detailed enough for another researcher to be able to replicate the findings (Bryman & Bell, 2015). To ensure replicability in our study, we have presented a detailed outline of how we have collected the data. In addition, the case description contains a thorough explanation of the procedure employed to develop it. Also, the excel attachment contain all numerical data and formulas used in calculating the transportation costs and environmental emissions. In this way, it is reasonable to assume that this research could be repeated by other researchers and yield very similar results.

3.5.2. Validity

Validity is concerned with the integrity of the conclusions derived from the research (Bryman & Bell, 2015). In this sense, it is important that the study actually research what it says it was going to research. In addition to primary data, this thesis includes secondary data and it may be difficult to identify to what extent the data is accurate. It is essential that the data collected is used and analysed correctly. However, we consider HeidelbergCement, NorBetong and the Port of Oslo as trustworthy sources that are of high validity. The numerical data collected from the interviews is used internally at the respective organisations. Hence, the calculations will provide realistic results. This strengthen the thesis' validity. In addition, a detailed case was developed to sufficiently explain the context of research by using the extended ARA model. By doing so, we increased the level of validity concerning the measures derived in the research.

Measurement validity is concerned with whether the quantitative research reflects the concept it is supposed to represent (Bryman & Bell, 2015). Since we have not calculated costs and emissions from production facilities and investment cost by expanding the Sjursøya terminal (see section 3.4), the validity of the study is somewhat weakened, as we are unable to capture the full effect of changing the logistics systems. Including analysis of these elements could have given valuable insights and a more comprehensive calculation of the logistics systems, but data concerning these issues were not possible to obtain. However, cost and emission calculations from transportation and emissions from operations in Sjursøya terminal are calculated and analysed. This has enabled us to compare the current distribution system with the alternative future systems with regards to greening the construction industry.

Another concern is the *generalisability*, also known as external validity (Bryman & Bell, 2015). However, research argue that case studies are not designed to investigate regular situations (Tsoukas, 1989). It could be very difficult to obtain the required number of cases in order to satisfy the statistical requirements. Still, case studies are valuable in explanatory contexts. As there is little research done within the field of dry bulk distribution in the construction industry, this thesis provides valuable knowledge. Moreover, the case can be used by other ports, cities and municipalities as a benchmark for calculating the effects of modernising distribution systems of dry bulk via ports.

4.0. Case Presentation

This chapter provides a thorough description of the case using the NETLOG 4R resource-framework. The case presents HeidelbergCement's current logistic system for concrete in the Oslo market and their two potential future logistics systems. Moreover, the case highlights the changes in the resource constellation that are necessary to modernise and develop the Sjursøya terminal.

Background

HeidelbergCement want to modernise their logistic system supplying the Oslo market to reduce their environmental footprint and secure sustainable sourcing of raw materials. Their main concrete facility serving the Oslo market is located in the Port of Oslo and it is therefore necessary that HeidelbergCement continue to ensure a long-term stable relationship with the Port of Oslo. In order to develop the distribution system, HeidelbergCement is seeking to modernise their logistics set-up by (1) consolidating the production of concrete from facilities around Oslo to the Sjursøya terminal (NorBetong) and (2) make the logistics system more environmentally friendly. To to this, it is necessary to renew logistics operations, and expand and modernise the facilities in Sjursøya terminal.

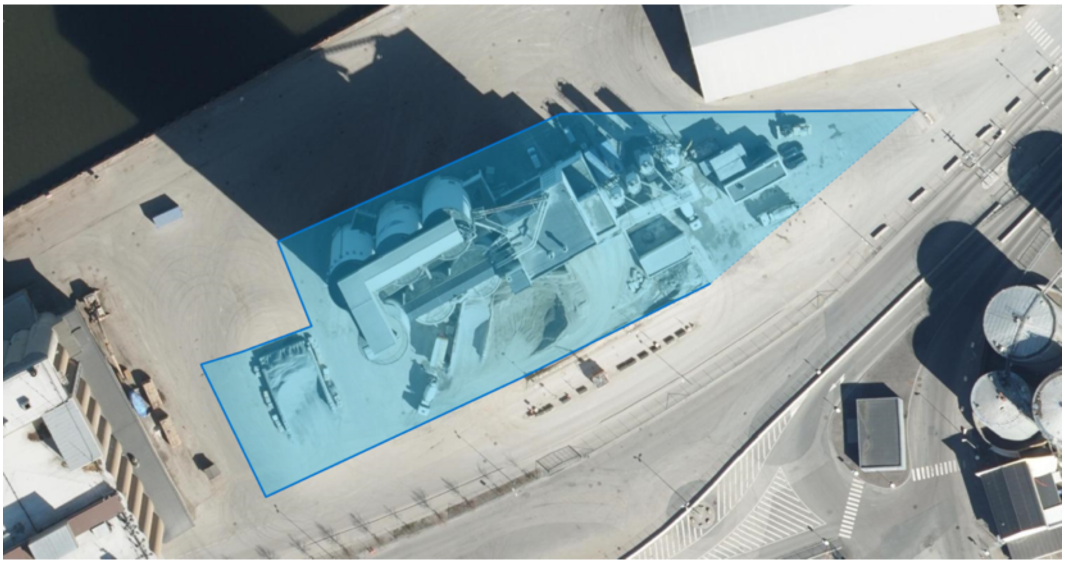
The relationship between the Port of Oslo and HeidelbergCement is a pivotal element in modernising the distribution system. Given the Port of Oslo's environmental goal to reach zero-emission operations by 2030, the desired development and changes in HeidelbergCement's terminal can only be achieved through close collaboration with the port. By analysing the different interfaces between HeidelbergCement's resources, this case highlights the changes that are necessary and how they will alter the interfaces in order to secure a long-term sustainable supply of raw materials. It is the interfaces between resources and how they are combined that determines the potential value of the logistics systems. The focal resource is in this case is HeidelbergCement's terminal at Sjursøya in the Port of Oslo.

First, we present the current distribution system for HeidelbergCement. The inbound system includes transportation of aggregates and cement to production facilities at Alnabru, Sjursøya and Steinskogen, while the outbound system concerns last-mile delivery of concrete to market. Following the presentation of the current system are the presentations of the two potential future systems, both which features distribution solely via Sjursøya terminal, and what changes that are needed in the current resource constellation with regards to the terminal. This includes looking into important resource connections in the distribution system and how these interfaces are altered when changes are made in the current set of resources.

4.1. Description of the focal resource - the facility

The Sjursøya terminal constitutes a vital role in HeidelbergCement's concrete value chain. The terminal connects the inbound transportation to the outbound distribution with its concrete production facility. HeidelbergCement has two subsidiaries NorBetong and Norcem, both of which operates in the Sjursøya terminal. NorBetong's factory at Sjursøya is the main facility supplying the Oslo market with finished concrete.

HeidelbergCement's facility is around 6 000 m2 (storage facilities and concrete factory only) with a 125 m long quay (see picture 4.1). The cement vessels unload cement through a pneumatic system which transport the cement into silos, while aggregates are unloaded using excavator on the vessel deck loading onto trucks for internal transport in the terminal. Although Norcem and NorBetong are operating in the terminal. The two subsidiaries and their share of the Sjursøya terminal is explained in greater detail below.



Picture 4.1: HeidelbergCement's terminal at Sjursøya

Cement - Norcem

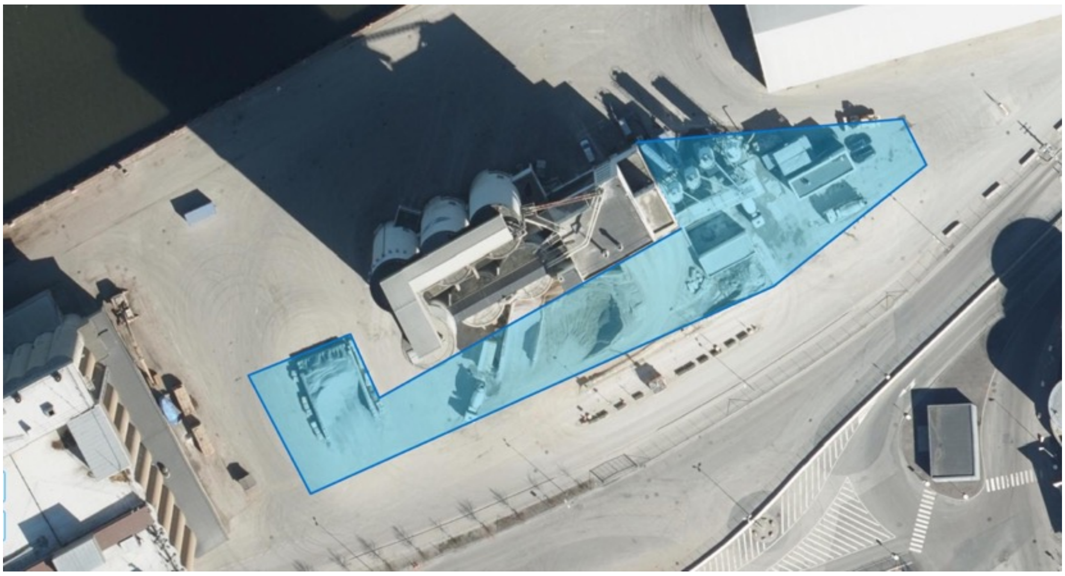
The terminal contains six cement silos (see picture 4.2) that Norcem use for storage before either transporting cement as input to the production of concrete or distributing directly to customer. In 2018, these silos received about 430 000 tons of cement delivered over 94 port calls. Approximately 60 000 tons of the cement from Norcem's storage facility was used in the concrete production in all three factories (Sjursøya, Alnabru and Steinskogen). Norcem also has a storage and distribution facility at Slemmestad, but this facility is expected to be partly closed in the next few years. Some of the capacity will be moved to the Sjursøya facility to be positioned closer to the Oslo market. The capacity expansion of cement storage in Sjursøya will not have a direct effect on the logistics system of concrete production. The cement used in production is already supplied by Norcem's storage facilities in the Sjursøya terminal. Hence, the required cement for concrete production is already accounted for in the current storage capacity. However, the expansion of the storage facility will affect the interface with other resources in the terminal in terms of space scarcity.

Picture 4.2: Norcem's area in the terminal

Concrete - NorBetong

The Sjursøya terminal also contains NorBetong's concrete production factory. In 2018, the total unloaded volumes of aggregates from vessels were around 153 000 tons delivered over 131 port calls. The production of concrete requires different types of gravel. We use the indications 8/16 and 16/22, referring to the diameter of the stones, for the different gravel types. NorBetong's facility also features separate stalls for storage of aggregates to be used in the production of concrete, with a total storage capacity of 4 550 tons. The standalone stall for storage of aggregates (to the left in the picture) has a capacity of 2 500 tons. However, very often, the volumes stored is much higher. The concrete factory has a production capacity of 50 m3 of concrete per hour. In 2018, NorBetong produced 92 500 m3 (equivalent to 220 000 tons) of concrete that was delivered to the Oslo market.

The picture below shows NorBetong's area of the terminal, including the concrete factory on the right, aggregate storage behind the cement silos and on the left side of the terminal.



Picture 4.3: NorBetong's area in the terminal

When concrete is produced it is distributed to the Oslo market with NorBetong concrete trucks. The average capacity per truck is about 6 m3 which is equivalent to around 14,5 tons. Taking last year's production volume of 92 500 m3 combined with the capacity of each truck it results in over 15 400 deliveries to the Oslo market.

Having explained the main features of HeidelbergCement's terminal at Sjursøya, the next section outlines HeidelbergCement's current logistics system. We provide a thorough mapping of the current distribution system presenting the flow of goods for each of the three concrete production facilities separately. We use the current inbound and outbound logistics as a baseline for analysing the necessary changes that follows from the potential future systems outlined in section 4.1.2.

4.1.1. Current logistics systems

HeidelbergCement's current logistics systems supplying the Oslo market include six quarries that delivers aggregates to the production facilities at Alnabru, Sjursøya and Steinskogen. Norcem's cement factory in Brevik supplies cement to the factories at Alnabru and Steinskogen through the Sjursøya terminal. In 2018, these factories combined delivered a total of 153 550 m3 (over 368 000 tons) concrete to customers in and around Oslo. However, each factory produced quite different volumes; 92 500 m3 concrete was produced at Sjursøya, 53 500 m3 at Steinskogen, while only 7 550 m3 was produced at Alnabru. Below, each of the concrete factories and their flow of goods are explained in greater detail.

The Sjursøya factory

The concrete factory at the Sjursøya terminal is supplied with aggregates transported by sea from Kragerø (gravel 8/16) and Svelvik (sand), and by truck from Folbergåsen (gravel 16/22). The factory receives cement transported by sea from Norcem's cement factory at Brevik. The different characteristics of dry bulk and cement vessels require different equipment for unloading at the quay. The aggregates are unloaded from the vessel using excavators on board and trucks for internal movement, while cement vessels use a pneumatic system. This is further explained in section 4.2.3. As Norcem has a distribution centre of cement in the terminal, a majority of the volumes from Brevik is distributed directly to customers, both outside and inside Oslo. Hence, only a minor share of the volume is used in concrete production at the concrete factories in Sjursøya, Alnabru and Steinskogen. Last-mile delivery of concrete to customer is conducted using NorBetong's concrete trucks. Figure 4.1 below illustrates the logistics systems to and from the Sjursøya concrete factory, with corresponding figures related to volumes, capacities and deliveries/port calls per year.

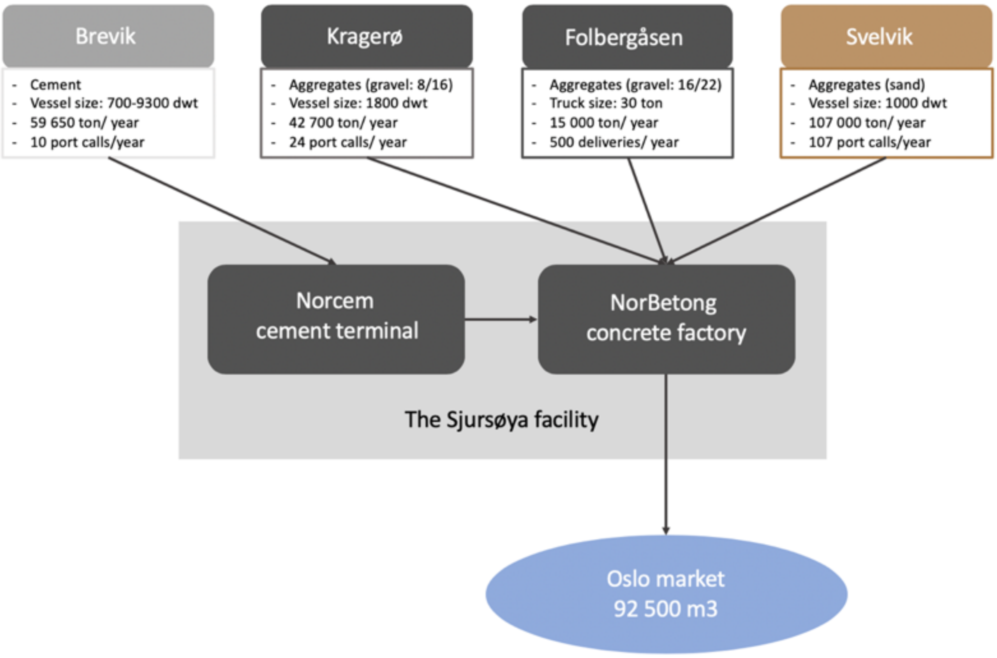


Figure 4.1: Concrete logistics system through Sjursøya terminal

The Alnabru factory

The Alnabru concrete factory is located approximately 12 km from the Sjursøya terminal. This factory is supplied with aggregates by trucks from Folbergåsen (gravel 16/22), Hadeland (gravel 8/16) and Svelvik (sand). Furthermore, cement is supplied from Norcem's storage facility in the Sjursøya terminal. In other words, after cement has been transported by sea from the factory in Brevik it is loaded on to cement trucks and transported to the concrete production factory at Alnabru. Last-mile delivery of concrete to customer is conducted using NorBetong's concrete trucks. The figure below illustrates the logistics systems to and from the Alnabru concrete factory, with corresponding figures related to volumes, capacities and deliveries per year.

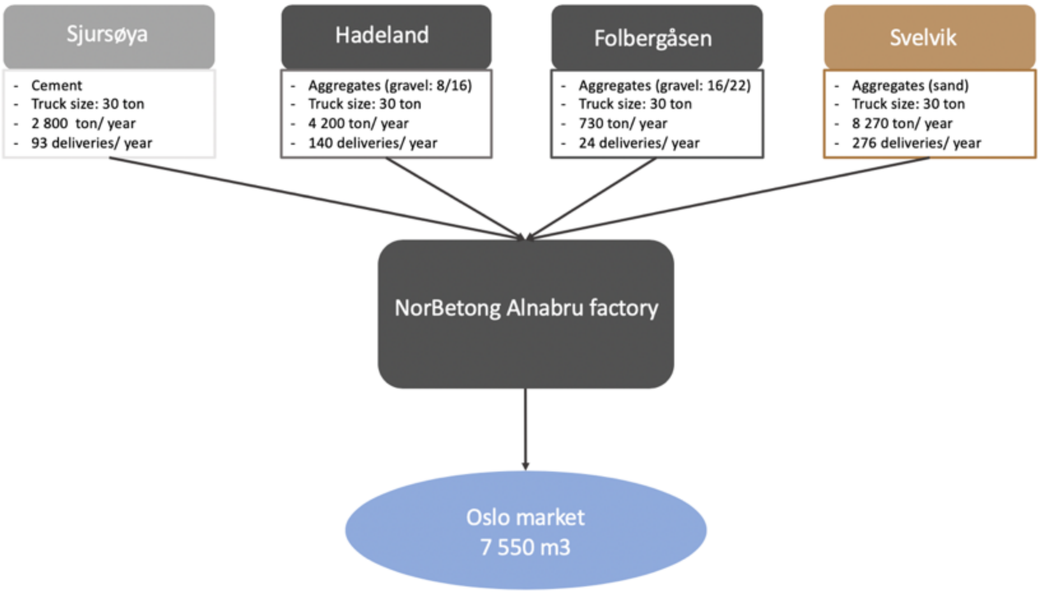


Figure 4.2: Concrete logistics system through Alnabru factory

The Steinskogen factory

The concrete factory at Steinskogen is located in Bærum at the Franzefoss quarry. The factory is supplied with gravel (8/16 and 16/22) directly from this quarry, and we assume only 0,2 km as transportation distance to production. Sand is transported by truck from Lyngås. Similar to the concrete factory in Alnabru, Steinskogen is supplied with cement from Norcem's storage facility in the Sjursøya terminal, 23 km away, by truck. Last-mile delivery of concrete to customer is conducted using NorBetong's concrete trucks. Figure 4.3 illustrates the logistics systems to and from the Steinskogen concrete factory, with corresponding figures related to volumes, capacities and deliveries per year.

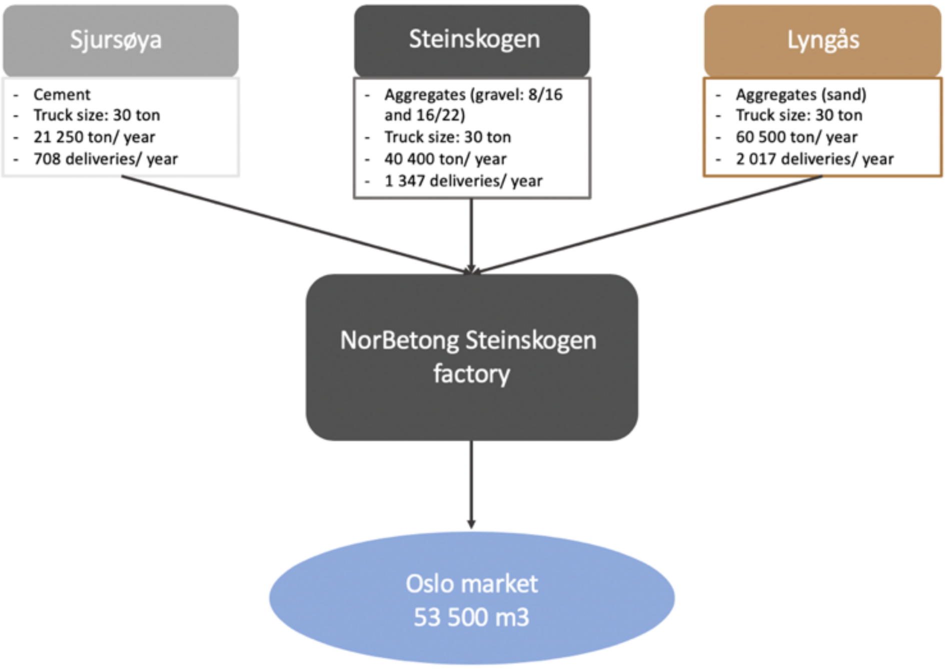


Figure 4.3: Concrete logistics system through Steinskogen factory

Distribution of concrete from all three factories

From all the factories wet concrete is distributed to the Oslo market. Wet concrete is a delicate product that can only be transported about 15 km before it starts to harden. This feature limits the feasible transportation distance between the concrete factory and the market it serves. Last year, the average distance from Sjursøya, Steinskogen and Alnabru to the Oslo market was 10,44 km, 12,88 km and 11,77 km, respectively. Figure 4.4 below show these distances measured in air-distance. The roads in Oslo are not straight lines, and thus the figure may give an inaccurate illustration of the distances from factory to customer. However, the map gives an indication of the areas for which each factory supplies.

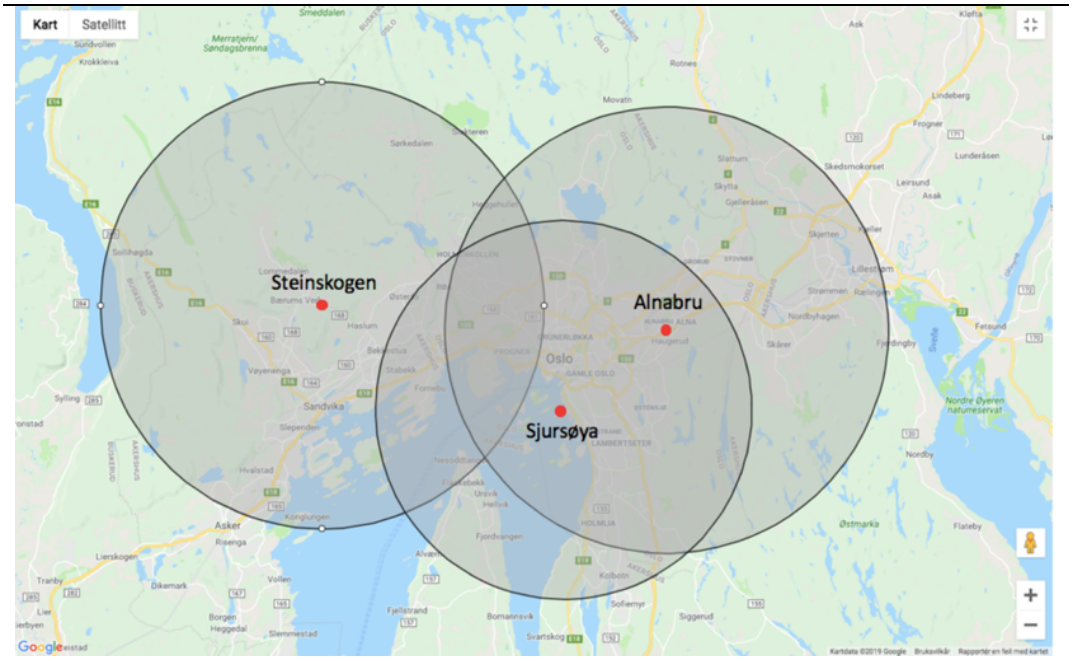


Figure 4.4: Approximate distances from concrete factories to customer

To sum up, HeidelbergCement's logistic systems for concrete features three factories in and around Oslo; Sjursøya, Alnabru and Steinskogen. These factories are supplied with aggregates from six distinct quarries, all in which are owned by third party suppliers. However, Alnabru and Steinskogen factories are supplied with cement from HeidelbergCement's own cement factory in Brevik via Norcem's storage facility in the Port of Oslo. From these factories, the concrete is distributed to the Oslo market.

In the next section we present and distinguish between the two potential logistic systems, i.e. system 1 and system 2, both featuring the same consolidation of concrete production from Alnabru and Steinskogen to Sjursøya. In addition, we outline the required changes that is needed for each system which is based on the current situation that is outlined above. Extraction of raw materials (operations at quarries, loading vessel at quarry) and production of cement is not included in the case description, and will thus neither be part of the analysis.

4.1.2. Future logistics systems

The case differentiates between two alternative distribution scenarios via the Sjursøya terminal. The development of the resources in the terminal and the outbound distribution of finished concrete to the market is similar for both potential systems. However, for the inbound transportation the systems differentiate in terms sourcing strategies that have specific requirements in regard to vessels types, volumes, and routes. The decrease in storage capacity at Norcem's cement facility in Slemmestad in the future system will require a capacity increase in cement storage in Norcem's facility at the Sjursøya terminal. However, this will not change the logistics systems concerning the supply of cement to the production of concrete, as mentioned in part 4.1.

The main change in the inbound logistic system is the new sourcing strategies of aggregates. Moreover, the consolidation of concrete factories in and around Oslo to Sjursøya results in only one factory supplying the Oslo marked. This means that volumes distributed from Alnabru and Steinskogen in the current system will be transferred to Sjursøya and replace inbound road transportation with sea transportation. The average distance to end-customers are quite similar for all production facilities in the current system. As the factories are positioned in relative proximity to the market already, it is estimated that the change in average distance from the Sjursøya facility to the customer after consolidation is minimal. Thus, the current outbound average distance of 10,44 km is kept in both future distribution systems. In addition to change in the inbound and outbound systems, both future systems require development and modernisation of port activities. The measures for terminal modernisation will be presented in part 4.2.

System 1

The first potential future logistic system is characterised by sourcing aggregates from Jelsa on the West Coast of Norway, using 6 000 dwt vessels. This means that all aggregates, i.e. sand and gravel, will be shipped from HeidelbergCement's subsidiary NorStone's quarry in Jelsa in Rogaland (see figure 4.5). Hence, the sourcing of aggregates will change from six locations as it is in current situation (for all three factories) to just one.

The quarry in Jelsa is the biggest quarry in Europe and produce about 10 million tons of aggregates each year. However, the quarry only produces stone and gravel which means that the quarry has no access to natural sand. Thus, the sand will be machine made from crushed stone and gravel. This future scenario suggests that cement will continue to be transported by sea from Brevik to Sjursøya, as it is today. The figure below shows the logistics systems to and from the Sjursøya factory. The figure includes key information such as volume in ton, vessel size, number of port calls and production volume at factory.

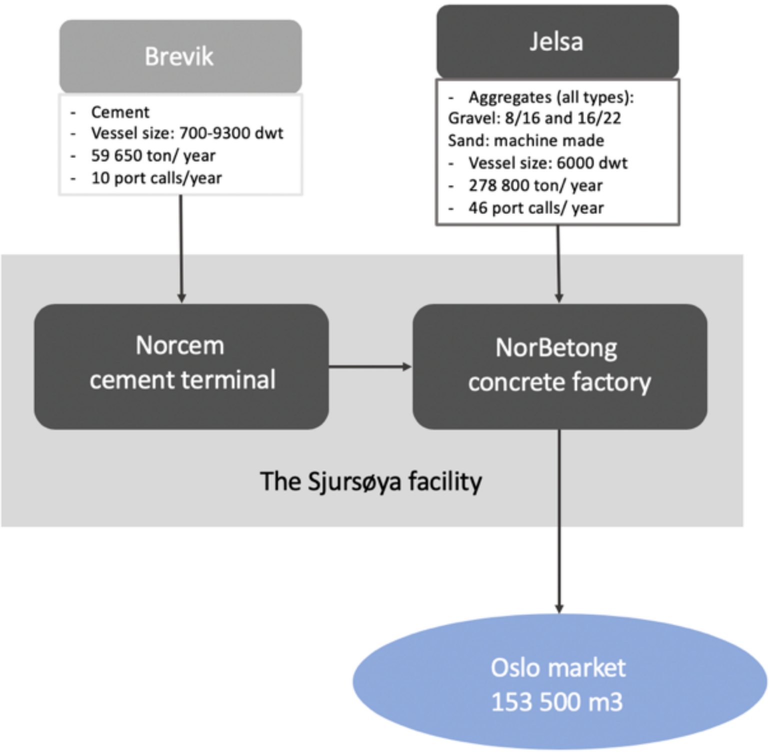


Figure 4.5: System 1 logistics system

System 2

The second potential future logistic system suggest sourcing aggregates from quarries located in Oslofjorden. The logistic system includes shipments of cement from Brevik as it is in the current situation, but there are changes made in the sourcing of aggregates (see figure 4.6). Hence, this system features reducing the number of aggregate quarries from today's six to two. HeidelbergCement will keep Svelvik as the main supplier of natural sand while Kragerø will continue to supply gravel. However, in order to move more of the transportation of aggregates from road to sea, sourcing of gravel type 16/22 will also be sourced from the quarry in Kragerø. The vessel size for sand from Svelvik will remain the same, i.e. 1 000 dwt, but the vessels shipping gravel from Kragerø will change from today's 1 800 dwt to 4 000 dwt. As both gravel types will be sourced from Kragerø, there will be an increase in volume and port calls to the Port of Oslo. The logistics systems to and from the Sjursøya factory is illustrated in the figure below. The figure includes key information such as volume in ton, vessel size, number of port calls and production volume at factory.

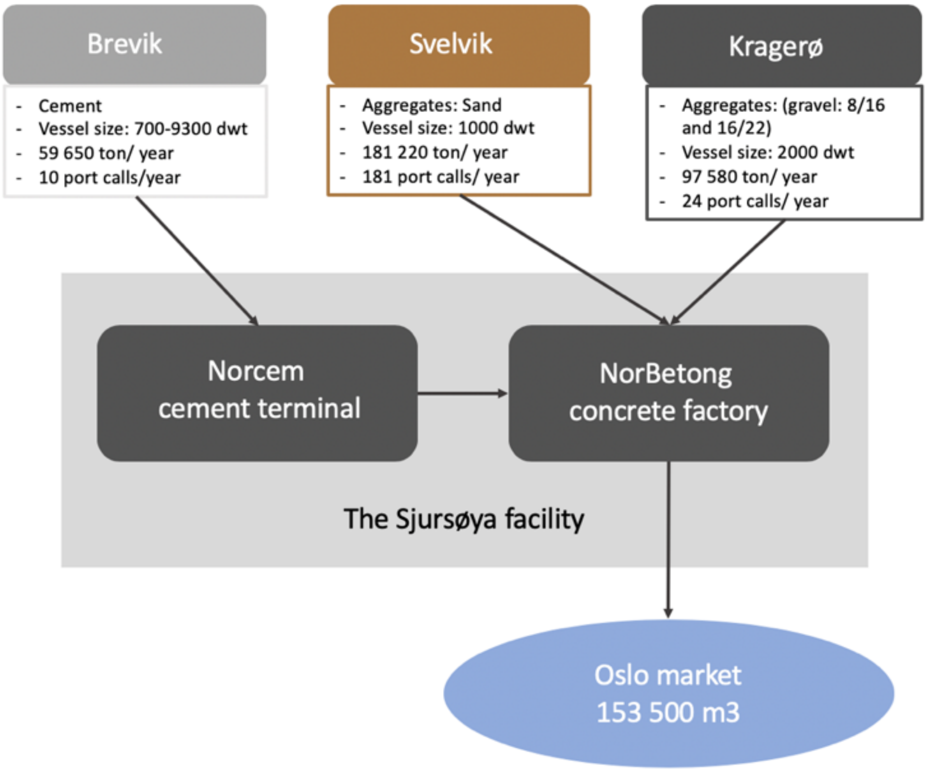


Figure 4.6: System 2 logistics system

To sum up, the current inbound logistic system includes six distinct suppliers of aggregates and one supplier of cement. The current outbound logistics system features three factories supplying wet concrete to the Oslo market. The potential systems (i.e. either system 1 or 2) suggests a consolidation of factories at Alnabru and Steinskogen to the Sjursøya terminal. This also includes that all aggregate types are transported to the factory by sea. In short, the main differences between system 1 and 2 is the location of the quarries and vessel size. System 1 suggests sourcing aggregates from the West Coast with 6 000 dwt vessels while system 2 is sourcing aggregates from Oslofjorden with 1 000 dwt and 4 000 dwt vessels.

The current system is based on a given set of resources that are combined in a particular way that yields a specific set of features and characteristics. In order for HeidelbergCement to modernise their distribution through Sjursøya, it requires investment in resources at the terminal. The consolidation and changes to the logistics systems will require an increase in capacity at the Sjursøya facility, both in terms of storage and production. These specific changes are addressed in the next section.

4.2. Interfaces with other facilities

This section focusses on processes, activities and facilities that make up HeidelbergCement's distribution system. There are multiple facilities that are connected to the Sjursøya terminal, both externally and internally. The external facilities include vessels (cement and dry bulk vessels), pneumatic system onboard the cement vessels, excavators on vessels, the Brevik cement factory, aggregate quarries, all quays/ports the aggregate are shipped from, and concrete trucks. The internal facilities are trucks and wheel loaders used for internal transport of aggregates, storage facilities for aggregates and cement, and the concrete factory at the terminal. The features of the external and internal facilities are dependent on their interfaces with each other and other facilities. When one resource feature is changed, it changes the feature of other facilities it is connected to. The potential future distribution systems (system 1 and system 2) includes a new set of resources and may alter some of the existing resources due to the change in logistical set-up.

The following section explains how the resource interface change when altering the logistics system to and from the Sjursøya terminal. There are many facility resources that are connected to the Sjursøya facility, and we have selected a few which we consider the most important. These are the interface between the Sjursøya terminal and vessels, concrete trucks, terminal operation equipment, and storage and production.

4.2.1. The Sjursøya terminal and vessels

The interface between the terminal and vessels is essential as the vessels are used to transport all inputs to concrete production. There are two types of vessels that are used to transport inputs to the concrete production at the terminal; dry bulk vessels (for transportation of aggregates) and cement vessels. Below, we outline the dry bulk and cement vessel's connection to the terminal and the resulting change in interfaces for each of the potential future logistics systems.

4.2.1.1. Dry bulk vessels (for aggregates)

Both future logistics systems suggest changes in the size and capacity of the vessels. In the current system aggregates are shipped to the Sjursøya terminal from Svelvik (sand) and Kragerø (gravel 8/16) using 1 000 and 1 800 dwt vessels, respectively. The dry bulk vessels are equipped with an excavator on deck which unloads the aggregates. On average, the excavator unloads 300 tons per hour. The two future logistics systems suggest replacing inbound road transportation with sea. Moreover, the systems suggest changes to the aggregate quarries and vessel size.

System 1

System 1 features sourcing aggregates from only one quarry located in Jelsa on the West Coast of Norway. As we keep the 2018 volumes of aggregates and concrete fixed when analysing the new systems, this implies that almost 280 000 tons of aggregates will be sourced from Jelsa. The dry bulk vessels for aggregates will change from today's 1 000 and 1 800 dwt vessels to 6 000 dwt vessels.

As a result of altering the vessel capacity, the number of port calls will be reduced compared to the current system, despite increasing the volume; approximately 150 000 tons and 131 port calls in the current system vs. approximately. 280 000 tons and 46 port calls in system 1. The reduction in port calls means that unloading activities at the terminal will be conducted less frequently. However, the time spent on unloading the vessel will increase because the volume per delivery is higher. Hence, vessels will stay in landside for a longer time period than in the current system. Bigger vessels will also change requirements for storage capacity for aggregates to accommodate higher volumes per delivery. The storage capacity needs to be able to handle the unloading of a 6 000 dwt vessel (the current capacity is approximately 4 500 tons).

An important feature of dry bulk vessels is that it can transport different types of dry bulk products. Since the quarry at Jelsa is located on the West Coast, the vessels can be used to transport other types of cargo when returning to quarry. Instead of sailing over 300 nautical miles with empty compartments, the vessel route facilitates for return transport of cargo from Oslo to other ports along the coast. Hence, system 1 can contribute to increased use of sea transportation. For example, the vessels transporting aggregates to Oslo for HeidelbergCement can transport grains on its way back to Stavanger for Strand Unikorn (Norheim & Moe, 2018).

System 2

System 2 includes sourcing from two quarries at different locations in Oslofjorden. The closeness to the Sjursøya terminal means that vessels will be employed with capacities of 1 000 dwt for sand and 4 000 dwt for gravel, which is slightly bigger than the vessels in the current system. Accordingly, the interfaces between vessels and terminal is different from the current system and system 1. In addition, the increased volumes, as a result from consolidation, demand more storage capacity.

As a result of sourcing from more than one quarry with the given volume of aggregates (almost 280 000 tons), the number of port calls will be higher compared to system 1; the combination of volumes and vessel sizes generates 206 port calls each year. Compared to system 1, it is natural to assume that system 2 will demand a higher level of coordination as there are almost three times as many port calls. However, in contrast to system 1, the time spent on unloading these vessels will be significantly shorter due to smaller vessels. Moreover, each of the vessels in this system demand less space in the quay, simply because they are smaller, which potentially allows for other vessels to dock at the same time. It is also possible to facilitate for return transportation in this system. However, the geographical area in which the vessels sail limits possible markets that can be delivered to. The dedicated transportation system from Svelvik to Oslo constrain the area in which the vessel can sail. However, the Kragerø - Oslo route covers a wider geographical area making it easier to facilitate for return transport.

4.2.1.2. Cement vessels

Given the distinct characteristics of cement, the product requires specialised vessels for shipment. Thus, cement vessels rarely transport other products. All shipments have a full utilisation of the vessel capacity. However, after cement is unloaded at the Sjursøya terminal the vessels almost every time return empty, which creates an unbalance in the direction of transportation.

In the current logistics system, cement is transported from Brevik on a regular basis with approximately two port calls each week. The vessel capacities vary between 700 to 9300 dwt, but 6 000 dwt vessels are normally used. In 2018, the total volume of cement transported to the Sjursøya terminal at the Port of Oslo was 430 000 tons. The cement is unloaded by using a pneumatic system which blows the cement from the vessels directly into silos for storage. On average, the systems are able to unload about 500 tons per hour. This means that for a 6 000 dwt vessel the unloading process takes around 12 hours (effective unloading time).

The inbound transportation of cement will be the same as in the current logistic system. This is because total volume of cement used in the production of concrete is already shipped to Sjursøya as part of further distribution to Alnabru and Steinskogen. Therefore, consolidation will not affect the inbound quantities of cement to Sjursøya that is used in the production of concrete.

4.2.1.3. Vessel modernisation

The current dry bulk fleet in Norway has an average age of 30 years (DNV GL, 2019) and is driven solely on diesel fuel. However, selected vessels have in the last few years been rebuilt to run on electricity while at berth. With such technology available, there exist potentials to develop and modernise the dry bulk fleet as well. Rebuilding the vessels to run on on-shore electricity requires specific facilities in the port that take up space. The Port of Oslo on-shore power supply strategy states developments of the system in the years to come (Port of Oslo, 2012).

Cement vessels are less environmentally friendly than dry bulk vessels in that the unloading process requires the motor to run to generate enough electricity for the pneumatic system. Hence, the majority of the emissions from cement transportation takes place when the vessel is at berth. Because of the difference in unloading process of dry bulk and cement vessels, the potential reduction in emission by the use of on-shore power supply is thus greater for cement vessels. With regards to dry bulk vessels, it is also possible to replace excavators on the deck. Today's excavators run on diesel fuel, but construction machine producers have begun to produce electric excavators (Brekkhus, 2018). By modernising the excavators on board, the dry bulk vessels (for aggregates) to run on electricity, the unloading process can be more environmentally friendly.

4.2.2. The Sjursøya terminal and concrete trucks

The outbound transportation of concrete from the production facility to the customer is conducted using specialised concrete trucks. HeidelbergCement's car park consists of three types of concrete trucks. The standard and most commonly used concrete trucks can carry a load of 6 m3 which gives a total truck weight of around 30 tons (concrete alone = 14,4 ton). The three types of truck used in distribution and their associated load capacity are presented below:

- 8 m3 capacity, concrete weight: 19,2 ton
- 7 m3 capacity, concrete weight: 16,8 ton
- 6 m3 capacity: concrete weight: 14,4 ton

The current outbound distribution system features only diesel trucks. As a part of the development and modernisation of the logistics systems, HeidelbergCement is collaborating with suppliers to make the concrete trucks more environmentally friendly. However, the development and innovation in making concrete trucks fully electric is slow. As a first step towards reducing the transportation emissions, NorBetong has already initiated the rebuilding of today's trucks into hybrid trucks where the concrete drum rotation is electric (Strand, 2018). These initiatives are first steps in modernising the trucks and both HeidelbergCement and NorBetong state that the near future holds for fully electric concrete trucks.

The current system and facilities in port do not feature fuel stations for the trucks. However, implementing electric vehicles will require charging stations. With charging stations follows the need for space where the trucks can stay while charging, possibly also queuing. However, this is challenging as space scarcity is already an issue in the port. Furthermore, as the consolidation of factories makes the Sjursøya terminal the sole supplier of finished concrete to the market, all outbound distribution is done from Sjursøya. Thus, the new terminal layout needs to be designed to handle the intensified traffic. The loading of trucks, charging time, and total time spent on terminal for each truck are aspects that needs to be dealt with in order to reduce the likeliness of long queues at the terminal.

4.2.3. The Sjursøya terminal and terminal operation equipment

As explained, there are several facilities which make up the Sjursøya production facility. When modernising the current logistic system, the two future logistics systems also features a modernisation of the terminal operation equipment.

4.2.3.1. Equipment and systems for unloading vessels

It is necessary to modernise terminal equipment and systems used for unloading vessels in order to develop a zero-emission terminal. The current pneumatic system for unloading cement is run by electricity generated from the vessel motor, which runs on diesel, and can unload about 500 tons of cement per hour. Making the system emission free will require vessel modernisation as the system is a part of the cement vessel. Hence, we will focus on how modernisation of equipment linked to unloading dry bulk vessels can be improved in the future systems.

The unloading of aggregates from dry bulk vessels are done with excavators onboard the vessels. From the excavators, the aggregates are loaded onto trucks at the quay. The trucks are owned by a third party and are only present at the terminal when an aggregate vessel is at berth. Together, these trucks have a capacity of transporting 400-500 tons per hour and drives in shuttle traffic between the vessel and storage unit on a 4-6-hour interval. The excavator on board the vessel is a bottleneck due to its capacity of loading about 300 tons per hour. Thus, unloading a 1 800 dwt dry bulk vessel takes about 6 hours effective work.

In both future systems, transportation activities to and from the vessel and aggregate storage will be eliminated due to the introduction of conveyor belts for unloading. Accordingly, noise and manual labour connected to unloading will be reduced. This will reduce the likeliness of accidents involving humans. Moreover, it is estimated that the conveyor belt can unload 500 tons per hour. However, as the excavator can unload approximately 300 tons per hour, the full capacity of the conveyor belt will not be utilised. Still, by using a conveyor belt, the turning radius of the excavator will be shorter, and it eliminates idle time used on breaks by truck and wheel loader drivers. It is therefore likely that today’s unloading capacity of 300 tons per hour will slightly increase. Moreover, the excavator onboard the vessels can be replaced by an electric excavator, which means that the emission from the six hours work, i.e. current situation, is eliminated.

4.2.3.2. Internal movement and transportation

In the current system, after trucks have unloaded sand and gravel to the storage facility a wheel loader is used for pushing aggregates upwards into the open stalls and for transportation to concrete production (see figure 4.7and 4.8). The current solution for storing the aggregates is not optimal, as the wheel loader is not able to fill the stalls properly when the pile of aggregates gets too steep, which is very often. Moreover, the wheel loader runs on diesel and generate a lot of noise when moving the aggregates around the terminal. We return to the issue of aggregate storage in in section 4.2.4.

Figure 4.7: Aggregate truck movement on terminal

Figure 4.8: Wheel loader movements on terminal

To sum up, both of the future scenarios suggest a more effective way of unloading vessels. With the mutual interest between HeidelbergCement and the Port of Oslo to reduce the environmental footprint from port operations, the future scenario eliminates the use of trucks for unloading aggregates and wheel loaders in the terminal. All transportation and movement of aggregates will be conducted using electric conveyor belt(s), involving as little human interaction as possible. This will in turn lead to reduction in worker injuries.

4.2.4. The Sjursøya terminal and Storage and Production

4.2.4.1. Cement storage

Cement transported from Brevik is today unloaded and stored in six silos. Both future scenarios of modernisation and consolidation will require increased storage capacity for cement based on the reduction in Norcem's facility in Slemmestad. In other words, the cement facility will be expanded to handle the increased volumes. The space scarcity is constraining HeidelbergCement in terms of how much they can expand in the width dimension (also, see next section about expanding aggregate storage). Therefore, the expansion will require them to expansion in the height. This means that cement silos will be more visible to residents and the people that frequents in Oslo, which is not always preferable in a city port.

4.2.4.2. Aggregate storage

As the production of concrete will be consolidated it is also necessary increase today's storage space for aggregates. The current aggregate storage system has a capacity of 4 550 ton divided into multiple outdoor stalls separating each aggregate type. Each stall has different storage capacities; 1 700 ton for sand, 2 500 ton for gravel type 8/16 and 350 ton for gravel type 16/22.

Given the consolidation of factories it is estimated a need for 14 000 ton storage capacity, regardless of which future logistics system is chosen. By expanding storage facility to accommodate the increased volumes, the terminal can also handle bigger shipments from a single port call, as is the case in system 1. Given the restrictions resulting from space scarcity in the terminal, HeidelbergCement can achieve better use of their area by establishing silos (expanding in height) for storing of aggregates in contrast to the current solution. In this way, they can expand storage capacity without expanding the occupation of area in the terminal and remove internal transportation from storage to production of concrete. The expansion of cement silos constrains the available area for expanding aggregate storage facilities. Therefore, the layout of these two facilities are heavily dependent on each other. The expansion of aggregate storage will also yield the same visual concern as mentioned with expanding cement silos in the height dimension.

4.2.4.3. Concrete production

The concrete factory at Sjursøya is an essential part of the terminal. The factory has a current production capacity of 50 m3 per hour and in 2018 the factory produced about 92 500 m3 of concrete. In order to handle the increasing volumes from consolidating factories it is necessary to expand the current factory's production capacity. Using 2018 numbers, the consolidated production volumes from the factories is 153 500 m3 per year. Consolidation and expansion will naturally lead to economies of scale and lower production costs per unit. To be able to compare the current system with the future potential systems, we keep the same volume of production (153 500 m3) when analysing the effects of modernisation.

The expansion of the production facility is necessary in order to use more of sea transportation. Without the expansion in production capacity, there is no need for an expansion of aggregate storage. In this way, the development of these two facilities are dependent upon each other. The current facility is designed in a way that contributes to the use of internal transportation (truck and wheel loader); the current solution hinders initiating measures to reduce emissions.

To sum up this section, the expansion of facilities in a city port yields specific challenges. The factory is positioned relatively close to private residents and urban areas, which make factors such as noise, visuality and design important to consider. Any changes of the factory and storage facilities in the terminal has to be approved by the Port of Oslo. Thus, the relation between HeidelbergCement and the Port of Oslo becomes an important factor. The production facility is located in the port, and the port has to consider different laws and regulations and the port can either be the enabler or prevent these necessary changes. Moreover, there is space scarcity in the terminal, which means that expanding one facility reduces the available space to expand other facilities. Without an increase in production capacity storage, there is no need to increase input storage capacities. Thus, these facilities are interdependent and have to be considered together when changing and modernising the terminal structures.

4.3. Interfaces with other resources

In addition to interfaces with other facility resources, HeidelbergCement's Sjursøya facility is connected to other types of resources. The following section of the case outlines the interface between Sjursøya facility and other physical resources, such as products, and organisational resources, such as business units and business relationships. In addition, relevant changes in interfaces as a result of changing logistic system will be outlined where appropriate.

4.3.1. Facility vs. Products

The following describes how the Sjursøya facility is connected to products. The section outlines the interfaces with the inputs (aggregates and cement) in the production of concrete, and how these interfaces are affected as a result of altering the current system.

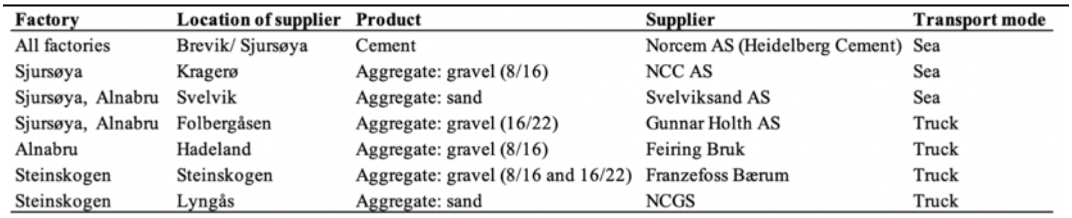
4.3.1.1. Cement

The Sjursøya facility is one of HeidelbergCement's primary distribution centres of cement to the Oslo market. The cement is produced at the factory in Brevik. The factory produces different types of cement, including cement suitable as input in concrete production. From the factory in Brevik, around 430 000 tons of cement was shipped to the facility in 2018. 14 % of these volumes was shipped to Sjursøya, Alnabru and Steinskogen as input in concrete production.

The suggested future systems feature an increase in concrete production at Sjursøya as a result of consolidation. Increased concrete production means increased use of inputs. Despite this, the volumes of cement shipped to Sjursøya will not be affected by the change in logistics systems, as the cement used in Alnabru and Steinskogen is already transported through the Sjursøya terminal. When it comes to storage capacity, reduction in the Slemmestad cement storage facility implies the need for an increase in the cement storage facility at Sjursøya. The Slemmestad facility is to close down 7 of the 11 silos, which will result in capacity decrease of approximately 64 %. Therefore, the future system requires a need for increased capacity. The Sjursøya facility also needs to fit the capacity expansion to handle all the different types of cement, i.e. separate silos for each type. Even though this will not affect the distribution of cement in the concrete production system, it will require a capacity increase in cement silos at the terminal.

4.3.1.2. Aggregates

The production of concrete requires four type of inputs; sand, gravel (fine and coarse), cement and water. The aggregate mix consists of 60 % sand, 30 % fine gravel (8/16), 10 % coarse gravel (16/22). 8/16 and 16/22 are indications of different types of gravel in terms of size of the stones. Hence, gravel 8/16 indicates gravel where the stones' diameter is between 8 and 16 mm. Today, the inputs for production are sourced from seven separate locations and shipped to the three production facilities Sjursøya, Steinskogen and Alnabru. The table below contains sourcing information regarding all inputs to concrete production in all three facilities.



Factory	Location of supplier	Product	Supplier	Transport mode
All factories	Brevik/ Sjursøya	Cement	Norcem AS (Heidelberg Cement)	Sea
Sjursøya	Kragerø	Aggregate: gravel (8/16)	NCC AS	Sea
Sjursøya, Alnabru	Svelvik	Aggregate: sand	Svelviksand AS	Sea
Sjursøya, Alnabru	Folbergåsen	Aggregate: gravel (16/22)	Gunnar Holth AS	Truck
Alnabru	Hadeland	Aggregate: gravel (8/16)	Feiring Bruk	Truck
Steinskogen	Steinskogen	Aggregate: gravel (8/16 and 16/22)	Franzefoss Bærum	Truck
Steinskogen	Lyngås	Aggregate: sand	NCGS	Truck

Table 4.1: Aggregate suppliers for Sjursøya, Alnabru and Steinskogen factories

Both of the future scenarios feature new sourcing locations for aggregates. An important change in sourcing of inputs is featured in system 1. This system suggests sourcing all aggregates from the same quarry. The current system is using natural sand sourced from Svelvik (and Lyngås). However, the quarry in Jelsa does not have a natural sandpit, which means that the sand has to be machine made by crushing gravel. Quality wise, it is possible to replace natural sand by machine made sand in concrete production and this has gained increased attentions by companies exploring the substitution (Byggfakta.no, 2019; Hasle, 2019; Skoglund, 2019). The change in suppliers of aggregates will naturally have an effect on HeidelbergCement's supplier base. With new suppliers follow new interfaces and relations. This issue is outlined below in the section about interfaces with business units.

4.3.2. Facility vs. Business units

This section outlines business units as organisational resources which possess specific organisational capabilities and abilities which are important to the Sjursøya facility and to HeidelbergCement's distribution system.

The Sjursøya terminal and NorBetong

HeidelbergCement's subsidiary, NorBetong, is one of the two subsidiaries operating in the Sjursøya facility. Thus, this interface is important to consider. NorBetong is one of Norway's leading suppliers of finished concrete to the construction industry. They have concrete factories that supply most of the markets located in South-Norway.

The Sjursøya terminal is among the three concrete factories serving HeidelbergCement's biggest customer base; the Oslo market. All three factories are owned and operated by HeidelbergCement's subsidiary NorBetong. As mentioned earlier, the three factories had very different production volumes in 2018; Sjursøya about 92 500 m3, Alnabru about 7 550 m3 and Steinskogen about 53 500 m3, making Sjursøya the primary factory serving the Oslo market. Closeness to market is crucial when distributing wet concrete which makes the location of the terminal an important element enabling production of concrete in the terminal.

The future scenario of consolidation the production to the Sjursøya terminal will increase the importance of this facility. As Steinskogen and Alnabru will close, Sjursøya will be the only concrete factory to serve HeidelbergCement's biggest market for concrete. Being dependent on only one factory to serve the primary market will generate some risk, such as not being able to deliver the product in the case of production breakdowns. However, the new terminal will also generate economy of scale in production due to the expansion of facility.

The Sjursøya terminal and Norcem

HeidelbergCement's subsidiary Norcem is connected to the Sjursøya terminal through storage facilities and distribution of cement to external market, as well as the supply of cement to concrete production. Norcem is the single producer of cement in Norway with facilities in Kjøpsvik and Brevik. Almost all of the cement produced is distributed in Norway, but they also supply foreign markets. In addition, they have long experience with sea transporting as this is their primary transport mode. Therefore, the Sjursøya terminal is important for Norcem to be able to transport cement by sea. Norcem produce cement for construction, micro cement, and other products such as lime fillers. In short, Norcem has long traditions with supplying the construction market.

All cement used in NorBetong's production in the terminal is supplied from Norcem's cement production facility in Brevik. Of the total 430 000 tons cement going via Norcem's silos in Sjursøya only 59 650 tons was used in production of concrete, in all factories combined. More specifically, the cement volumes in 2018 transported to Alnabru, Steinskogen and Sjursøya were 2 800 tons, 21 250 tons and 35 600 tons, respectively. This means that approximately 14 % of all the cement transported via the HeidelbergCement is terminal in Sjursøya is used in concrete production. Moreover, approximately 8 % of the total volume of cement was used in concrete production at Sjursøya alone. These relatively small volumes of cement to concrete production shows that Norcem has a solid external market for distribution of cement; around 86 % of the total amount.

The future scenario requires a capacity expansion in the facility, both in terms of storage of inputs, such as cement, and production of concrete. As mentioned earlier, this is already an existing issue as the port is continuously pressured to become smaller. Silos are excellent storage units for cement. As the storage capacities at Norcem's facility in Slemmestad is reducing as well, the new logistics systems require an increase in storage of cement at the Sjursøya facility resulting in increased activities in the terminal.

The Sjursøya terminal/HeidelbergCement and Suppliers

The current logistics set-up and sourcing strategy features only third-party suppliers, i.e. the quarries are not owned by the HeidelbergCement group. For example, the quarry in Kragerø is owned by NCC, and the quarry in Steinskogen is owned by Franzefoss. Both of the future inbound logistics systems suggest changes regarding what quarries and suppliers to use.

System 1 suggest sourcing all aggregates from NorStone's quarry in Jelsa, which implies switching from third party suppliers to sourcing "inhouse". There is no interface between the Sjursøya terminal and HeidelbergCement's subsidiary NorStone in the current logistics system. As NorStone then becomes the sole supplier of aggregates they become an important part of the distribution system. Based on the use of aggregates for Sjursøya, Alnabru and Steinskogen from 2018, it is estimated that approximately 3 % of Jelsa's total production volume will be generated from aggregates shipped to the new Sjursøya terminal. However, this interface will only occur if HeidelbergCement implements system 1.

System 2 suggests reducing the number of suppliers from three to two, by increasing the volume of gravel from NCC in Kragerø. The increased volume of gravel is a result of substitution of suppliers; NCC in Kragerø will supply the volume that was previously supplied from Folbergåsen. Hence, the volume of gravel from Kragerø will increase from almost 43 000 tons to 98 000 tons. The volumes of sand from Svelviksand will increase from 107 000 tons to 180 000 tons.

The Sjursøya terminal/HeidelbergCement and Customers in Oslo

HeidelbergCement/NorBetong operates in both B2B and B2C markets which implies that they distribute concrete both to construction sites and to private residents in and around Oslo. Development and modernisation of the logistics systems will not affect or change HeidelbergCement's customer base in any revolutionary way, but rather contribute to improving the industry's overall emissions. Moreover, when HeidelbergCement is to reconsider their sourcing strategies it is important that the new quarries and suppliers' products are as sustainable as possible while at the same time fulfils the required quality that is demanded from their customers.

4.3.3. Facility vs. Business relationships

There are many businesses that can be identified as being related to the focal facility, Sjursøya terminal. These includes; HeidelbergCement, shipowners, Port of Oslo Authority, public authorities, quarries, and extraction sites. We have selected the interfaces between the Sjursøya terminal and the business relationships we consider to be the most important ones in the distribution system. These are HeidelbergCement and Port of Oslo, and HeidelbergCement and shipowners. Below, we outline characteristics of each business relationship and the effect it has on the development and mobilisation of resources.

HeidelbergCement and the Port of Oslo (Oslo Havn KF)

HeidelbergCement (Norcem) has transported cement to the Port of Oslo since the 1960s. From then to now, collaboration has been the most prominent feature of this business relationship. Without collaboration, the terminal layout and operations would not be as it is today; there would not exist cement silos nor production facility for concrete in the terminal. This is due to the administrative role of the port (port authority); without close communication and collaboration, it would be difficult for HeidelbergCement to gain acknowledgement for the necessities that are essential for an effective terminal. As a result, the Port of Oslo is crucial in HeidelbergCement's distribution system.

The cement silos were built in 1960s and initially owned by the Port of Oslo. These silos and the establishment of the terminal at the port enabled HeidelbergCement to transport cement by sea as an alternative to road. Without these silos, HeidelbergCement would not be competitive to serve the Oslo market. Today, the silos are owned by Norcem. In 2009, NorBetong and the concrete production facility was established at Sjursøya terminal whereas the Port of Oslo constituted a key role. The Planning and Building Act, for which the Port of Oslo is a subject to, is in its nature restricting users of the port to conduct industrial activities. However, as the Port of Oslo is continuously working to facilitate for increased use of sea transportation, they also communicated to public authorities about the potential gains from establishing the current concrete factory in the terminal. In this way, HeidelbergCement's relation to the Port of Oslo has provided the base for enabling modernisation of activities in the port.

The Port of Oslo has also been continuously involved with HeidelbergCement in the planning and development processes in the Sjursøya terminal to how it is today. One aspect that is valued by the Port of Oslo is the visual layout. As the Port of Oslo is a city port, it is essential that new facilities in the port follow the visual design of the surroundings to gain acceptance from e.g. nearby residents and the local community. Because of this, the Port of Oslo could easily make firm demands to HeidelbergCement regarding the visual aspects of the terminal. However, during the planning and development process there was continuous dialogue where the focus was on mutual problem-solving rather than the port authorities imposing demands.

The collaboration was a give and take process that has ensured that the end-results were accepted by all affected parties. It was evident that both parties were able to consider the other parts needs and demands, as they both recognised the importance of the Sjursøya terminal. Clearly, it would not be possible to develop the terminal if it had not been for the long-term perspective from HeidelbergCement to transport inputs to production of concrete by sea. Therefore, HeidelbergCement's long-term presence has been important for the development of the terminal. Furthermore, underpinning the dyadic relationship is their mutual interest towards continuously becoming more sustainable. HeidelbergCement's continuous effort to reducing their environmental footprint (i.e. incorporated sustainability measures) is aligned with the Port of Oslo's strive to reduce the environmental and social impact on the local community (i.e. zero-emission plan). The mutual interests in reducing environmental impact has made it possible for the continuous development of the terminal.

HeidelbergCement and Shipowners

HeidelbergCement is chartering vessels from various shipowners on time charter. Most of the quarries that HeidelbergCement source aggregates from is located fairly close to the production facility at Sjursøya. Oslofjorden is an area where the market for chartering dry bulk vessels has stagnated. Here, HeidelbergCement plays an important role. Their need and demand for the smaller vessels and regular shipments to the Port of Oslo contributes to that the shipowners can keep their vessels in the area. HeidelbergCement is in turn dependent on the vessels to be close and available for transportation. The shipowners with vessels operating in Oslofjorden are dependent on HeidelbergCement to do business, and HeidelbergCement is dependent on the dry bulk vessel market. Hence, there exists an important resource interdependence, connecting the vessels (shipowners) and the Sjursøya terminal (HeidelbergCement) together. The business relationship is characterised by frequent interactions where both sides benefit from mutual adaptations.

The dyadic relationship between HeidelbergCement and shipowners is also characterised by another important feature. A vast majority of HeidelbergCement's shipments constitutes of volumes suitable for vessels in the range from 1 000 to 6 000 dwt. However, the Norwegian dry bulk fleet with the respective size has the average age of 30 years (DNV GL, 2019) and there is a lack of interest and willingness for shipowners to invest in building new modern smaller vessels as the market calls for bigger ones. As the quarries HeidelbergCement source aggregates from are located in places with relatively small quays, there is a constraint on how large the vessel can be before it is not able to dock. In other words, HeidelbergCement is dependent on having smaller vessels available, and thus, the relationship with the shipowners is essential when HeidelbergCement is greening their value chain through increased use of transportation by sea. The vessels, as with the other transportation elements in the value chain, needs to be developed and modernised, and the relationship is an important in this sense.

The shipowners offer available vessels to HeidelbergCement when they are located in the right area; Oslofjorden. Moreover, if HeidelbergCement do not have sufficient volumes to utilise the whole capacity of the vessel, the shipowners are willing to either delay the shipment or ship without full capacity. This is an important example which show the shipowners' ability and willingness to give a small sacrifice by rather valuing the long-term nature in the business relationship. Also, HeidelbergCement's shipments enables the shipowners to charter vessels to other less frequent customers located nearby. The two parties almost always end up with a beneficial outcome for both, with mutual adaptations in a collaborative give-and-take process. For example, after a shipment for HeidelbergCement to the Sjursøya terminal the vessel can load products from another customer, e.g. located in Moss, and ship it to another destination. In this way, the shipowner's loss from not shipping full capacity for HeidelbergCement is gained with another customer. In other words, the relationship and collaboration between HeidelbergCement and the shipowners facilitates for mutual benefits that also benefits others.

4.4. Case Summary

The case presentation has provided a detailed description of the resource facility and its connection to important resources by applying the ARA model and NETLOG 4R resource-framework. The case has outlined the connections between HeidelbergCement's current resource constellation and explained how the interfaces change as a result of modernisation. To reduce the environmental footprint and to ensure a sustainable, long-term securement of raw materials, HeidelbergCement seeks to develop and modernise their logistics systems connected to the Sjursøya facility. The current logistics system supplying the Oslo market with concrete features three concrete factories supplied by six aggregate quarries. By consolidating production of concrete, the Sjursøya factory will be HeidelbergCement's sole supplier of concrete to the Oslo market. The expansion and development of the Sjursøya facility calls for modernisation and change to the logistics systems, enabling HeidelbergCement to switch suppliers of aggregates which will increase the use of transportation by sea. The potential future logistics systems feature transportation by sea as the only transportation mode for aggregates, increased production and storage capacity at the facility, and a distribution set-up which facilitates for development towards zero-emission solutions.

The transition to the future logistics systems will affect the resource constellation as it is today and its associated connection to other resources in the network surrounding the facility and HeidelbergCement. Moreover, these changes are fundamental to achieve long-term sustainable securement of raw materials and reduce the environmental footprint. We have identified the interfaces between the Sjursøya facility and production and storage facilities, products, vessels, equipment for unloading vessels and handling in the port, and concrete trucks as essential in the modernisation process. However, the core to achieve the desired future scenario lays in the business relationships between HeidelbergCement, Port of Oslo and the shipowners. HeidelbergCement's relationship with the Port of Oslo is based on a long-term presence in the Sjursøya terminal and their mutual interests in reducing environmental impact, while the relation with shipowners is formed by the mutual dependence on each other's resources; HeidelbergCement's need of smaller vessels in Oslofjorden, and the shipowner's need for demand. These distinct business relationships are thus based on different conditions whereas they have effect on the available resources that HeidelbergCement use and the development of new ones.

5.0. Findings and discussion

So far, we have presented the case using the Industrial Network Approach with the ARA model which has enabled us to outline the logistics system and explore the background and development of the connection between HeidelbergCement and the Port of Oslo in the industrial context. Furthermore, due to the relational nature of the problem statement, we have outlined ports role in supply chains with emphasis on the importance of collaboration with ports. As HeidelbergCement wants to modernise their distribution set-up, we have outlined important interfaces between the resources in their current system and how these interfaces change according to the future system. In light of this, whatever chosen potential distribution system, it needs to contribute to a greener construction industry. Below is a recap of the problem statement that we will discuss in light of our findings.

How can a construction material supplier contribute
to the Green Shift in the construction industry by changing its logistical
distribution system through port integration?

This chapter consists of three parts. The first part presents the results from our quantitative analysis. This includes calculations of CO2, NOx and SO2, and transportation costs. Both emissions and transportation costs in the current logistics system is used as a benchmark to evaluate the future systems. Calculations are based on the sustainability measures in subchapter 3.4.

The second part provides a discussion on the practical implications of the case. This entails a discussion of how HeidelbergCement contribute to the Green Shift in the construction industry by modernising distribution system in light of the economic, socio-political and environmental dimensions.

The final part consists a discussion on the theoretical implications. The section discusses the findings in light of the academic literature and theoretical framework. This includes discussing the role and function of port in the resource dimension as an enabler for HeidelbergCement to modernise their distribution system.

5.1. Results from quantitative analysis

5.1.1. CO2 emissions

The analysis is initiated by presenting the results of the current logistics system featuring the three concrete factories supplying the Oslo market; Steinskogen, Alnabru and Sjursøya. Then, we present the analysis of CO2 emissions generated from the two potential future logistics systems. Lastly, we sum up the analysis and compare the emission levels of the current system with the two potential future systems.

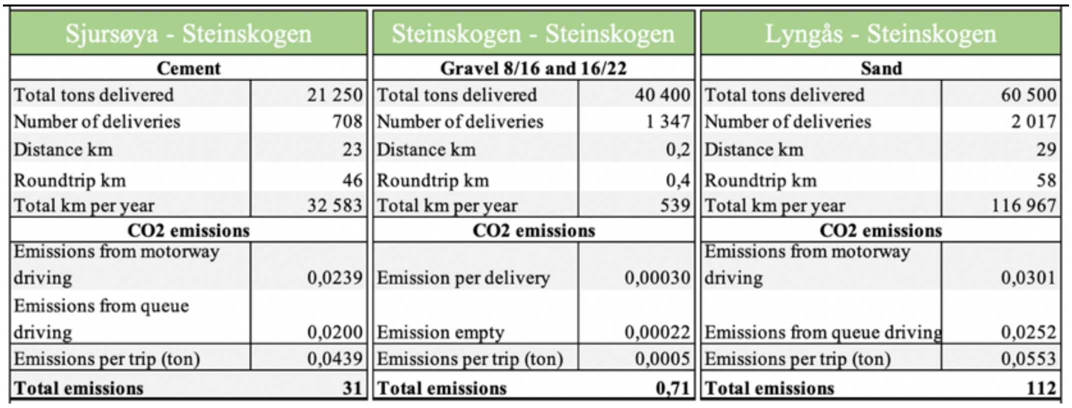
5.1.1.1. CO2 emission analysis of current logistics systems

We present the inbound transportation to each factory separately with the associated findings. As the sea transportation of cement from Brevik is equal in the current and future distribution system we do not distinguish the resulting emission according to each factory, rather we present it in the total emissions part 5.1.1.3. This is because the cement volumes used by the concrete factories is transported by sea to the storage at Sjursøya before being transported to the respective factories and will yield the same results as the future system due to consolidation. We present the emissions from port activities at Sjursøya in a separate part to illuminate and discuss the effects of modernisation of the terminal in the future logistic system. The outbound transportation from all factories in the current system are presented together before ending with concluding remarks of the current system.

Inbound transportation

Steinskogen factory

In 2018, total production of concrete from Steinskogen facility was 53 500 m3 (128 400 tons). All inbound transportation of aggregates is conducted by road. As the production facility is located in the quarry that supplies gravel, emissions related to transportation is approximately equal to zero. We assume 0,2 km driving and only emissions generated from queue driving as it is natural to assume that the trucks drive at a low speed. Steinskogen calculations includes three distinct routes as shown in table 5.1.



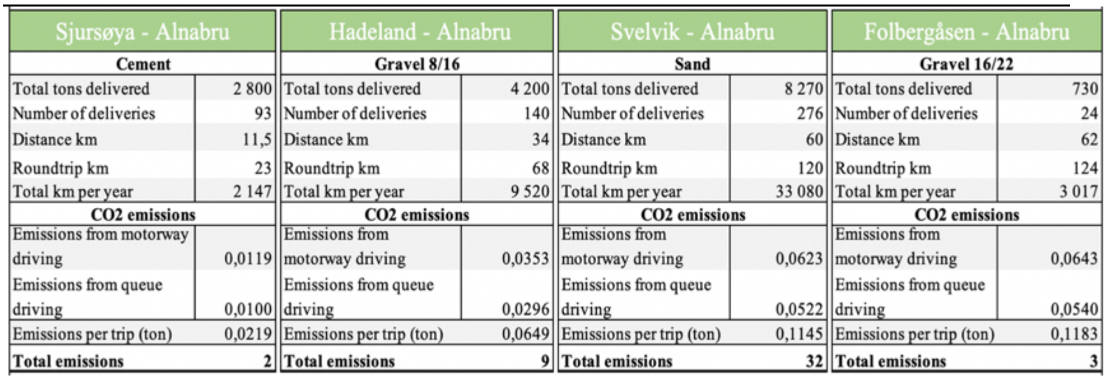
Sjursøya - Steinskogen		Steinskogen - Steinskogen		Lyngås - Steinskogen	
Cement		**Gravel 8/16 and 16/22**		**Sand**	
Total tons delivered	21 250	Total tons delivered	40 400	Total tons delivered	60 500
Number of deliveries	708	Number of deliveries	1 347	Number of deliveries	2 017
Distance km	23	Distance km	0,2	Distance km	29
Roundtrip km	46	Roundtrip km	0,4	Roundtrip km	58
Total km per year	32 583	Total km per year	539	Total km per year	116 967
CO2 emissions		**CO2 emissions**		**CO2 emissions**	
Emissions from motorway driving	0,0239	Emission per delivery	0,00030	Emissions from motorway driving	0,0301
Emissions from queue driving	0,0200	Emission empty	0,00022	Emissions from queue driving	0,0252
Emissions per trip (ton)	0,0439	Emissions per trip (ton)	0,0005	Emissions per trip (ton)	0,0553
Total emissions	**31**	**Total emissions**	**0,71**	**Total emissions**	**112**

Table 5.1: Inbound transportation to Steinskogen factory in the current logistics system

The total CO2 emission from inbound transportation is 143 tons which equals approximately 29 % of the total transportation emissions related to Steinskogen. By splitting the total emission of CO2 according to routes it is evident that emissions are much higher for the route between Lyngås - Steinskogen than for Sjursøya - Steinskogen. The route distance is approximately the same which showcase that the volume transported is decisive for the emission level. As can be seen from the calculations, delivery of inputs to Steinskogen requires a total of 4 072 road deliveries to production each year. All inbound routes require driving through populated areas, but delivery of cement from Sjursøya features driving through the city of Oslo. However, it has a direct impact on populated area even though this route has the fewest deliveries.

Alnabru factory

In 2018, the total production from Alnabru facility was 7 550 m3 (18 120 tons), which is less than both Sjursøya and Steinskogen factories. Similar to Steinskogen, the Alnabru facility only receives inputs to concrete production transported by road. However, there are four distinct routes delivering to Alnabru compared to Steinskogen’s three routes outlined above. Total CO2 emissions from inbound transportation to Alnabru was 46 tons in 2018.



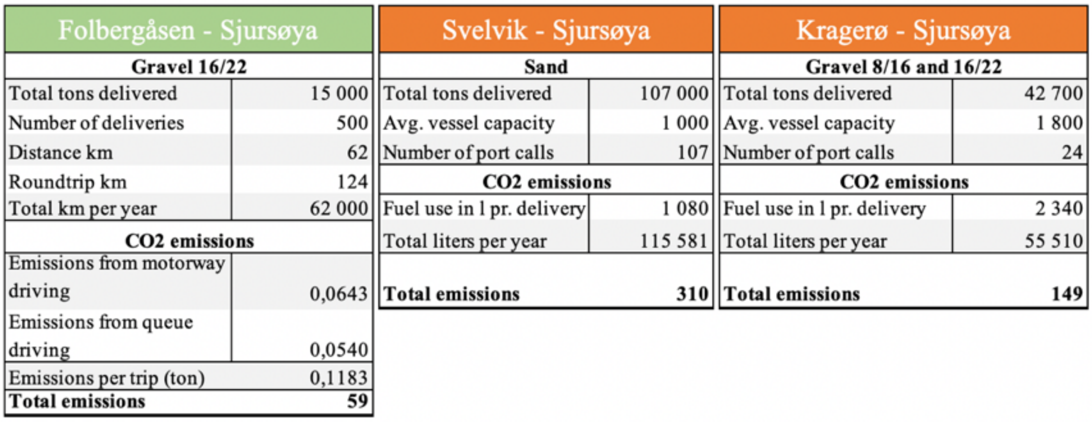
Sjursøya - Alnabru		Hadeland - Alnabru		Svelvik - Alnabru		Folbergåsen - Alnabru	
Cement		**Gravel 8/16**		**Sand**		**Gravel 16/22**	
Total tons delivered	2 800	Total tons delivered	4 200	Total tons delivered	8 270	Total tons delivered	730
Number of deliveries	93	Number of deliveries	140	Number of deliveries	276	Number of deliveries	24
Distance km	11,5	Distance km	34	Distance km	60	Distance km	62
Roundtrip km	23	Roundtrip km	68	Roundtrip km	120	Roundtrip km	124
Total km per year	2 147	Total km per year	9 520	Total km per year	33 080	Total km per year	3 017
CO2 emissions		**CO2 emissions**		**CO2 emissions**		**CO2 emissions**	
Emissions from motorway driving	0,0119	Emissions from motorway driving	0,0353	Emissions from motorway driving	0,0623	Emissions from motorway driving	0,0643
Emissions from queue driving	0,0100	Emissions from queue driving	0,0296	Emissions from queue driving	0,0522	Emissions from queue driving	0,0540
Emissions per trip (ton)	0,0219	Emissions per trip (ton)	0,0649	Emissions per trip (ton)	0,1145	Emissions per trip (ton)	0,1183
Total emissions	**2**	**Total emissions**	**9**	**Total emissions**	**32**	**Total emissions**	**3**

Table 5.2: Inbound transportation to the Alnabru factory in the current logistics system

From our calculations, we see that sand transported by road from Svelvik generates the highest level of emission from all inbound transport to Alnabru. Although the distances from the quarries in Svelvik and Folbergåsen to the factory is approximately equal, it is the volume transported that is the decisive element, resulting in different levels of emissions. Interestingly, the sand from Svelvik accounts for about 52 % of the input volumes, yet it generates 70 % of the total emissions. This transportation route is a significant contributor to Alnabru inbound emissions. Transportation of inputs require a total of 533 deliveries to production each year. This is far less than for Steinskogen and is due to the low production volume. However, these transportations are conducted driving through populated areas.

Sjursøya factory

The total production of concrete in Sjurøya was 92 500 m3 (222 000 tons) which is the highest volume among the three factories. Sjursøya is the only facility that use sea transportation of aggregates. There is no additional transport of cement by road as the cement transported from Brevik by sea is unloaded at the Sjursøya terminal.



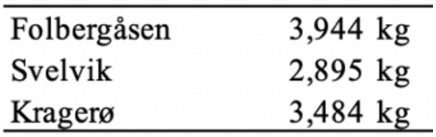
Folbergåsen - Sjursøya	
Gravel 16/22	
Total tons delivered	15 000
Number of deliveries	500
Distance km	62
Roundtrip km	124
Total km per year	62 000
CO2 emissions	
Emissions from motorway driving	0,0643
Emissions from queue driving	0,0540
Emissions per trip (ton)	0,1183
Total emissions	**59**

Svelvik - Sjursøya	
Sand	
Total tons delivered	107 000
Avg. vessel capacity	1 000
Number of port calls	107
CO2 emissions	
Fuel use in l pr. delivery	1 080
Total liters per year	115 581
Total emissions	**310**

Kragerø - Sjursøya	
Gravel 8/16 and 16/22	
Total tons delivered	42 700
Avg. vessel capacity	1 800
Number of port calls	24
CO2 emissions	
Fuel use in l pr. delivery	2 340
Total liters per year	55 510
Total emissions	**149**

Table 5.3: Inbound transportation to the Sjursøya factory in the current logistics system

The inbound transportation for Sjursøya generates a total of 518 tons CO2. In terms of number of deliveries conducted by road it requires a total of 500 delivers. This is fewer than both Steinskogen and Alnabru and is a result from transporting the majority of the volumes by sea. As our calculations show, sea transportation generates the highest level of CO2 emissions to the Sjursøya factory. However, when we analyse the emissions per ton aggregate, the emissions are higher for road transportation than sea transportation (see table below).



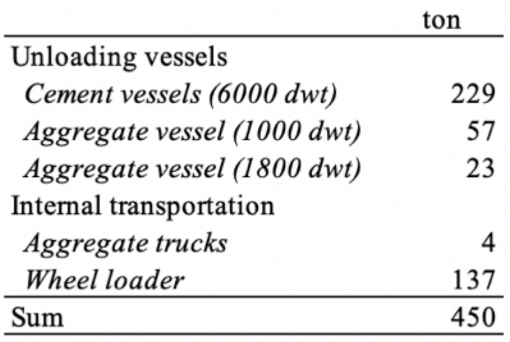
Folbergåsen	3,944 kg
Svelvik	2,895 kg
Kragerø	3,484 kg

Table 5.4: CO2 emissions per ton of aggregate delivered to Sjursøya

The differences are a result of the number of trips required to deliver the specific volume; as one truck's capacity is estimated to be 30 tons, it requires 500 trips to deliver 15 000 tons which equals 62 000 km of driving. We investigate this further in a sensitivity analysis comparing emissions between road and sea transportation, presented in section 5.2.3.

Port activities at Sjursøya

We present the CO2 emissions analysis from port activities in Sjursøya in a separate part to illuminate the effects of consolidation and modernisation in the future system. The analysis includes emissions from vessel at berth, unloading activities and internal transportation of aggregates in the terminal. The activities related to unloading generate the highest levels of CO2 emissions, especially with regards to cement vessels. This is due to the substantial diesel use to generate electricity to the pneumatic system. The aggregate vessels have lower emissions as they use the excavator and the trucks on quay.



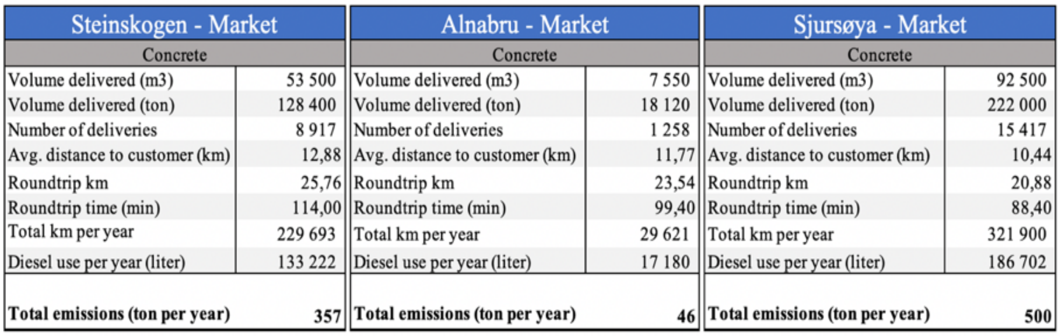
	ton
Unloading vessels	
Cement vessels (6000 dwt)	229
Aggregate vessel (1000 dwt)	57
Aggregate vessel (1800 dwt)	23
Internal transportation	
Aggregate trucks	4
Wheel loader	137
Sum	450

Table 5.5: CO2 emissions from port activities

We estimated a roundtrip to/from the vessel and storage to be approximately 200 meters and use emission factor from queue driving as the trucks operate at a low speed. We used the same truck capacity as the inbound aggregate trucks; 30 tons. This results in CO2 emissions of 4 tons per year given the volume unloaded. The wheel loader uses approximately 17 litres of diesel per hour. The estimated total hours of active use per year is approximately 3 000 hours. However, this is highly dependent on the volume unloaded from the aggregate vessels. Hence, there are some uncertainty related to the total emissions per year of 137 tons of CO2. We have conducted a sensitivity analysis to investigate this further. The results show that by increasing the use of the wheel loader by (only) 1000 hours per year, the emissions will increase from representing 30 % of total emissions from port activities to 41 % (see Appendix 2). Hence, the extensive use of the wheel loader should be avoided.

Outbound - all factories

The CO2 emission from outbound transportation of concrete are calculated based on concrete trucks using on average 0,58 diesel litre/km. Moreover, we assume combustion of one litre diesel to emit 2,68 kg CO2. The number of deliveries is calculated using the average concrete truck load capacity of 14,4 ton (6 m3).



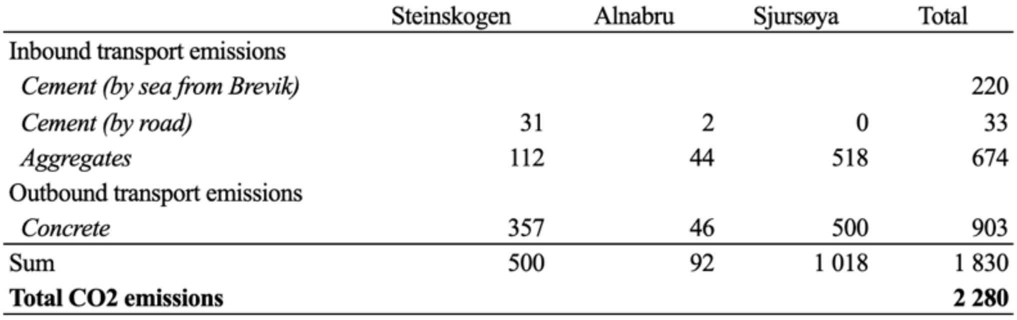
Steinskogen - Market		Alnabru - Market		Sjursøya - Market	
Concrete		Concrete		Concrete	
Volume delivered (m3)	53 500	Volume delivered (m3)	7 550	Volume delivered (m3)	92 500
Volume delivered (ton)	128 400	Volume delivered (ton)	18 120	Volume delivered (ton)	222 000
Number of deliveries	8 917	Number of deliveries	1 258	Number of deliveries	15 417
Avg. distance to customer (km)	12,88	Avg. distance to customer (km)	11,77	Avg. distance to customer (km)	10,44
Roundtrip km	25,76	Roundtrip km	23,54	Roundtrip km	20,88
Roundtrip time (min)	114,00	Roundtrip time (min)	99,40	Roundtrip time (min)	88,40
Total km per year	229 693	Total km per year	29 621	Total km per year	321 900
Diesel use per year (liter)	133 222	Diesel use per year (liter)	17 180	Diesel use per year (liter)	186 702
Total emissions (ton per year)	**357**	**Total emissions (ton per year)**	**46**	**Total emissions (ton per year)**	**500**

Table 5.6: Outbound transportation from all factories to the Oslo market

The average distance to customer is relatively similar for all factories and the concrete trucks are fully utilised in each delivery, i.e. every delivery is 6 m3. As our calculations show, distribution from the Sjursøya factory generate the most CO2 emissions. This is because Sjursøya produce by far the largest volume of finished concrete which results in the highest number of deliveries. The outbound CO2 emissions per year for all factories combined are 903 ton.

Summary of the current distribution system

The table below show the total CO2 emissions for each concrete factory and the aggregated sum. The emissions from transportation of all inputs to production and delivery of concrete to customer generate 1 830 ton CO2 per year. If we include the emissions from activities in the Sjursøya terminal, the total emissions are 2 280 ton CO2 per year.

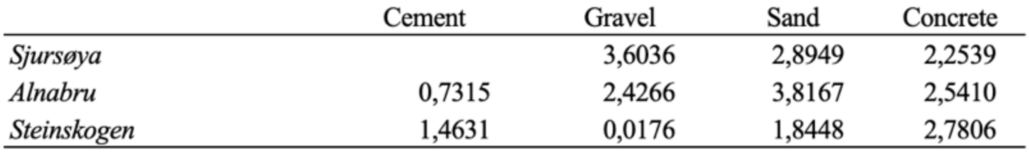


	Steinskogen	Alnabru	Sjursøya	Total
Inbound transport emissions				
Cement (by sea from Brevik)				220
Cement (by road)	31	2	0	33
Aggregates	112	44	518	674
Outbound transport emissions				
Concrete	357	46	500	903
Sum	500	92	1 018	1 830
Total CO2 emissions				**2 280**

Table 5.7: CO2 emissions in the current system

The inbound transportation of cement by sea affect the emissions of all the factories and is thus kept as a total for the current system. However, the emissions from transporting cement from Sjursøya to Steinskogen and Alnabru is included. From the calculations, we see that the outbound transportation of concrete accounts for the largest portion of CO2 emissions. Furthermore, inbound transportation of aggregates represents the second largest share of the CO2 emissions.

By comparing the concrete factories and their respective inbound and outbound deliveries, we see that Sjursøya generate a greater share of the emissions, followed by Steinskogen. Alnabru is the factory which generate the smallest amount of emissions. However, when looking at emissions per ton delivered of each product, it reveals some interesting results. The table below show the emissions generated from transportation when delivering one ton of each product (emissions of cement transportation from Brevik and terminal activities are not included).



	Cement	Gravel	Sand	Concrete
Sjursøya		3,6036	2,8949	2,2539
Alnabru	0,7315	2,4266	3,8167	2,5410
Steinskogen	1,4631	0,0176	1,8448	2,7806

Table 5.8: Kg CO2 per ton product type delivered to factory/customer

For cement transportation, we see that transportation to Steinskogen generate twice as much CO2 as transportation to Alnabru, which is explained by the transportation distance from Sjursøya. Interestingly, the results from Steinskogen show the effect on transportation of gravel when the concrete factory is located in a quarry; only 0,0176 kg CO2 is generated from transporting one ton gravel 200 meters. Comparing the emissions per ton of sand between Alnabru and Sjursøya provides another interesting result; one ton of sand transported to Alnabru generate 3,8 kg CO2, while one ton of sand transported to Sjursøya generate 2,9 kg CO2. This is investigated further in a sensitivity analysis (see Appendix 4). Lastly, we see that delivering one ton of finished concrete to customer generate very similar emission levels for each factory. The minor differences are related to the average distance from factory to customer.

When dividing the total transportation emission (excluding cement by sea from Brevik and emissions from port activities) for each factory on the respective produced volume in m3, we are left with the total emission from delivering one m3 to customer (see table 5.9).

	Steinskogen	Alnabru	Sjursøya	Total
Kg CO2 per m3 delivered	9,35	12,13	11,01	11,92

Table 5.9: Kg CO2 per m3 concrete delivered to customer

The table above provide three important results regarding HeidelbergCement's distribution. First, Steinskogen is the best alternative in terms of CO2 emissions as it generates the least per m3 delivered. This is because the factory is located in the quarry providing gravel. Second, Sjursøya is the second best alternative since it includes sea transportation. Last, Alnabru is the generates the most CO2 per m3. This is because Alnabru is neither located in a quarry nor using sea transportation as means of transport mode. These results showcase that closeness to quarry and sea transportation are important elements in delivering inputs to concrete production.

5.1.1.2. CO2 emission analysis of future logistics systems

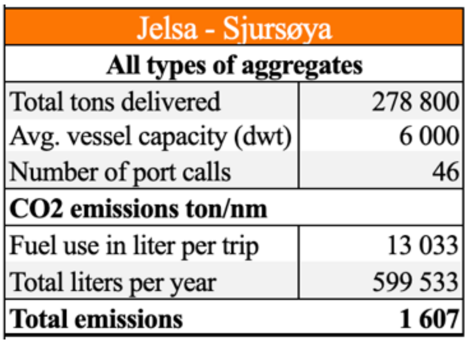
In the two future systems, the total volume of cement, aggregates, and the concrete production volume is kept equal to the 2018-volumes in the current system. We present the CO2 emissions from inbound transportations for each of the suggested future systems, before discussing the effects of modernising terminal activities and outbound distribution, which is equal for both systems.

Inbound transportation

The two potential future logistics systems feature different inbound transportation of aggregates. Naturally, this affects the system's CO2 emission. Both of the systems feature only sea transportation for inbound transport of inputs. Cement is transported by sea from Brevik as in the current system and is included when presenting the total emissions.

System 1

System 1 features only one quarry delivering all types of aggregate needed in the production of concrete. From Norstone's quarry in Jelsa, there will be transported both sand (machine made) and gravel in 6 000 dwt vessels for concrete production at Sjursøya.



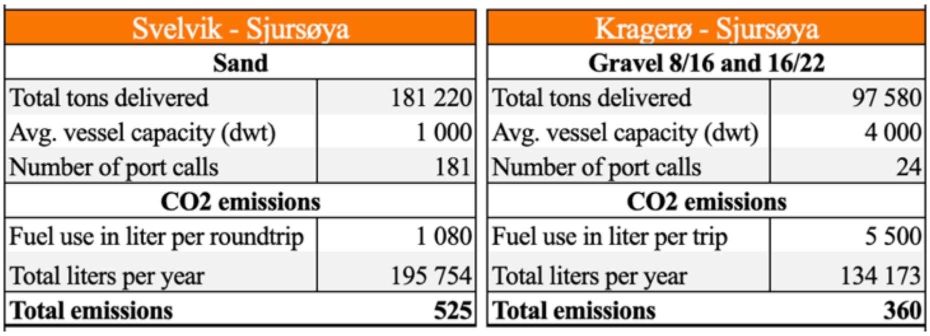
Jelsa - Sjursøya	
All types of aggregates	
Total tons delivered	278 800
Avg. vessel capacity (dwt)	6 000
Number of port calls	46
CO2 emissions ton/nm	
Fuel use in liter per trip	13 033
Total liters per year	599 533
Total emissions	**1 607**

Table 5.10: CO2 emissions from system 1

From the calculations, we see that delivering 278 800 tons of aggregates to Sjursøya generates 1 607 tons of CO2 per year. This implies that transportation of 1 ton of aggregate generates 5,8 kg of CO2.

System 2

This system features sourcing of sand from Svelvik and gravel from Kragerø. The 1 000 dwt vessels from the current system is kept for transportation of sand from Svelvik. However, the vessels size delivering gravel from Kragerø will change from 1 800 dwt to 4 000 dwt.



Svelvik - Sjursøya	
Sand	
Total tons delivered	181 220
Avg. vessel capacity (dwt)	1 000
Number of port calls	181
CO2 emissions	
Fuel use in liter per roundtrip	1 080
Total liters per year	195 754
Total emissions	**525**

Kragerø - Sjursøya	
Gravel 8/16 and 16/22	
Total tons delivered	97 580
Avg. vessel capacity (dwt)	4 000
Number of port calls	24
CO2 emissions	
Fuel use in liter per trip	5 500
Total liters per year	134 173
Total emissions	**360**

Table 5.11: CO2 emissions from system 2

From the calculations we see that delivering 181 220 tons of sand from Svelvik and 97 580 tons of gravel from Kragerø will generate 885 tons CO2 per year. This means that delivering 1 ton of aggregate will generate on average 3,2 kg of CO2 in this system.

Port activities at Sjursøya

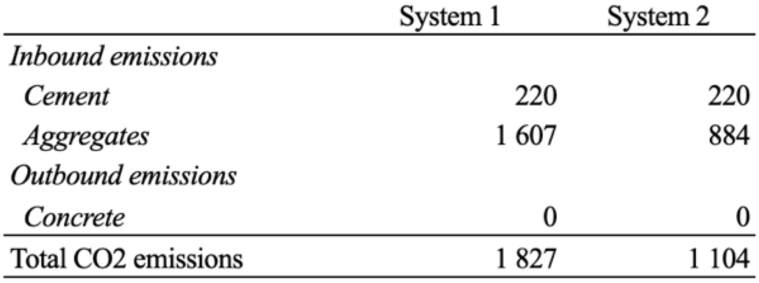
The modernisation of the Sjursøya terminal is independent of the inbound logistics systems presented above. The future scenario of the Sjursøya facility includes several features. While docking, vessels will be connected to on-shore power supply. This means that unloading of the cement vessels is emission free as the pneumatic system will be supplied with electricity from the terminal. Regarding the dry bulk vessels, on-shore power supply along with using electric excavators on deck will eliminate the emissions while docking. Moreover, the aggregate trucks and wheel loader used in the current system is replaced by an electric conveyor belt. The modernised aggregate storages will allow the conveyor belt to unload the different types of aggregates into separate silos. In summary, these measures will eliminate all emissions from port activities calculated in the current system, i.e. 450 tons of CO2 per year.

Outbound transportation

The future systems feature electric concrete trucks for outbound transportation from the Sjursøya factory to the market. Hence, all outbound emissions from the current system will be eliminated as the transportation is emission free. This implies a reduction of 903 ton CO2 per year.

Summary of future systems

To summarise, all the inbound transportation of inputs to concrete production at Sjursøya will be done by sea. Dependent on which inbound system chosen, the CO2 emissions per year will be either 1 827 tons per year (system 1) or 1 104 tons per year (system 2). The table below show the calculations of CO2 emissions for both suggested future systems.



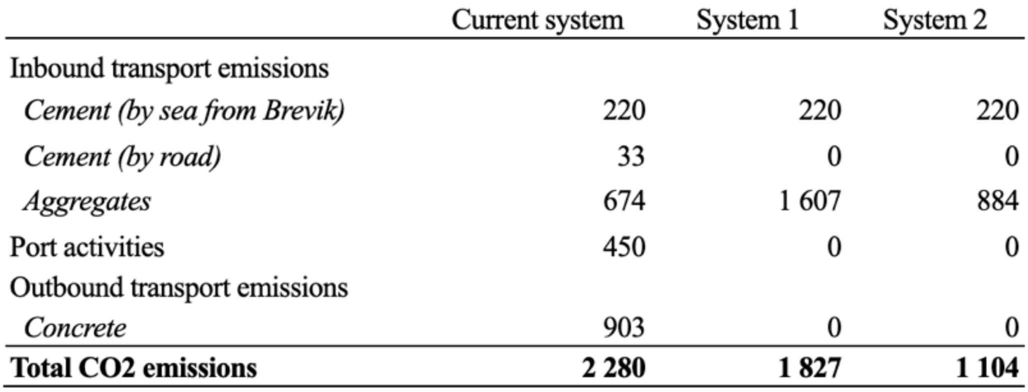
	System 1	System 2
Inbound emissions		
Cement	220	220
Aggregates	1 607	884
Outbound emissions		
Concrete	0	0
Total CO2 emissions	1 827	1 104

Table 5.12: CO2 emissions from future logistic systems

The difference between the emission of system 1 and 2 concerns the transportation of aggregates. There is a distinct difference in the distance of which the aggregates are transported; 301 nautical miles in system 1 versus 136 nautical miles in system 2. The distance and vessel size affect the fuel consumption and thus the level of CO2 emissions. Also, the distribution of concrete will be emission free due to electric concrete trucks.

5.1.1.3. Comparing systems

The results of CO2 emission from aggregate transportation in system 1 and system 2 is 1 607 tons and 884 tons per year, respectively. Emissions from cement transportation is equal in both systems; 220 tons CO2 per year. This results in total emissions in system 1 of 1 827 ton per year, and of 1 104 ton per year for system 2. The distribution of concrete is similar for both systems and includes electric concrete trucks which results in emission free transportation. The table below show the yearly CO2 emissions of all systems compared.



	Current system	System 1	System 2
Inbound transport emissions			
Cement (by sea from Brevik)	220	220	220
Cement (by road)	33	0	0
Aggregates	674	1 607	884
Port activities	450	0	0
Outbound transport emissions			
Concrete	903	0	0
Total CO2 emissions	**2 280**	**1 827**	**1 104**

Table 5.13: Comparing CO2 emissions from current and future logistic systems

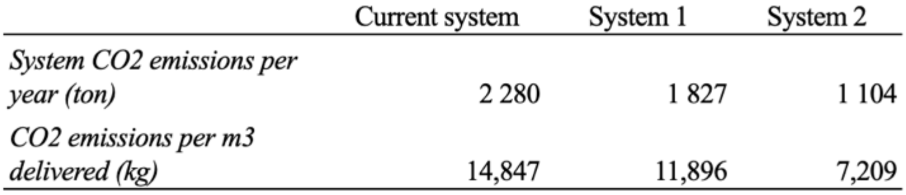
Table 5.13 show the differences in CO2 emissions for each part of all the logistics systems. As our calculations show, system 1 and 2 generates lower level of CO2 emissions than the current system. In total, system 1 will yield a reduction of 20 % CO2 emissions per year, while system 2 will yield a reduction of approximately 50 %. This is dependent on a combination of modernising port activities and using electric concrete trucks. Looking at transportation of aggregates separately, our findings show that increased use of sea transportation increase CO2 emissions.

However, when comparing systems, consolidation of production volumes to Sjursøya yields lower CO2 emissions than the current system. The characteristics of the current logistic system with regards to the location of the Steinskogen factory in a quarry, the low production volume at Alnabru and the use of sea transportation of aggregates to Sjursøya, results in relatively low CO2 emissions (see discussion on page 85.

Using diesel driven concrete trucks for outbound distribution in system 2 will still reduce the total emissions, in this case, by over 11 % compared to the current system. As system 2 features shorter transportation distances than system 1, it shows that the location of quarries relative to the concrete factory has a positive effect on CO2 emissions from sea transportation.

By implementing either future systems, transportation of over 153 000 tons of masses will be removed from the roads in and around Oslo (both aggregates and cement). Assuming 30 ton capacity per truck, this implies a reduction of 5 105 truck deliveries each year in and around Oslo.

If we compare the total emissions relative to the volume of concrete produced in m3, now including cement transportation by sea and port activities, we get CO2 kg per m3 delivered for each system (see table 5.14).



	Current system	System 1	System 2
System CO2 emissions per year (ton)	2 280	1 827	1 104
CO2 emissions per m3 delivered (kg)	14,847	11,896	7,209

Table 5.14: Kg CO2 per m3 concrete delivered to customer for each system

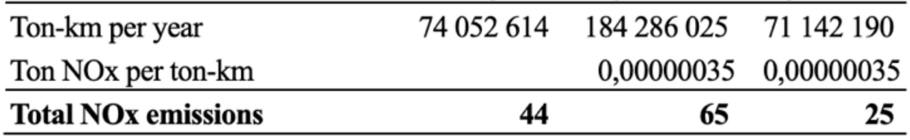
From this, we see that delivering one m3 concrete with the current system is the least environmentally friendly. Moreover, delivering one m3 in the current system yields twice as high CO2 emissions as one m3 delivered using system 2. These results imply that system 2 is the most environmentally friendly system among the three, in terms of CO2 emissions.

It is also important to point out that the CO2 emission analysis of the current system has assumed that ⅓ of the roundtrip distance is affected by queues. This ratio is estimated based on continuous observations of each distance traffic pattern, using Google Maps. Because of the level of uncertainty in this ratio, we have conducted a sensitivity analysis to investigated how different queue ratios affect the emissions from inbound transportation. The results show that when changing the queue ratio from 33 % of the roundtrip distance to 70 %, the total CO2 emissions per year increase with 21 %. Moreover, if we reduce the queue ratio to only 10 % of the roundtrip distance, the total emissions per year decrease by 13 % (see Appendix 3). From this, we see that queue driving has a considerable effect on inbound emissions.

5.1.2. NOx and SO2 emissions

To quantify the effect of local emissions when altering the logistic systems, we have calculated NOx and SO2 emissions for each system, i.e. the current system, system 1 and system 2. This analysis is not as detailed as the CO2 emission analysis, but rather give an overall presentation for each system's total emission. The NOx and SO2 emission factors are general estimates used in the Norwegian National freight transport model and was provided by Stein Erik Grønland (thesis supervisor). Hence, the calculations and results will not show the actual emissions, but rather the magnitude to illustrate the differences between the systems. For road transportation, NOx and SO2 is measured as 0,95 gram per ton-km and 2 gram per ton-km, respectively. For sea transportation NOx and SO2 is both measured as 0,35 gram per ton-km.

The NOx and SO2 emission factors are higher per ton-km for heavy vehicles than for vessels. The tables below show a summary of the emissions, expressed in ton per year for the respective systems.



	Current system	System 1	System 2
Ton-km per year	74 052 614	184 286 025	71 142 190
Ton NOx per ton-km		0,00000035	0,00000035
Total NOx emissions	**44**	**65**	**25**

Table 5.15: Comparing NOx emissions from current and future logistic systems

	Current system	System 1	System 2
Ton-km per year	74 052 614	184 286 025	71 142 190
Ton SO2 per ton-km		0,00000035	0,00000035
Total SO2 emissions	**75**	**65**	**25**

Table 5.16: Comparing SO2 emissions from current and future logistic systems

Our calculations show that the current system generates the most SO2 compared to system 1 and 2. With regards to NOx, system 1 generates the highest emission level. System 2 generate the lowest level of emission of both SO2 and NOx compared to the other systems. In both system 1 and system 2 the last-mile delivery, which is the most transport intensive part, is conducted using electric concrete vehicles. Hence, SO2 and NOx generated from this transportation in the current system is eliminated in the both future systems. Furthermore, system 2 yields better results than system 1 due to that the volume transported is equal but system 1 is transporting over a longer distance.

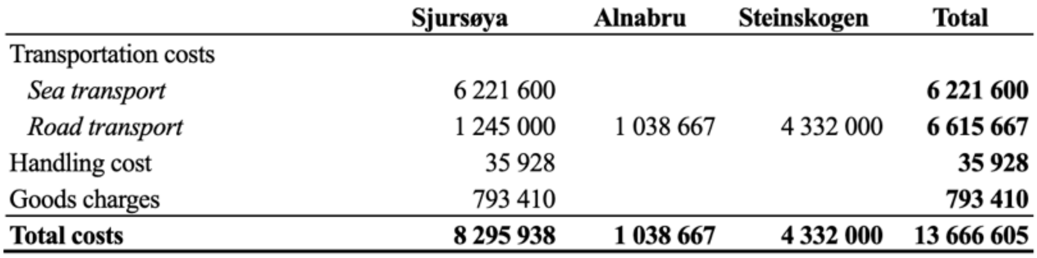
5.1.3. Transportation costs

The transportation costs for the current system is based on key figures obtained from HeidelbergCement for sea transportation and NorBetong for road transportation. The analysis below will only reflect inbound transportation costs and costs related to handling in the port, as we were not able to obtain transportation costs for outbound distribution. The cost of transporting cement from Brevik to Sjursøya is confidential and we do not include this cost. Although the potential future systems are fictional, the cost of transportation per ton are real price estimates from HeidelbergCement's suppliers. We present the results for the current and both of the future systems separately, followed by a comparison analysis.

5.1.2.1. Cost analysis of current system

The costs related to sea transportation comprise of three cost components; transportation cost, handling cost and goods charges. The transportation cost covers loading of vessel at quay and sailing to Sjursøya and is expressed as cost per ton for each distance. The handling cost is only relevant for shipping of aggregates, as it relates to unloading the vessel at Sjursøya. The handling cost includes transport of aggregates from vessel to storage by truck and use of wheel loader and is calculated based on the volumes unloaded per port call. The trucks used in the terminal to transport aggregates from the vessel to storage are owned by a third-party supplier.

The total cost of sea transportation, i.e. handling cost and goods charges included, in the current system is around 7 million NOK. The costs of road transportation for both aggregates and cement are fairly straight forward; the transportation cost is expressed as cost per ton transported which includes loading at quarry, driving and unloading at factory. For the current system, total road transportation costs are around 6,6 million NOK. The table below show a summary of the calculated transportation costs for each factory.



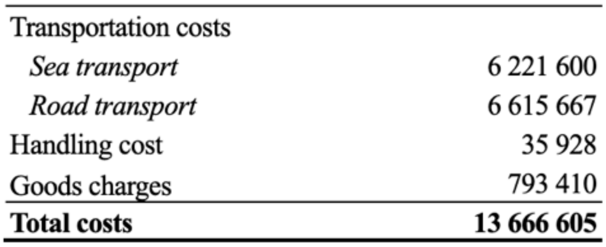
	Sjursøya	**Alnabru**	**Steinskogen**	**Total**
Transportation costs				
Sea transport	6 221 600			**6 221 600**
Road transport	1 245 000	1 038 667	4 332 000	**6 615 667**
Handling cost	35 928			**35 928**
Goods charges	793 410			**793 410**
Total costs	**8 295 938**	**1 038 667**	**4 332 000**	**13 666 605**

Table 5.17: Detailed result of cost analysis of the current system

Comparing the transportation costs per ton aggregate delivered to concrete factory provides interesting results. The difference in costs per ton aggregate delivered by road transportation versus sea transportation is not that different; 43 NOK versus 42 NOK, respectively. However, when we include other costs related to sea transportation, such as handling cost at terminal and goods charges, the cost per ton increase to 47 NOK.

The cost of transporting cement from Sjursøya by truck to the concrete factories at Alnabru and Steinskogen is included in the total costs of the current system. The result show that transporting cement from Sjursøya to Alnabru and Steinskogen generate a yearly cost around 1,2 million NOK (for transport of around 24 000 ton cement).

The table below show the total costs of the current system. The calculations are based on delivery of 278 800 tons of aggregates (149 700 tons transported by sea and 129 100 by road).



Transportation costs	
Sea transport	6 221 600
Road transport	6 615 667
Handling cost	35 928
Goods charges	793 410
Total costs	**13 666 605**

Table 5.18: Result of cost analysis in the current system

5.1.2.2. Cost analysis of system 1

System 1 features sourcing all aggregates from Jelsa with 6 000 dwt vessels. The yearly aggregate volume of 278 800 tons will require approximately 46 port calls each year. Based on the estimated cost per ton, around 57 NOK, transportation of 278 800 tons of aggregates from Jelsa to Sjursøya is estimated to 17,5 million NOK per year.

The modernisation of the Sjursøya terminal will eliminate the trucks and wheel loader used for transporting the aggregates from the vessel to storage. Hence, system 1 does not include any handling costs. As we do not consider any price changes in the goods charges at the Port of Oslo, the change in costs will simply be a result of increased volume of aggregates. The calculated increase in goods charges for aggregates is around 684 000 NOK, which results in a total of 1 477 000 NOK per year.

The table below show a summary of the calculated costs for system 1. The calculations are based on delivery of 278 800 tons of aggregates (all transported by sea) to concrete production and give a total cost of around 17,5 million NOK.

Transportation costs	
Sea transport	16 064 456
Road transport	0
Handling cost	0
Goods charges	1 477 640
Total costs	**17 542 096**

Table 5.19: Result of cost analysis in system 1

5.1.2.3. Cost analysis of system 2

System 2 features sourcing sand from Svelviksand in Svelvik as in the current system, but increase the current volume sourced from NCC in Kragerø to replace the volumes sourced from Folbergåsen. The vessel size transporting sand will remain the same as in the current system; 1 000 dwt. Transporting 180 000 ton sand to a cost of 45 NOK per ton results in a yearly cost of 8 155 000 NOK. The vessel size transporting gravel from Kragerø will change from the current size of 1 800 dwt to 4 000 dwt. The transportation cost per ton is estimated to be 45 NOK. The required volume of around 97 000 tons will give a yearly transportation cost of 4 390 000 NOK. This result in a total transportation cost for system 2 of around 12,5 million NOK.

The modernisation of terminal activities will eliminate the handling cost related to unloading aggregates at the port. Moreover, the goods charges will be equal to the cost in system 1; 1 477 000 NOK.

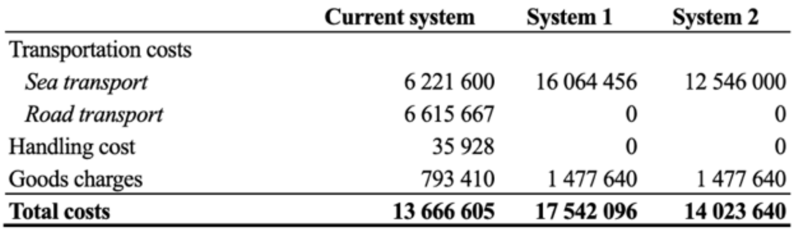
The table below show a summary of the calculated costs for system 1. The calculations are based on delivery of 278 800 tons of aggregates (all transported by sea) to concrete production and gives a total cost of around 14 million NOK.

Transportation costs	
Sea transport	12 546 000
Road transport	0
Handling cost	0
Goods charges	1 477 640
Total costs	**14 023 640**

Table 5.20: Result of cost analysis in system 2

5.1.2.4. Comparing systems

When comparing the systems, we see that both system 1 and system 2 are more costly than the current system resulting in approximately 3 880 000 and 357 000, respectively. Although we assume only sea transportation and eliminate handling costs, the future systems are still more expensive than the current system (see table 5.21). However, if we do not consider the goods charges at the port, system 2 will have a lower transportation cost than the current system.



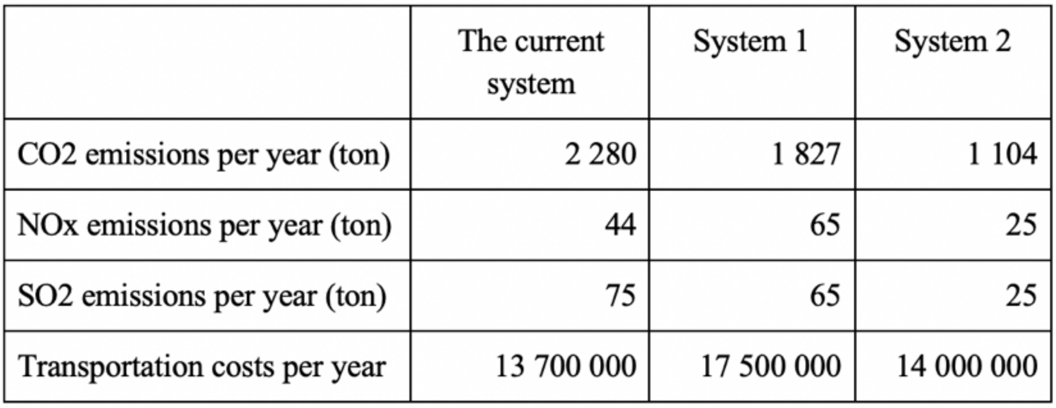
	Current system	**System 1**	**System 2**
Transportation costs			
Sea transport	6 221 600	16 064 456	12 546 000
Road transport	6 615 667	0	0
Handling cost	35 928	0	0
Goods charges	793 410	1 477 640	1 477 640
Total costs	**13 666 605**	**17 542 096**	**14 023 640**

Table 5.21: Comparison of cost analysis of current and future systems

The transportation cost difference between system 1 and system 2 is around 3,5 million NOK. The difference is reflected by the transportation cost per ton, which is connected to the respective distances.

5.1.4. Summary of quantitative analysis

The table below show a summary of the findings from the CO2, NOx, SO2 and transportation cost analysis (rounded numbers).

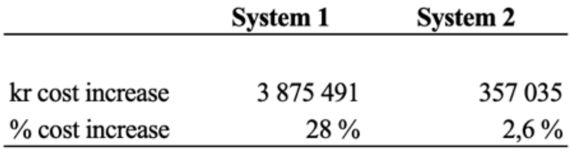


	The current system	System 1	System 2
CO2 emissions per year (ton)	2 280	1 827	1 104
NOx emissions per year (ton)	44	65	25
SO2 emissions per year (ton)	75	65	25
Transportation costs per year	13 700 000	17 500 000	14 000 000

Table 5.22: Summary of quantitative analysis

From the calculations we see that system 1 and system 2 generates lower CO2 and SO2 emissions than the current logistics system. However, the NOx emissions for system 1 are the highest among the three. Considering all the emissions combined, system 2 is the most environmentally friendly logistic system.

The transportation costs calculated are as mentioned based on the inbound transportation cost per ton, and handling cost and goods charges in Sjursøya. The analysis shows that system 1 and system 2 are more costly than the current system. The table below show the increase in transportation cost for each system.



	System 1	System 2
kr cost increase	3 875 491	357 035
% cost increase	28 %	2,6 %

Table 5.23: Increase in transportation costs in future systems

We see that system 1 is around 3 875 000 NOK more costly than the current system, while system 2 is around 357 000 NOK more costly.

In summary, the two suggested future systems provide the following effects for HeidelbergCement's logistic system through the Port of Oslo:

1) Implementing system 1 will reduce the CO2 emissions per year by 20 % and SO2 by 15 % but increase the NOx emissions by 47 % and demand 3,875 million NOK more than the current system per year.
2) Implementing system 2 will reduce CO2 emissions per year by almost 52 %, SO2 by 70 % and NOx by 49 %, but require approximately 350 000 NOK more than the current system per year.

As stated in part 2.3.2 regarding measuring sustainability, this quantitative analysis has shown the economic and environmental effects of altering the logistic system. Hence, social sustainability needs to be considered to provide an overall analysis of the sustainability of the future systems. The next subchapter provides a practical discussion of the economic, socio-political and environmental dimensions with regards to modernising HeidelbergCement's distribution system.

5.2. Practical Implications

There are several practical implications presented in the case presentation and showcased in the results of the quantitative analysis. This section evaluates how HeidelbergCement can contribute to the *Green Shift* in the construction industry by changing their logistical distribution system.

For HeidelbergCement to contribute to greening the construction industry there are different dimensions they need to consider. First, the development and change of the logistic system needs to be economically viable. That is, the investment costs need to be justified by cost savings from consolidating production volumes. If the costs of modernisation are too high the system will not be economically competitive. Secondly, the change in the system needs to contribute in a positive way to society at large. That is, the change needs to be aligned with national and local sustainability goals. Lastly, the development and modernisation need to contribute to reducing their environmental footprint i.e. be aligned with the company strategy, and national and local environmental goals.

The comparison of the current and alternative systems shows that system 2 generates the lowest environmental emission levels of CO2, NOx and SO2 emissions. However, the inbound transportation cost analysis shows that it is slightly more costly than the current situation but significantly less than system 1. Hence, the discussion below is based on the effects of implementing system 2 compared to the current situation.

5.2.1. Economic Dimensions

For system 2 to be a realistic choice it has to be economically viable for HeidelbergCement. This means that the cost savings from moving production to Sjursøya must be greater than the increase in transportation costs. There are several cost components that HeidelbergCement needs to consider when changing their distribution system. The consolidation of production volumes to a single factory in Sjursøya yields reduced indirect and direct costs as well as to free up capital by selling equipment and facilities. However, it will also require heavy investments in new facilities at Sjursøya. Therefore, in order to provide a justification for implementing system 2 the investment cost must be justified by decreased running costs.

Moving inbound transportation from road to sea affects the total transportation cost. Although the increased use of sea transportation results in reduced transportation costs per ton for aggregates, it implies an increased cost in goods charges at the port. As a result, the transportation costs in system 2 is approximately 360 000 NOK higher per year than the current situation. However, changing distribution system from the current situation to system 2 generates several cost saving elements. First, system 2 features electric concrete trucks for outbound transportation to market. This means that diesel expenses will be eliminated. Secondly, with regards to implementing conveyor belts it is reasonable to assume that the aggregate vessel time for at berth will be reduced and therefore decrease cost related to time charter. This is because it eliminates idle time related to breaks and improves the efficiency of the unloading process as a result of shortening the excavators turning radius. Thirdly, the use of on-shore power supply will eliminate the diesel use at berth generated from the auxiliary engine. Lastly, the closing down of factories will decrease costs of labour, maintenance and repair, rental costs, direct production costs and contract labour.

The modernisation of the logistics system in Oslo will require investments in the Sjursøya terminal. As presented in the case, the modernisation includes expansion of storage facilities for both cement and aggregates, increased production capacity, and new handling equipment’s. Moreover, investment in the required number of electric trucks and charging stations will demand high investment costs. Nevertheless, Enova has offered financial support to organisations that contribute to reducing the greenhouse gas emissions (Enova, 2018). Although the new system requires extensive investment costs, the consolidation of production volumes contributes to eliminating operational costs in Steinskogen and Alnabru as well as reducing production costs as a result of economy of scale.

The economic dimension is the first barrier to overcome and a precondition for HeidelbergCement to modernise the logistic system. System 2 needs to yield better economic results than the current system. The system needs to be competitive, both in comparison to the current system and to other competitors in the market. If the reduction in cost is too small compared to the investment costs, it will damage the system's competitiveness. Because of this, it will be difficult for the Port of Oslo to demand investments in making the Sjursøya terminal emission free, as it depends on HeidelbergCement's investment ability. The cost of investment needs to be justified by the cost reductions from consolidating volumes and decreased production cost per unit. More precisely, the new facility needs to provide economies of scale and be more efficient than the current system.

5.2.2. Socio-political Dimensions

This dimension concerns achieving political acceptance for HeidelbergCement to conduct industrial operations. As mentioned in section 1.1.2., HeidelbergCement state that they aim to create long-term value for stakeholders and to society at large. Hence, HeidelbergCement needs to evaluate the effects from changing the distribution setup up against the socio-political dimension. As the Port of Oslo is subject to public regulations (see section 2.4.2.), HeidelbergCement's investment in modernising Sjursøya is dependent on public approval. Therefore, it is important that HeidelbergCement contribute to national and local sustainable development goals (outlined in section 2.4.1.).

For HeidelbergCement it is crucial to cover the market demand in Oslo. When customers are ordering concrete one can assume that they have weighted their need for concrete higher than the resulting impact on city and nearby communities. Because of this, HeidelbergCement should make sure that the transportation intensity and impact on society is as low as possible and develop the remaining in light of their own and public sustainability goals.

The Norwegian Government's strategy for transportation activities involves effective, available and safe transportation systems that covers societies demand and enables regional development (National Transport Plan, 2018). One of the initiatives concerns transferring volumes from road to sea. System 2 includes a reduction in heavy vehicles transporting inputs to concrete production in urban areas by moving the volumes from road to sea. This implies removing transportation of over 153 000 tons, i.e. approximately 5 100 truck deliveries, in and around Oslo. The reduction of vehicles circulating in Oslo contributes in a positive way by lowering noise and probability of accidents. Furthermore, use of electric concrete trucks will reduce the noise level from transportation even more.

Removing transportation from urban areas improves the local emission in the city. Moreover, by investing in electric concrete trucks HeidelbergCement eliminates emissions from outbound transportation. By eliminating inbound road transportation and investing in electric concrete trucks, the pollutants SO2 and NOx which has direct impact on local air quality, is reduced. These initiatives are in line with the Municipality of Oslo's focus on improving air quality and reducing transport intensity in the city. Therefore, system 2 contributes to increased mobility in the city as well as improving living conditions.

The rapid population increase in Oslo creates infrastructural challenges. It is stated in Oslo's Municipality Plan towards 2040 that there is a need to develop social and cultural infrastructure (Oslo Kommune, 2018b). The closing the Alnabru factory results in available area that can be used for societal benefits. The central location of Alnabru makes the area attractive for the society and can be used to develop e.g. parks, playgrounds, kindergartens, households or cultural arenas. Of course, the consolidation of volumes to Sjursøya raise public concerns regarding more activities in the port and visual aesthetic from expanding facilities. Still, the modernisation of the terminal involves replacing noise generating activities, such as trucks used for unloading of activities and wheel loader used between the stalls, with electric conveyor belts.

As the Port of Oslo together with the Municipality of Oslo has developed a zero-emission plan (see section 2.4.1) it is important that HeidelbergCement contribute to achieving these goals in order to gain acceptance for consolidating volumes to Sjursøya. Moreover, the heavy investments required to implement system 2 showcase the long-term perspective from HeidelbergCement to use the Sjursøya terminal. This stimulates to increased collaboration between HeidelbergCement and Port of Oslo to work jointly towards a future to secure zero-emissions from HeidelbergCement's activities in the port. The long-term presence and frequent port calls also enables to balance the flow of goods, e.g. return transport of surplus masses from construction activities transported by road, through the port. As sea transportation generates lower levels of emissions, the potential to transfer volumes from road to sea is reducing the impact from road transportation on society. Furthermore, the increased use of sea transportation, in particular smaller vessels, enhances the incentive for shipowners to modernise vessels in terms of using more environmentally friendly fuels and to use on-shore power supply. In this sense, the local emissions from smaller vessels could be improved.

5.2.3. Environmental Dimensions

In addition to be economically viable and contribute in a positive way to society at large, the new distribution system has to be developed in a way which is aligned with their company strategy. The core in HeidelbergCement's environmental strategy, *Sustainability Commitments 2030*, is concerned with reducing their environmental footprint. For HeidelbergCement to satisfy the environmental dimension they also need to consider national and local goals. The Norwegian Government's overall climate and environmental strategy within the transport sector is to reduce greenhouse gas emissions. As this case study concerns HeidelbergCement supplying the construction industry in Oslo it is also important that they contribute to reaching the Municipality of Oslo's environmental goals including the Port of Oslo's zero-emission plan (see section 2.4.1).

From the quantitative analysis of total CO2 emissions, system 2 generate far less emissions than the current system; CO2 emissions can potentially be reduced by over 50 %. In fact, if system 2 involves keeping the outbound concrete trucks as-is (not investing in new electric trucks), this system still reduces total CO2 emissions by 11 % compared to the current system. In addition, system 2 contributes to reducing the local emission levels per year of NOx by 43 % and SO2 by 67 %, which illuminates the systems positive impact on the air quality of the port's surroundings and the city. Looking closer at the current distribution system, the CO2 emissions per ton sand and gravel delivered to Steinskogen generate the lowest level of emissions compared to Alnabru and Sjursøya. This is because the factory is sourcing from quarries within relatively short distance. Hence, changing the logistics set-up to system 2 results in higher level of CO2 emission generated from transporting aggregates. In other words, HeidelbergCement is contingent upon modernising operations in order to improve the systems CO2 emission levels (see table 5.13).

The environmental effects of altering HeidelbergCement’s logistic system depends on the degree of change; the whole system or parts of it. For example, the queue driving effect on CO2 emissions show that the emissions can be reduced considerably by planning deliveries avoiding rush hours (see Appendix 3). A sizable contributor to emissions in the current system is related to port activities. The unloading of cement and use of wheel loader generates the largest share of CO2 emissions in the terminal (see Appendix 2). The use of on-shore power supply is an important measure to reduce the emissions from the unloading process of cement vessels. Moreover, if no measures to reduce the use of the wheel loader are initiated, the CO2 emissions will increase as a result of increased volumes. Hence, system 2 involves electric conveyor belts that replaces the need for wheel loader and thus eliminates the CO2 emissions from this activity. As the CO2 emissions generated in the terminal is of interest to the Port of Oslo (the zero-emission plan), reducing the emission level is a mutual interest of HeidelbergCement and the Port Authorities. Moreover, reducing emissions is aligned with local and national sustainability goals. The modernisation of terminal activities will then contribute to both HeidelbergCement’s strategy and to national and local environmental goals.

To underpin the importance of sea transportation for HeidelbergCement, we have conducted a sensitivity analysis investigating the competitiveness of sea transportation of aggregates. The analysis assumes transportation of 100 000 tons of aggregate and investigates at what distance the two transportation modes (sea and road) generate equal levels of CO2 emissions. The results show that sea transportation of 106 km generate the same amount of CO2 emissions as road transportation of 91 km. Hence, sea transportation generates the same amount of emissions as 14 % shorter distance by road (see Appendix 4). This example showcases that by modernising activities in system 2 according to the case description, it decreases the overall CO2 emission level. Therefore, modernisation of the current logistics system towards system 2 is in line with HeidelbergCement’s sustainability strategy.

In summary, HeidelbergCement needs to consider the economic, socio-political and environmental dimension when altering the logistic system of concrete supplying the Oslo market. How HeidelbergCement considers these dimensions (both individually and compared to each other) will have implications in three different aspects; reputation, acceptance by the society and competitiveness. Firstly, this will affect their reputation in the market as a responsible business that values sustainable solutions. In this way, HeidelbergCement can strengthen their position as a leading example in their industry for other businesses to follow. Secondly, this will have impact on the acceptance of conducting industrial activities in the port, being close to the city, by the port and local authorities. This is important for HeidelbergCement to secure a long-term supply of raw materials through the Sjurøya terminal. Lastly, it will affect their competitiveness as a supplier in the construction industry as HeidelbergCement can assure and guarantee that the emissions from the supply chain is as low as possible.

5.3. Theoretical Implications

5.3.1. Theoretical Implications on Academic Literature

This study contributes to several theoretical implications. These implications are presented below.

Firstly, to challenge DNV GL (2019) findings, we have conducted a sensitivity analysis investigating the competitiveness of sea transportation, in terms of CO2 emissions, with regards to transportation distance. The findings are in line with the DNV GL (2019) conclusions. That is, sea transportation over longer distances can compete with road transportation over shorter distances (see Appendix 4). This showcase that sea transportation in the dry bulk segment can be used for transporting volumes of relatively short distances.

Secondly, our findings show that sea transportation relative to distance generate very different levels of CO2, NOx and SO2 emissions. With regards to CO2 emissions, system 1 emit twice as system 2. For NOx and SO2, system 1 emit approximately three times more than system 2. Hjelle and Fridell (2012) discussed that the environmental competitiveness of sea transportation is not so clear when it comes to short sea shipping. These findings contribute to the theory by showcasing that sea transportation over short distances can be competitive in terms of environmental emissions.

Thirdly, the case illuminates the importance of acknowledging the characteristics of the dry bulk segment to facilitate for change. As mentioned earlier, the main focus in the literature lies with container and unit loads and these products have other characteristics than aggregates and cement. The quantitative analysis has shown that processing and production of inputs to concrete production in Sjursøya yields better environmental results. As shown in table 5.14, distribution from the Alnabru factory would have contributed the most to the total emissions given an equal production volume for all factories. This is because it is neither located in a quarry nor using sea transportation. In other words, there exist a need to conduct research on aspects of dry bulk segment in order to facilitate in the best possible way.

Lastly, the thesis shows the importance of integration and collaboration with city ports, in regard to the issues of area scarcity and public regulations, where mutual adaptation is a key constituent. The Sjursøya terminal has been specialised for HeidelbergCement's operations through close collaboration with the Port Authorities over time. This is in line with Notteboom & Winkelmans (2001) view that close collaboration is required to allocate the best use of terminal scarcity. The port can constitute an important role as it enables potential changes in terminal setup. It is therefore through continuous adaptations to new market requirements that enables modernisation in a public port. Furthermore, the study showcases the importance of integration and collaboration with the port for dry bulk companies. For HeidelbergCement it is crucial to have production facilities in the Port of Oslo. Hence, the port should be considered as an integral part of the supply chain. This is underpinned by Panayides & Song (2009) stating that the level of integration is based on the characteristics of the particular industry in which the terminal operator is a part of. This is because the Port Authorities have the ability to impact the understanding of public authorities, which may hinder essential terminal operations, such as concrete production.

5.3.2. Theoretical Implications on Theoretical Framework

In addition to contributing to academic research, the findings in this thesis also showcase the value of using Industrial Network Approach and the ARA model when analysing a phenomenon in the industrial context.

5.3.2.1. Key features of resources

This thesis has provided two valuable implications regarding resources. The first implication concerns the importance of understanding the nature of resources and its interfaces when seeking to improve the distribution system. It is not meaningful to analyse how a resource is utilised in isolation, rather one need to analyse how it is connected and combined with other resources. Even though the same resource is utilised, e.g. vessel, it gives very different results according to how it is combined with other resources. The study presents how an actor seeks to modernise the current utilisation of resources by changing the features or their resource constellation. To do so, the case illustrates the nature of resources by classifying them according to physical (facilities and products) and organisational resources (business units and business relationships). Furthermore, it outlines the interfaces between the resources that make up the distribution system. The study shows why one need to involve different types of resources when looking into how a single resource is utilised. This is because the feature of a resource is always dependent on the interfaces with other resources. Resources has several interfaces and thus when a resource is changed the initial interface with connected resources are changed as well. In our study, the current combination of resources is a choice made by HeidelbergCement based on the availability of resources. In other words, how HeidelbergCement operates today in its business context can be improved by alternative usage or enhancing the exploitation of the logistic resources at hand.

The second implication concerns that interfaces between resources do not evolve by themselves. These interfaces are formed in various ways based on the organisational (business units and business relationships) connection to the resources. Investments in resources change their interfaces and features. The investments in physical resources are enabled through interaction between business units. This entails that business relationships between business units that possesses certain resources are important and function as a bridge for developing these resources. Furthermore, the development of resources is based on the internal and external goals of business units (e.g. reducing environmental footprint and increasing profit). Consequently, physical and organisational resources must be considered together when analysing the development of resources.

5.3.2.2. The role of relationships in the development of resources

The utilisation and development of resources, as described in the case presentation, occurs from interactive processes between business units. This is because it is through interaction between involved business units that the development of resources is discussed. Consequently, resources are developed according to the underlying goal of the interaction process. This is illustrated in the case where HeidelbergCement and the Port of Oslo have mutual overall goals in terms of reducing their environmental footprint. In this sense, the modernisation of terminal activities and operations are designed with regards to reducing the environmental impact.

Another important aspect is that business relationships give access to resources that other business units control. As illustrated in this study, if HeidelbergCement was not allowed to carry out production activities in the Port of Oslo it might not have been possible to source from the same quarries as suggested in system 1 or system 2. Therefore, the interaction process is crucial to achieve the most efficient and effective use of resources.

5.3.2.3. The role of actors and relationships

This thesis shows that resource constellations are never stable. This is because various actors are continuously initiating efforts to modify and change the features of interfaces between the resources at hand for them to yield the highest value as possible. When one resource is modified it also alter the interface with other resources. These changes can constrain the development of other resources as shown in the case presentation where expanding a facility creates constraints with regards to the available space for expanding other facilities. In other words, there exists interdependencies between resources that actors' control.

There is no one obvious direction that a resource should be developed. In this sense, business relationships between actors play an important part in the development process. The relationship between HeidelbergCement and the Port of Oslo has showcased that long-term presence of HeidelbergCement has been crucial in the development process of their terminal in Sjursøya. As their business relationship has evolved over time the resources of the two has become more mutually oriented. Furthermore, this dyadic relationship is also connected to and affected by other relationships (e.g. public authorities and shipowners). Hence, these business relationships are interrelated. Therefore, the decision-making process of one actor is not only enabled through the distinct dyadic relationship. In order to understand the development and outcome of a decision-making process it is important to analyse the focal firm in the context of industrial networks. Likewise, collaboration between multiple actors operating in the industrial network is crucial to to achieve the “greenest package”. Otherwise, one end can end up with a situation where the “second best” alternative is chosen.

6.0. Conclusion

HeidelbergCement has developed the Sustainable Commitments 2030 as a response to the UN Sustainable Development Goals. In order to reach their sustainability goals, HeidelbergCement seeks to reduce their environmental footprint and to create long-term value for stakeholders and society. This involves consolidation of volumes and modernisation of their logistic system through the Sjursøya terminal in the Port of Oslo. The port constitutes an important role in this process as it can either prevent or enable modernisation of the terminal. Hence, the objective of this thesis was to investigate how HeidelbergCement, as a construction material supplier, can contribute to the Green Shift in the construction industry by modernising their distribution system through port integration. The research question was the following: *How can a construction material supplier contribute to the Green Shift in the construction industry by changing its logistical distribution system through port integration?*

The core of the thesis is based on the complex interplay between resources and the securing of sustainable sourcing of raw materials. By using the ARA model this thesis has provided a thorough case presentation of the Sjursøya terminal and its resource interfaces with HeidelbergCement's resource constellation. The case study has showcased the importance of involving different types of resources when looking into how a single resource is used. This is because the feature of a resource always depends on the interface with other resources. Furthermore, as the change in resources is enabled through interaction with other actors, the business relationships is what enables development of resources. Hence, the relationship between actors is important in the modernisation of the logistics systems.

The thesis has investigated how modernisation of the distribution system and port operations contributes to greening the construction industry. The findings are discussed in three dimensions that are important to consider; economic, socio-political and environmental sustainability. Firstly, the modernisation and development of the distribution system has to be economically viable to be competitive. The findings show that modernisation of the distribution system will increase the inbound transportation costs. However, although the transportation costs increase it is reasonable to assume that the reduction in production costs will be greater. Secondly, the new system needs to contribute in a positive way to society at large for HeidelbergCement to gain acceptance for conducting industrial activities in a city port. The findings show that modernising the distribution system contributes to National and Local sustainability goals by reducing NOx and SO2 improving the local air quality, reducing noise from industrial operations, transferring volumes from road to sea, reducing number of vehicles circulating in urban areas and offer areas for alternative use. Lastly, the modernisation must reduce the environmental emissions. The results show that by moving transportation of raw materials from road to sea, consolidation in port, and modernisation of terminal activities and outbound distribution can potentially reduce the CO2 emissions by around 50 %. Moreover, increased use of sea transportation will improve the local emissions of NOx and SO2 in the city area.

Our findings indicate that the modernisation of distribution system contributes to economic, socio-political and environmental dimensions. Therefore, the study can be used as an example to showcase how sea transportation and port integration can contribute to greening the construction industry. This illuminates the role and function of a port in a supply chain where long-term relation can facilitate for reducing environmental footprint and sustainable securement of raw materials.

6.1. Limitations and Recommendations for Further Research

The research in this thesis has focused on how HeidelbergCement can reduce their environmental footprint and secure sustainable sourcing of raw materials. The thesis has provided an analysis of CO2, NOx and SO2 emissions from transportation of inputs and concrete to the end-market. With regards to port activities, CO2 emissions have been analysed separately. Due to the limitations in regard to time and confidentiality of certain data, the analysis does not contain emissions and costs from the production of concrete, terminal operations at Alnabru and Steinskogen, or production of inputs. A comprehensive analysis of the total concrete chain's environmental emissions and costs would have provided a more accurate system analysis and given valuable insight to emissions levels and costs from modernising distribution system.

Including investment costs from modernising the Sjursøya terminal and production costs of concrete would have enriched the cost analysis and provided more accurate results. Inclusion of these elements would have provided a more comprehensive analysis and discussion on the economic implications of modernising HeidelbergCement's distribution system. Therefore, in order to fully determine if the modernisation of distribution system is economically viable it is important to include analysis of investment and production costs.

With regards to the level of emissions resulting from production of concrete it has a significant impact on the environment. It is reasonable to believe that consolidating production volumes to Sjursøya would generate significantly less CO2 emissions from production than in the current system. An analysis of this aspect would have enriched the emission analysis by providing valuable insights into how modernisation affects the environment.

A complete analysis of the emissions could be used to further demonstrate the importance of the Sjursøya facility, and how HeidelbergCement along with the Port of Oslo could contribute to reducing the environmental emissions in Oslo. A more comprehensive analysis of the emissions from port operations would be of value for academic research investigating the role and function of ports in a supply chain. These results could also be of value to researchers investigating port integration and modernisation.

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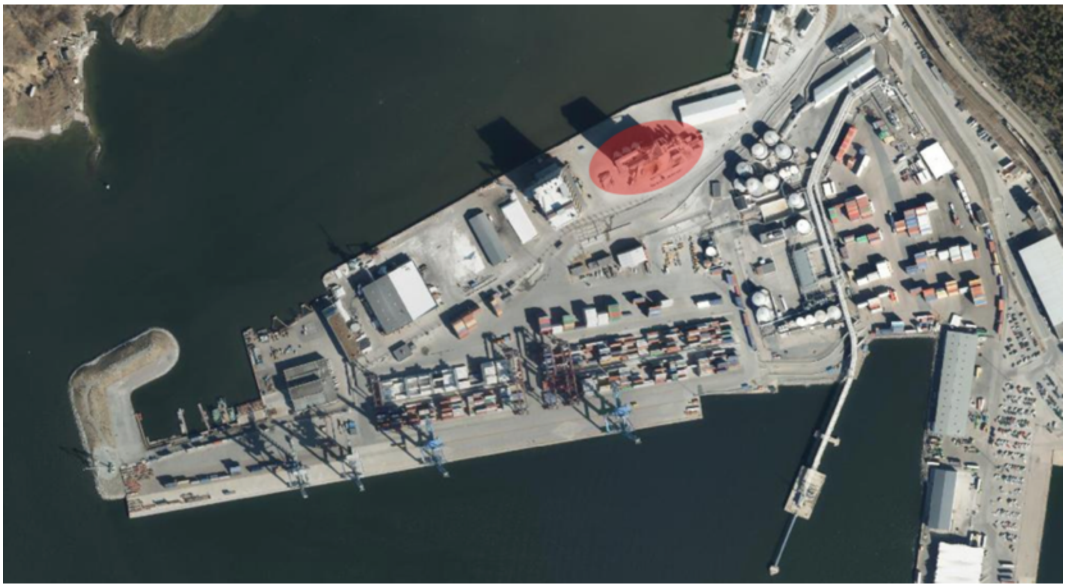
Appendices

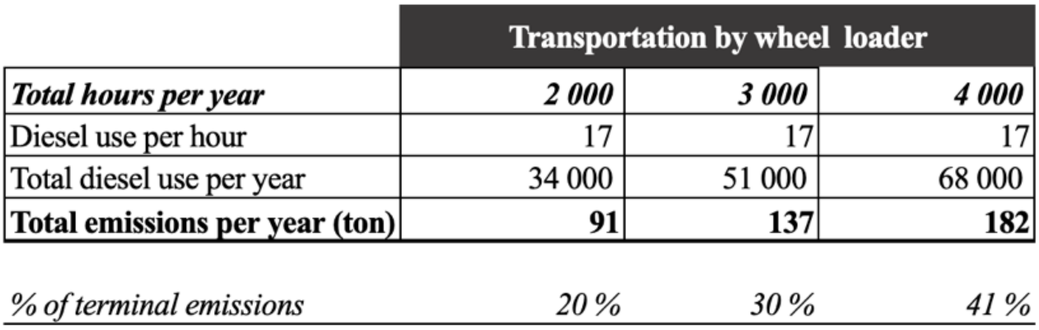
Appendix 1

HeidelbergCement's terminal at Sjursøya in the Port of Oslo



Appendix 2

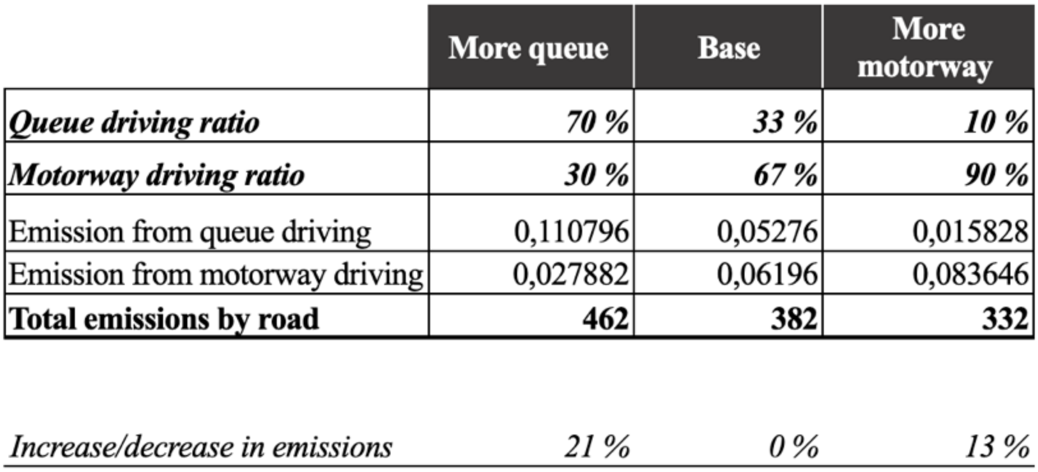
Sensitivity Analysis 1: Wheel loader use impact on emissions from port activities



	Transportation by wheel loader		
Total hours per year	***2 000***	***3 000***	***4 000***
Diesel use per hour	17	17	17
Total diesel use per year	34 000	51 000	68 000
Total emissions per year (ton)	**91**	**137**	**182**
% of terminal emissions	*20 %*	*30 %*	*41 %*

Appendix 3

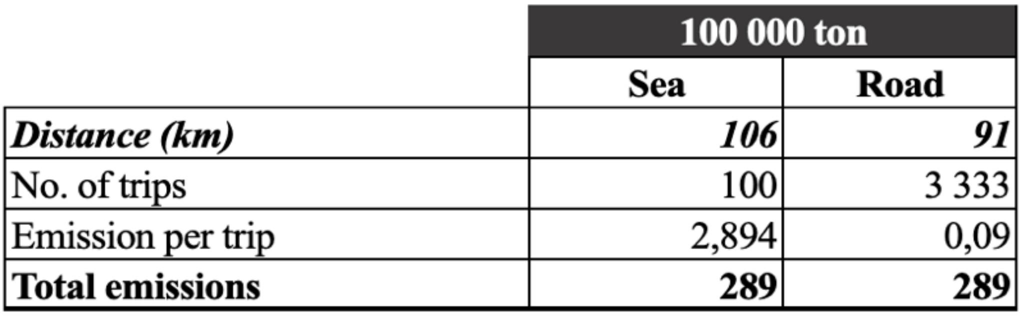
Sensitivity Analysis 2: The effect of queue driving



	More queue	Base	More motorway
Queue driving ratio	***70 %***	***33 %***	***10 %***
Motorway driving ratio	***30 %***	***67 %***	***90 %***
Emission from queue driving	0,110796	0,05276	0,015828
Emission from motorway driving	0,027882	0,06196	0,083646
Total emissions by road	**462**	**382**	**332**
Increase/decrease in emissions	*21 %*	*0 %*	*13 %*

Appendix 4

Sensitivity Analysis 3: Distance effect on emissions: sea vs. road



	100 000 ton	
	Sea	**Road**
Distance (km)	***106***	***91***
No. of trips	100	3 333
Emission per trip	2,894	0,09
Total emissions	**289**	**289**