Erasmus University Rotterdam

MSc in Urban, Port and Transport Economics

Pioneering the West Michigan Agricultural Shoreline

An economic analysis on possibilities of agricultural exports through the port of Muskegon

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Executive summary

Providing employment to almost a quarter of the workforce in Michigan, the agricultural sector is of substantial importance to the state. Although surrounded by the Great Lakes basin, waterborne transportation of agricultural commodities in Michigan is almost non-existent. This thesis aims to identify opportunities for out of state export flows of grain and oilseeds by water. The starting point of the analysis is the port of Muskegon since it is the only natural deep draft port on the west coast of Michigan.

In order to assess the possibilities, the main goal is to identify substantial advantages of waterborne shipments out of Muskegon compared to current practices. The first part of the research involves a qualitative research. This reveals that transportation rate and transit time are the most important decision making variables in the process of freight modal choice. The qualitative research also identifies three specific agricultural commodities with the highest potential of waterborne exports: corn, soybeans and wheat. Moreover, five corridors for the economic assessment are designated. All corridors include a waterborne route via the port of Muskegon and at least one benchmark route. Two of the five corridors have Asia as final destination. Chicago, New Orleans and Europe make up for the other destinations.

A quantitative economic analysis has been carried out in the second part of the thesis. All routes within the five corridors are assessed and compared on current transportation rate and transit time. In addition, CO2 emissions are accounted for and future oil price scenarios are included as well. A final scenario-analysis on combining transportation of agricultural goods with high-value goods is also conducted.

Results show that in two out of five corridors waterborne transportation via Muskegon is able to provide a small cost advantage compared to the benchmark route. Transit time advantages are also present in these two corridors. Nevertheless, the qualitative research indicates that more decision making variables have to be taken into account as well. That is, switching costs are set at 14% of the transportation rate. Other factors as temporarily lower rates of current transportation providers, port reliability, frequency of operations and substantial amount of throughput are also at stake. Considering these factors including switching costs and the highest cost advantage of 13.1% the port of Muskegon has to offer in any scenario-analysis; waterborne agricultural export out of Muskegon has little chance of short-term success. In summary, the port of Muskegon is not able to provide substantial advantages over current transportation practices of agricultural commodities in the state of Michigan.

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Acknowledgments

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1. Introduction

The United States (US) are a net exporter of agricultural products, since the turn of the century the value of exported agricultural commodities rose from about $50 billion in 2000 to $133 billion in 2015 (USDA, 2016). This steep increase in value of exports is partly due to a stronger currency position of the US dollar since the quantity of standardized export units only rose from 157.7 million in 2000 to 197.5 million in 2015 (USDA statistics, 2016).

The currency effect is also present in recent agricultural trade surplus figures which state that this surplus is now at the lowest level since 2007 and with $19.5 billion at half of its 2014 value. However, USDA statistics (2016) show that the quantity of net exports only declined by 8.5% in contrast to the 50% when expressed in monetary terms.

Oilseeds and grains are the top exported agricultural commodities representing $59 billion of the export value in 2015 although this number is slightly decreasing in the last years. Top export markets for these commodities are China, Mexico, Canada, Japan and South-Korea (USDA statistics, 2016).

Among the oilseeds and grain categories; soybeans, corn, wheat and feed grains are the most valuable export commodities. Given their 5% share of total US exports and positive effect on the negative US global trade balance, which accounted a deficit of $746 billion in 2015, these commodities are of vital importance for the US economy and exports (US Census Bureau, 2016).

The majority of US grains and oilseeds is produced on the Upper Plains in the US Midwest. All of the twelve states that make up for the Midwest have a significant contribution to both the domestic production and export of agricultural commodities. Because of the vicinity of the Illinois and Mississippi River inland water transportation is the preferred way of oilseeds and grains to move to their final transhipment hub before being internationally exported. About 60% of the total grain exports originate from the Midwest and moves through the inland river system to the Mississippi Gulf. The Pacific North West region is also an important export hub for agricultural commodities and is connected to the Midwest via railroad systems (Yu et al, 2007). Although half of the Midwest states are located adjacent to the Great Lakes basin, only two percent of total US grain exports flow through the Great Lakes basin (GLSLS Study, 2007).

Global agricultural commodity markets are highly competitive and transportation costs have become a critical factor in determining whether or not the price of an agricultural commodity is competitive in world markets (Clott et al, 2015). Because of the importance of agricultural commodities for the US economy and the highly competitive international environment, the logistical structure including her bottlenecks and opportunities are important to continually asses in order for the US to maintain their position as a net exporter of agricultural commodities. Since the epicentre of agricultural production is located near inland waterways and the Great Lakes basin, this study will focus on waterborne transportation of agricultural commodities. More specifically, a feasibility study will be conducted for the port of Muskegon, located in West Michigan, in order to investigate the potential benefits of waterborne transportation of agricultural commodities produced in the state of Michigan.

1.1 Origin of research

This research is the result of a collaboration of the County of Muskegon, the Consulate General of The Netherlands in Chicago and the Erasmus School of Economics in Rotterdam. The County of Muskegon is awarded with a grand of the Michigan Corn Growers Association in order to conduct a feasibility study on the port of Muskegon to act as an agricultural transportation hub.

Reasons for the awarded grand include the fact that the port of Muskegon is the only deep draft port on the west coast of the state and its central location in Michigan. Moreover, the recent decommissioning of the Consumers Energy BC Cobb plant has resulted in a 1,000 feet long deep draft quay ready for new business purposes. This offers opportunities for new initiatives to revitalize the port of Muskegon.

Contact between the County of Muskegon and the Consulate General of the Netherlands in Chicago, including their connections with the Erasmus School of Economics, resulted in the opportunity for two MSc students from the Urban, Port and Transport Economics program to write a research thesis in the state of Michigan on agricultural transportation and port development. Financial support is offered by both the Consulate General of the Netherlands in Chicago and the Michigan Corn Growers Association grand.

1.2 Research objective

The objective of this thesis is to study the feasibility of the port of Muskegon to become a transportation hub for agricultural commodities which are produced in the state of Michigan. The state of Michigan is surrounded by the Great Lakes basin and is one of the larger agricultural producers in the US. Although surrounded by water, trucks dominate the transportation of agricultural commodities in Michigan and waterborne shipping is non-existent. Moreover current road and rail congestion around Chicago, a major agricultural transshipment hub for Michigan produced agricultural commodities, is an important bottleneck. Research on the underutilized waterborne transportation options of Michigan's agricultural commodities is therefore a contribution to the knowledge on current transportation practices.

This urge for further investigation results in the following research question this thesis aims to answer:

''Does the port of Muskegon has the potential to offer substantial transportation advantages for export flows via the Great Lakes for agricultural commodities in the state of Michigan compared to current non-waterborne transportation practices?''

By answering this research question while assessing all relevant aspects, the objective of this research is also to guide the West Michigan agricultural sector and the port of Muskegon into a direction for further action in order to utilize potential possibilities and overcome challenges.

1.3 Relevance

This thesis has practical relevance with potential implications for multiple stakeholders in the state of Michigan. Moreover, little academic research has been done on agricultural waterborne transportation in the Great Lakes area. Especially the state of Michigan has been investigated to only a very small extent regarding this topic.

1.3.1 Practical relevance

Current agricultural transportation networks do not include the use of the port of Muskegon. Nevertheless the port of Muskegon has the potential to offer a centrally located multi modal transportation hub which connects railroad, highway and Lake Michigan with each other. Since the agriculture sector services a large part of Michigan's economy and contributes $96 billion annually in total economic activity, it is relevant to research this particular sector. The support of the Michigan Corn Growers Association and several other agricultural related organizations also confirm the relevance of this thesis topic.

Studying possibilities of waterborne transportation on its own has current practical relevance as well. A large share of agricultural commodities in Michigan is transported by truck and rail to the congested highways and railroads in the greater Chicago area. By unburden the Chicago transshipment hub of some congestion, waterborne transportation to the Chicago area may have socio-economic benefits. From an environmental perspective there is also a relevance regarding this research since waterborne transportation is less polluting than trucking and in most cases also than train transportation (Comer et al, 2010).

Several groups have a relevant stake in the research objective. An expansion of port related activities adds to the economic activity in the region and creates jobs for the people in the County of Muskegon. Moreover, producers and processors of agricultural commodities in West Michigan may gain in cost efficiency and strengthen their market position. Local shipping companies have the potential to enlarge their activities by focussing on waterborne transportation of agricultural commodities. Finally, contributing to a practical problem with possible real-life implications makes this thesis both social and economic relevant.

1.3.2 Academic relevance

Most of the academic literature regarding inland waterway transportation of agricultural commodities in the US focuses on the Mississippi River and the Gulf of Mississippi. Given the large amount of commodities shipped on these waterways, especially in comparison to the Great Lakes area, this may not come as a surprise.

Short sea shipping is widely investigated in academic papers for both European and US cases. However, the Great Lakes region is hardly part of the US literature since it mostly emphasizes coastal shipments on both the east and west side of the country.

By focusing on both agricultural commodities and the Great Lakes area, this thesis tries to fill and combine the identified gaps in previous literature. Additionally, the academic relevance must result from the unique perspective of taking one specific port in West Michigan as starting point.

1.4 Thesis structure

Chapter 2 provides background information on the port of Muskegon while chapter 3 will explain the set-up of this research including the formulation of the main and sub research questions. In the following chapter relevant literature is reviewed and used to gain insights with respect to the thesis topic. Chapter 5 provides information on the production, transportation and trade of agricultural commodities in Michigan. In chapter 6 possibilities of waterborne transportation of agricultural commodities originating from West Michigan will be elaborated on. It will also provide general information about the Great Lakes – St. Lawrence Seaway and the Chicago Area Waterway System. The economic analyses will be conducted in chapter 7. Transportation costs and transit time of current routes are compared to alternative waterborne options. Analysis on future oil prices and CO2 emissions will be conducted as well. The broader assessment of combining agricultural commodities with other sorts of cargo is done in chapter 8. Conclusions about the general findings and final remarks will be drawn in chapter 9. A management advice for the County of Muskegon will be given in chapter 10.

2. The port of Muskegon

This chapter provides background information on the port of Muskegon since the research question of this thesis takes this port as the starting point.

The port of Muskegon is located at Lake Muskegon which connects to Lake Michigan via the Lake Muskegon Channel. Some major Great Lakes ports as Chicago (183 km) and Milwaukee (140 km) are located within one sailing day from the port of Muskegon. Five commercial docks are operating in the port and twelve recreational marinas are situated at Lake Muskegon. An overview of the port of Muskegon is provided in figure 1.

Figure 1: Overview of Muskegon Lake and the commercial port facilities

Source: West Michigan Port Operators

The port of Muskegon is unique in a sense that it is the only natural deep water port at the west side of Michigan. With a maximum draft of 8.2 metres (27 feet) it is able to facilitate all kinds of barge vessels, lake vessels and even ocean-going ships. This draft is also well maintained by the United States Army Corps of Mariners since they provide funding for dredging the Muskegon Lake Channel (Port of Muskegon, n.d.).

An important characteristic of the port of Muskegon is the missing of a central port authority. This makes development of the port more complicated since private operators are reluctant to make general investments. More coordination and organization among stakeholders would enhance developments in the port.

A major development in the port of Muskegon is the decommissioning of the Consumers Energy B.C. Cobb energy plant in April 2016. While it was responsible for a large share of the annual port throughput, the closure will leave its mark on the port. On the other hand, it provides opportunities for new activities since the B.C. Cobb Dock will be available for new business as of 2017 and is characterized by a 1,000 feet deep draft quay including 18 acres of laydown space (West Michigan Port Operators, n.d.). The following paragraphs will elaborate more on freight transportation and other port activities.

2.1 Freight transportation

Freight transportation in the port of Muskegon is characterized by bulk materials which are mainly transported by tug-barge combinations or self-unloading lake vessels. Despite the presence of intermodal connections, no containerized cargo is currently shipped through the port. These intermodal connections include the US-31 highway, I-96 interstate, the Short Line railroad which overflows into the CSX network and the Muskegon airport which is located 13 kilometres (8 miles) from the port.

As mentioned earlier the B.C. Cobb coal energy plant used to be one of the major port users in Muskegon. This is also shown in table 1 which breaks down the annual tonnage shipped in the port of Muskegon while showing the significance of coal as cargo. The shipped tonnage is given in short tons which is equal to 907.2 kilograms or 2,000 US pounds.

Table 1: Annual freight throughput port of Muskegon, 2014

Commodity	**Volume (short tons)**
Coal	1,046,643
Limestone	428,486
Non-metallic minerals	181,686
Cement and concrete	76,574
Slag	68,710
All other	50,500
Total	**1,850,497**

Source: Navigation Data Centre US, 2014

The data of the Navigation Data Centre US (2014) also shows that freight transportation in the port of Musekgon is a one-way stream while all throughput are receipts. The only exception is the outgoing shipment of 63,488 short tons of slag. Moreover, the data shows that 85% of the cargo is shipped within domestic waters. The main cargo that is imported internationally are non-metallic minerals from Canada.

In the 5-year period of 2010-2014 none of these transportation characteristics has changed significantly. Total cargo throughput rose with 25.1% in this timeframe, mainly due to an increase in coal receipts. Nevertheless, the transportation characteristics of the port of Muskegon will change in the upcoming years because of the recent decommissioning of the B.C. Cobb energy plant. The loss of coal shipments will have a severe impact on the throughput composition and is likely to halve the total amount of shipped cargo.

2.2 Other port activities

Besides cargo shipments, the port of Muskegon is also home to other port related activities. During the summer a Great Lakes cruise ship moors several times in the port of Muskegon. From June to October there is also a high-speed ferry active which ships commuters in 2.5 hours from Muskegon to Milwaukee or vice versa. There are also twelve marinas located at Lake Muskegon which are home to both motorized ships and sailboats.

The port of Muskegon also offers a number of commercial services which are freight related. These include both the storage and transhipment of bulk materials, break-bulk cargo handling and storage, a crane facility up to 600 ton, covered storage and tug/tow assistance (West Michigan Port Operators, n.d.).

2.3 Logistical firms in the port of Muskegon

Apart from the dock operators there are not many logistical firms present in the port of Muskegon. The dock operators are mainly dedicated to a limited number of heavy bulk cargo types. Together with the fact that the port of Muskegon predominantly has inbound flows, these two findings make it not attractive for logistical firms or marine operators to be present in the port of Muskegon.

Nevertheless there are a small number of logistical or marine related firms active in the port. The most notable and relevant one for this research is a marine transportation and chartering firm which is able to ship both dry and liquid bulk as well as other cargos by means of barge transportation. Other marine shipping firms are not present in the port area. Some other smaller specialized transportation firms who focus on road or rail freight are active in the Muskegon region but not specifically in the port.

The absence of larger logistical firms in the port of Muskegon highlights the fact that transportation in the West Michigan area is dominated by the trucks and trains whereas waterborne transportation comes secondary.

3. Research set-up

As mentioned in paragraph 1.1 this thesis is to a certain extent the result of a cooperation between multiple organizations. The entire research project is conducted by two students. Therefore the research set-up of this thesis will be somehow unique since two students aim to answer the same research question including corresponding sub research questions. Nevertheless, the set-up for both theses are from a different nature and two unique researches, including their findings, will be presented.

The distinction between both the theses has been made in the sense that the research of the fellow student, Chris Jan Weijzen, focuses on the general framework of port development and agricultural hubs including socio-economic implications. This thesis is of a transport-economic nature and assesses the economic feasibility of possible transportation routes while trade-offs with respect to transit time are also taken into account. In addition, both theses have identified general bottlenecks, challenges and opportunities for waterborne transportation of agricultural commodities in West Michigan.

In order to facilitate this research a main research question and several sub research questions are set up in the next paragraphs. Subsequently more information on the research design and methodology, data collection and the thesis structure is provided.

3.1 Main research question

The objective of this research is to assess comprehensively whether the port of Muskegon has the potential to act as a waterborne transportation hub for Michigan produced agricultural commodities. As mentioned in paragraph 1.2 this leads to the following main research question:

''Does the Port of Muskegon has the potential to offer substantial transportation advantages for export flows via the Great Lakes for agricultural commodities in the state of Michigan compared to current non-waterborne transportation practices?''

Putting the focus solely on agricultural commodities may seem as a narrow scope. However, it is already emphasized what kind of valuable role the agricultural sector has in the Michigan economy. Moreover it is of interest for this research that agricultural commodities are usually shipped in bulk. Waterborne shipment in the Great Lakes and US inland waterway system is namely dominated by dry bulk barge ships (Navigation Data Center US, 2014b). The activity and presence of these ships in the Muskegon region makes research on shipments of bulk commodities more relevant. Nevertheless this thesis will also address the possibilities of combining agricultural commodities with other cargo.

The geographical emphasize on the County of Muskegon follows from the fact that it has the only deep draft port on the western Michigan shore and its central location in the state. Additionally, the release of a substantial amount of quay because of the decommissioning of an energy plant is also at stake. The efforts made by both the County of Muskegon and the Michigan Corn Growers Association are also taken into account while designing the research set-up. However, it should explicitly be stated that this thesis is an objective research and of a complete independent nature.

As for the export flows no particular shipping routers are yet included in the main research question. This is due to the fact that more than one destination might be of interest to investigate in this thesis. Chapter 6 is dedicated to this topic and provides more clarity.

3.2 Sub research questions

Nine sub research questions are designed in order to answer the main research question to its full extent. Some of these questions will be assessed more thoroughly in this thesis while others obtain more attention in the thesis of mister Weijzen. The sub research questions are given below.

1) What are the main competing ports of Muskegon and what are their main advantages and disadvantages?
2) What are the key elements of an agricultural hub and what are the main opportunities that can be identified for the development of an agricultural hub in the port of Muskegon?
3) What are the main bottlenecks that can be identified for the development of an agricultural hub in the port of Muskegon which ships via the Great Lakes, and to what extent can these bottlenecks be reduced?
4) What are the regional socio-economic effects that can be identified when developing an agricultural hub in the Port of Muskegon?
5) What type of agricultural commodities are exported from the region?
6) What are the current trade relations and what are the characteristics in terms of balances and imbalances?
7) How are these commodities currently shipped and what are current transportation times and costs?
8) What are the effects on transportation costs and transit time for shippers when changing agricultural cargo flows from West Michigan through the port of Muskegon to their designated destinations?
9) Are there possibilities of combining agricultural goods with other sorts of goods in order to make shipping from the port of Muskegon more economical feasible?

While the thesis of Mr. Weijzen puts the focus on answering sub research questions 1 to 4, this thesis aims to provide answers on sub research questions 5 to 9. Combining the outcomes of both theses must result in a well substantiated answer to the main research question.

3.3 Research design and methodology

To conduct this research and answer the research questions, both qualitative and quantitative methods have been used. This thesis emphasizes the quantitative aspect more since economic calculations and trade-offs are made. In order to make these trade-offs, academic literature is reviewed to gain valuable insights in the decision making process of shippers and consignees while other relevant theories in the fields of waterborne transportation and agricultural commodities have been identified as well. Additionally in-depth interviews with field experts, relevant organizations and local shippers or agricultural producers have been conducted. In this way current practices are assessed and bottlenecks, challenges and opportunities regarding transportation of agricultural commodities in Michigan are identified.

Because of this approach no pre-determined hypothesizes have been put forward. Receiving relevant information and gaining useful insights during the research itself has led to adjustments in the approach and focus of this thesis. For example, the transportation corridors or specific commodities that are investigated have been adapted for this reason. The nature of this research is therefore inductive.

3.4 Data collection

The final aim of this thesis is to quantitatively assess whether waterborne transportation from the port of Muskegon has competitive advantages over current transportation practices. In order to do so data on relevant costs and transit times has been retrieved. Both desktop research and in-depth interviews have provided this information.

The interviews have preferably been done in a face to face situation, if this was not possible the interview was conducted by phone or e-mail. All interviews have been carried out in a semi-structured way with open questions and room for further discussions. Parties that have been approached for the interviews include governmental organizations, privately backed transportation and agricultural related organizations, agricultural producers and shipping companies. The condition is that all firms and organizations have to operate in the state of Michigan or Great Lakes region.

As for the data on both shipping cost and transit time, some problems have been encountered. Rates and transit times turned out not to be publically available for inland water transportation in the Great Lakes region. The same problem also occurred when investigating transshipment practices. However, interviews with field experts have resulted in useful insights and provided indications or exact information on both the rates and transit times.

Because of confidentially reasons none of the field experts have explicitly been named in this thesis. Notwithstanding, appendix 4 does provide a list of the type of persons and organizations which have cooperated and have been interviewed.

4. Many decision variables at stake but cost and transit time prevail

In this chapter an overview of previous relevant literature is given. The goal is to gain academic insights on topics that are relevant for a possible shift towards waterborne transportation of agricultural commodities. In order to gain these insights the following three fields of academic research are addressed: decision variables that influence the mode of transportation choice, benefits of (short distance) waterborne transportation and the logistical structure of agricultural commodities.

If possible, literature which touches subjects as agricultural commodities or relate to the US Midwest or Great Lakes region are included in the literature review since these may especially be relevant considering the scope of the research. All the three fields of academic research will be reviewed separately in the following paragraphs. A final paragraph with conclusions is also provided.

4.1 Decision variables that influence the mode of freight transportation choice

The transportation mode a customer, shipper or freight forwarder chooses is generally influenced by more than just the cost or delivery time (Reis, 2014). In an agent-based case study Reis (2014) investigates whether the variables price, transit time, reliability and flexibility of a transportation mode have influence on switching from road transportation to intermodal transportation on haulages shorter than 400 kilometres. Contradicting the general assumption, the simulation results show that only the price of transportation has a significant influence on freight forwarders in switching to other modes or intermodal transportation.

The importance of cost in the decision making of transportation modes is also found by Yu and Fuller (2005) who put the focus on price elasticities of grain transportation demand from the Upper Mississippi River to foreign export markets via the Gulf. As expected they find a short term negative elasticity of 0.5% in the barge-price/barge-transportation demand relationship, in the long term this elasticity becomes twice as large. In addition they also find that lower transportation prices of competing transportation modes have a negative influence on the amount of grain barged throughout the Mississippi River.

In a similar study Kim and Van Wee (2011) find that with respect to the break-even distance of rail and road transportation, either a 1% reduction in rail rate or a 1% increase in truck rate is respectively seven times, three times and twice as effective as a 1% change in terminal handling costs, rail distance and drayage costs. Although other decision variables as efficiency or service quality are not addressed, these findings also highlight the importance of transportation costs.

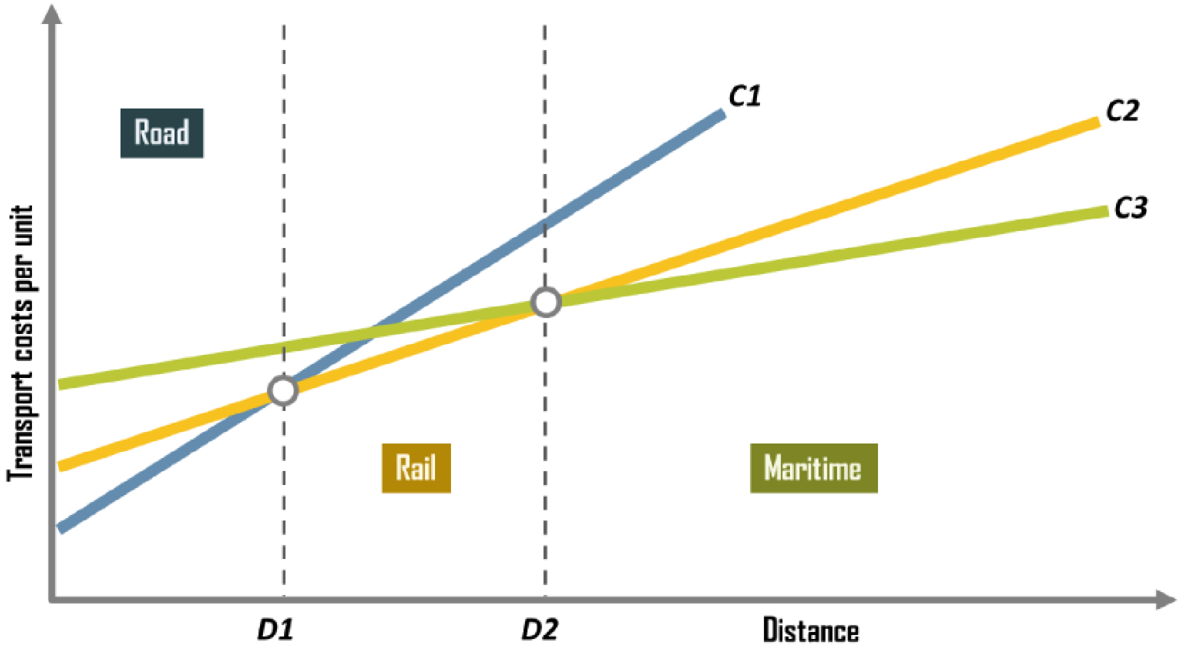
Further considering the trade-off between different transportation modes, the relative unexplored phenomenon of intermodal transportation cannot be excluded. Although intermodal transportation offers advantages and is encouraged by governments, it is not the most applied way of transportation and its competitiveness is not widely proven or accepted. Especially on shorter distances it is not the most competitive way of transportation (Suárez-Alemán et al, 2015).

Tsamblous (2008) confirms this during a European case study in which he finds that intermodal transportation generally becomes competitive at haulage distances of around 400 kilometres or more. For the United States this number is even set to 1,000 nautical miles (1852 km) if truck transportation and short sea shipping are compared with each other (Brooks et al, 2012).

On the contrary, Kruse and Hutson (2010) argue that there is not a single minimum distance required for short sea operations in order to be successful. Short sea shipping is assumed to fall under the umbrella of intermodal transport since cargo is either shipped to or from a port by truck or train. Although longer distance routes may have more potential, the specific geographical characteristics and alternatives for certain routes must be investigated individually to assess the possible success.

More general break-even points for the three most used freight transportation modes: truck, rail and maritime shipping are identified by Rodrigue (2013). In figure 2 the two break-even points are depicted, point D1 is generally located between 500 and 750 kilometres and D2 around 1,500 kilometres.

Figure 2: Transportation cost per unit and break-even points



Source: The geography of transportation systems (Rodrigue, 2013)

Transit time and cost of transportation are evidently of importance in the decision making process for freight transportation. The trade-off between time and costs in transportation is a widely studied topic in the field of economics. Considering freight transportation in particular, there has also been done substantial research on the rate of substitution between transit cost and time. Also referred to as freight value of time (FVOT). De Jong et al (2004) argue in a Dutch truck-based case study that low-value bulk goods, as agricultural commodities, have a FVOT twice as small as high-value perishable goods. This makes transit time a less important decision making variable when choosing a transport mode for agricultural commodities. Beuthe and Bouffioux (2008) confirm this and state that transit costs are of larger influence compared to transit time for low-value goods in general. Noteworthy, specifically for the category of minerals, fertilisers and agricultural goods they find that reliability, time and flexibility are important decision variables while transport cost come secondary. Coinciding with the De Jong et al (2004) and most other literature, García-Menéndez and Feo-Valero (2009) empirically find that agricultural products which are not highly perishable usually are more sensitive to price of transportation than transit time. Therefore they also see a favourable position for short sea shipping with respect to non-perishable cargo.

Other studies highlight different variables regarding the decision making of choosing a transportation mode. A recent European study by Suárez-Alemán et al (2015) shows that stimulation measurements of the European Union (EU) to promote short sea shipping over trucking by means of monetary grants is not efficient and does not result in the desired outcome. Since the 1990's the EU granted more than €895 million throughout several programs as PACT and Marco Polo l and ll. Participating firms were financially stimulated to shift from trucking to short sea shipping in order to foster intermodal competition. However, in the same period truck transportation gained market share while short sea shipping lost ground.

This policy failure indicates that cost is not the only or single most important decision variable in transportation. The fact that firms value delivery time differently should therefore not be ignored in policymaking. Suárez-Alemán et al (2015) also point out the importance of port efficiency and argue that policies should focus on promoting port efficiency to encourage short sea shipping as a serious competitor for road transportation. Besides the promotion of efficiency they also give the internalization of external cost of road transportation as an option to foster the competitiveness of intermodal transportation and short sea shipping.

'Efficiency' is also named by others as an important decision variable for transportation mode choice. More specifically, efficiency of waterborne transportation is port related while it regards the handling of cargo. This port efficiency can also be quantified into cost advantages. Wilmsmeier et al (2006) argue that doubling the port efficiency in a pair of ports has the same impact on international transportation costs as halving the distance between the two ports would have. In addition, Clark et al (2001) find in a comprehensive analysis that improving port efficiency from the 25th percentile to the 75th percentile will reduce transportation costs by 12%.

Baird (2007) also empathizes the importance of port efficiency. Not only the speed of handling is important but other aspects as cargo security, absence of bureaucracy, 24-hour work shifts, and highway access are also related to port efficiency and influence the decision making in transportation mode choices. By means of a survey carried out during the European Marine Moterways Project, he also identifies the following transportation decision variables besides port efficiency: prices, reliability, schedule, transit time and on-board facilities.

The importance of efficiency and service quality of maritime transportation is also found by Martinez-Zarzoso and Nowak-Lehman (2007) in a European case study were both road and maritime transport on a competing route are investigated. They identify efficiency and service quality as important cost determinants for maritime transportation while geographical distance is of big impact on the trade-off with respect to road transportation.

Other relevant decision variables are revealed by Paixao and Marlow (2002) who investigate the reluctance of shippers to accept short sea shipping above trucking. Hurdles that must be overcome include a lack of supply chain orientation, doubts about schedule reliability, excessive bureaucracy and regulations, high port and land-based service fees and poor integration with other transportation modes. The old fashioned and slow image of short sea shipping among shippers and freight forwarders must be changed as well. In order to do so participants must cooperate in partnerships, aggressive marketing has to be applied and the attitude of short sea operators must be more entrepreneurial. Paixao and Marlow (2002) conclude that short sea shipping must possess two major characteristics in order to succeed: first it must provide a competitive time/cost trade-off in comparison with other transportation modes (mostly trucking) and secondly, it must be as reliable and seamless as possible.

Brooks et al (2012) find in their Australian case study that the direction of the haulage is also of influence on the chosen mode in freight transportation. This comes from the fact that head haulage is usually costlier than back haulage since less cargo is generally available for these trips. Furthermore they emphasize the importance of operating frequency and show that shippers are willing to pay more if short sea shipping services will operate on a higher frequency. The latter finding is also the main conclusion of Puckett et al (2011) in a Canadian-US based case study on decision variables of shipping by road or water. Both studies also name reliability, measured as freight being delivered on time, as a major decision variable.

During a classic study, Morton (1972) argues that convenience of a transportation mode is also of value for shippers. In his study on intermodal competition he finds that shippers are willing to pay a rate premium of 15 to 20 percent for the service advantages that come with trucking in comparison with train transportation. More recent studies resulted in similar figures. In case study on US east coast short sea shipping versus road transportation Brooks and Trifts (2008) find that current trucking prices have to rise with 29.8% in order for decision makers to switch from road to waterborne transportation. Reasoning the other way around, Kruse and Hutson (2010) argue that short sea shipping rates in the US must drop 20 to 30 percent compared with trucking rates in order to compel shippers to switch.

The convenience of a current transportation mode for a shipper is also related to the fact that switching to another mode will yield transaction costs. In a study on collaborative hub networks Groothedde et al (2005) identify search costs and bargaining costs as barriers to switch from transportation mode. Quantifying the cost of switching is not straight forward and depends on the transportation mode and type of good. Raw materials as grain usually have lower switching costs than finished goods or food. The required discount rate a seasonal mode of transportation such as waterborne shipping on the Great Lakes has to offer compared to non-seasonal transportation as trucking is set around 14% of total shipping costs for raw materials (TEMS/RAND Corporation, 2007).

In a comprehensive literature review study, including in-depth interviews, which focuses on the US transportation market Kruse and Hutson (2010) identify the four most important decision variables for a shipper’s choice of transportation mode: travel time, reliability, costs and general preference for retaining the existing service structure. Especially the latter one is interesting and has not been specifically identified in previous mentioned literature although it can be grouped together with the convenience variable.

Considering the cost of transportation as the most important decision variable is becoming less seen in practice. Bravo and Vidal (2013) confirm this in a literature review where they investigate recent trends in freight transportation by comparing two groups of freight transportation decision making related papers, the first group of papers is recently published between 2009 and 2012 whereas the second group is published in the 1974-2008 period. Among the former group of articles, 14.6% analyzed trade-offs associated with transportation costs while this percentage in the group of older papers is 23%. This indicates a recent trend where transportation costs are becoming less important and other factors have more influence on transportation related decision making.

Lastly an official US Department of Transportation report by Reeve & Associates (2006) suggests that road congestion is also an important decision variable to take into account when the trade-off between road transportation and waterborne transportation has to be made.

Decision making in mode choice of freight transportation is a complex one. Unlike passenger travel, fewer more sophisticated buyers take decisions in this market and outsourcing of this decision making process is also commonly seen. This results in very few decision makers who account for large volumes of freight.

Keeping this in mind, it follows from the above literature that cost and transit time are not the only decision variables with respect to the freight transportation mode choice. Other variables as efficiency, reliability, service quality, frequency, convenience (to stay with status quo), haulage direction and road congestion are also of influence. Although the latter ones are relevant and may be of influence, price of transportation and the transit time remain very valuable to shippers and forwarders.

This statement is also supported by a comprehensive literature review on transport attributes considered by shippers and freight forwarders of Feo et al (2011). In all of the 30 investigated papers, cost of transportation is named as an important attribute. In 29 of the 30 papers transit time is also pointed out, followed by frequency which was mentioned in 15 out of the 30 papers. Therefore, both the cost and time trade-off regarding waterborne transportation will be the main focus during this thesis.

4.2 Advantages of (short distance) waterborne transportation

The urge for sustainable solutions is becoming of more importance in all industries worldwide. Freight transportation is no exemption and energy use and corresponding emissions in this sector are increasing at the fastest rate of all transportation sectors (Annual Energy Outlook, 2009). In 2007 the freight transportation sector accounted for 9% of total CO2 emissions in the USA (Comer et al, 2010). These findings make the freight transportation sector a non-negligible component of the sustainability discussion.

Analysing characteristics of different transportation modes has become a regular practice in the last decades. Comer et al (2010) have done an analysis on the Great Lakes region in a case study of containerized transportation from Montreal, Quebec to Cleveland, Ohio. Four different transportation modes were chosen: truck, train and two different kinds of marine vessels; a tug-barge combination and a container vessel. Results show the time of delivery was evidently the lowest for truck, followed respectively by train and the two vessels. On the other hand, the transportation costs of trucking were clearly the highest followed by train and again the two waterborne options. Besides transit time and costs, the study also emphasizes the importance of air pollution and therefore investigates CO2 emissions. Here it was again trucking that underperformed the others, now respectively followed by the container vessel, train and the tug-barge vessel which had the least emissions. Their main finding regards the stimulation of the economic and environmental friendlier waterborne transportation over trucking. Actions as penalizing emissions or subsidizing less polluting transportation modes as marine vessels are named as stimulators for a transition to more waterborne transportation.

These findings are in line with recommendations that are made in the GLSLS Study (2007) to improve the use of intermodal short sea shipping in the Great Lakes – St. Lawrence Seaway (GLSLS) area. The study states that incentives need to be encouraged to use the environmental friendlier mode of waterborne transportation as a complement to rail and road transportation modes. Furthermore, institutional impediments that discourage short sea shipping have to be addressed. They also acknowledges that some parties need to take the lead in pilot projects and have to experiment with short sea shipping services.

The cost and emission advantages of short sea shipping are also found by Paixao and Marlow (2002). Other potential benefits of short sea shipping that they identify are: geospatial advantages such a directly useable waterways near populated areas, lower social costs concerning less traffic accidents, less need to build road and rail facilities, human resource advantages such as reduced truck driver shortages, capacity advantages by means of improved utilization of waterways and lastly secondary positive effects as increased employment and investment in shipbuilding and intermodal transportation.

Cost competitiveness of short sea shipping has already been demonstrated in the specific case for the GLSLS region. Several surveys conducted by the U.S. Army Corps of Mariners show that industries save approximately $2.7 billion annually by using waterborne transportation on the Great Lakes instead of trucks or trains (GLSLS Study, 2007).

A study by Higginson and Dumitrascu (2007) on short sea shipping in the Great Lakes area also supports the movement towards more cargo-related usage of the waterways. They specifically see the potential for the longer distance bulk market and the short distance Ro/Ro market for trucks and containers. The former market is already existing, though revitalization is needed throughout promotion of smaller ships coming with lower port fees, more efficient tug-barge combinations and improved transhipment connections in ports. The success of the short distance Ro/Ro market depends on guaranteed frequent, fast and reliable service year-round. This guarantee is of vital importance since fast moving Ro/Ro ships have to be imported from outside the US, in contrast with tugs and barges, which makes the investment threshold larger.

The urge for more sustainability in freight transportation and the proven emission advantages of (short distance) waterborne transportation in the literature make this type of freight transportation an interesting alternative compared to railroads and especially truck transportation. From the literature it also follows that the proven cost advantages of waterborne transportation have to be balanced out against longer transit times. Conclusively (short distance) waterborne transportation has in the current era of sustainability some serious advantages over other forms of transportation and opportunities to capture a larger market share are present. Since transit times usually are longer compared to other modes, less time-sensitive goods are suited in particular for waterborne transportation.

4.3 Logistical structure of agricultural commodities

On longer distances, inland water transportation is the popular choice of transportation considering a study by Miljkovic et al (2000). In a case study on grain exports from the US Midwest to the Mexican Gulf it appears that barge transportation is popular since many grain producers are located near the inland waterway system leading to export or transhipment locations. The study shows that barges and trains exhibit a strong substitute relationship which indicates competition between the two transportation modes. The results further suggest that historical freight rates on this export route are important indicators for the current ones and seasonality is also of importance on quantities and prices of grains shipped in this particular corridor.

Taylor and Roach (2009) also acknowledge the intensive use of the US inland waterway system by agricultural commodities and investigate intermodal competition for US grain exports to Europe. Four different routes and transportation modes are investigated, all originating from the US Plains: direct ocean going vessels via the GLSLS, a Laker vessel moving from Duluth to the Gulf of Mexico, train transportation to the Gulf of Mexico and a train movement to St. Louis combined with a barge transhipment. Taking direct ocean shipping as the base, both the train transportation option ($1.74 per ton) and the train/barge combination ($1.33 per ton) have cost advantages while the Laker vessel turns out to be $4.74 per ton higher in costs. Though they recognize that the Laker vessel is the most applied option in current practices. This may indicate that cost inputs for the model may be flawed or other decision variables are at stake. In a similar model regarding the Canadian market they obtain contradicting findings since a Laker vessel is the best alternative next to direct ocean going vessels.

This indicates that the most economical transportation mode is dependent on the origin and destination of the commodity.

In a Belgium case study about cross price elasticities, Beuthe et al (2001) find that agricultural commodities are generally shipped by truck. Moreover, a 5% price decrease in overall transportation cost will affect the demand of train transportation in a positive way over trucking. Inland water transportation hardly shows elasticity. According to the paper this is because this mode of transportation is not common for agricultural goods. Though, these findings may be difficult to generalize since it is a Belgium case study.

The growing grain production and export sector in South-America utilizes for exampe inland waterways more than road or train transportation. In many cases this is cost-driven but sometimes there appear to be no alternatives (Fuller et al, 2003).

The different modal preferences in the above literature demonstrate that geographical and spatial differences of countries and transportation routes have to be taken into account while assessing the logistical structure of agricultural commodities. When no inland waterways are in the vicinity of agricultural production sites, train or trucks are the preferred way of transportation. In case of nearby waterways marine vessels may be used more given that additional services and infrastructure are sufficient.

When agricultural commodities are shipped overseas, the logistical structure is more homogeneous than domestic or regional shipments. Agricultural commodities are usually shipped overseas by means of bulk vessels who carry the cargo from one port to another without a fixed itinerary. Freight rates, terms and conditions are usually negotiated by shippers and carriers. Both demand and supply influence the performance of the dry bulk shipping market. The market structure is also of influence and is highly competitive in the dry bulk shipping sector (Brooks, 2000).

A more recent trend in international agricultural shipping is the shift of traditionally bulk shipped commodities towards container shipments. Drivers of this transition include generally rising commodity prices, fluctuations and rises in bulk shipping rates, relatively stable and even declining container shipping rates and low container backhaul prices due to global trade imbalances and corresponding empty backhaul containers (Rodrigue and Notteboom, 2015). Conformingly, Clott et al (2015) find that 5% to 7% of the US soybean exports already move in ocean containers and with substantial business and government support this could be as high as 15%.

Lirn and Wong (2013) identify several advantages and disadvantages of containerized grain shipments for shippers and consignees. Advantages include small batch sizes, easiness to pick up, quality control and traceability. Limited accessibility to empty containers on farms, congestion in container yards, increase in cargo loss-ratio and low utilization of dedicated grain silos on farms and in ports are among the disadvantages. Moreover, Lirn and Wong prove in their case study that major Taiwanese grain shippers and importers value bulk and container shipment equal in performance and do not have a strong preference for one or the other.

Summarizing the literature on the logistical structure of agricultural commodities, one can notice that domestic and regional logistical structures are heavily dependent on geographical and route-specific characteristics. On the contrary, overseas international structures are more homogeneous and dominated by bulk carriers with a growing potential for containerized agricultural commodities.

Above all, in global competitive markets such as agricultural commodities, the optimization of transportation is not merely an opportunity for more profits but has become a growing need.

Transportation costs are a major factor in whether or not the price of an agricultural commodity is competitive in world markets (Clott et al, 2015).

4.4 Conclusion: many decision variables at stake but cost and transit time prevail

Three academic research fields have been investigated: decision variables that influence the chosen mode of transportation, benefits of (short distance) waterborne transportation and the logistical structure of agricultural commodities. From the investigated literature it follows that there are many decision variables that might be of influence on the modal choice in freight transportation networks. As expected, the transportation price and transit time are the most important variables.

Transportation price and time are also important with respect to the potential benefits of waterborne transportation since in many cases this form of transportation is lower in cost compared to train and truck transportation. On the other hand, the transit times are usually longer and therefore the trade-off between these variables needs to be considered while keeping in mind that different cargo types value transit time differently. In addition, waterborne transportation has significantly lower emissions than trucking and in some case also than train transportation. This benefit is however not widely recognized.

This thesis focuses on a possible transition in transportation mode while cost are found to be very important in this decision making process. The cost of switching from one mode to the other is therefore in particular of in interest regarding this research. These costs are set at 14% of the total transportation rate and will be used throughout the economic analysis.

As of the logistical structure of agricultural commodities it is noteworthy that domestic or regional structures are highly dependable on geographical characteristics whereas international structures are homogenous and favour bulk shipping above containerization. Here again, the importance of transportation costs are highlighted since these have to be as low as possible in order for an agricultural commodity to be competitive on the global market.

Combining and applying the above findings; transportation cost and time are of significant importance. Moreover, the type of commodity and characteristics of the transportation route must also be taken into account in order to answer the main research question and corresponding sub questions.

As already stated in the introduction of this chapter, the scope of this research has been kept in mind and the literature review contains a significant number of papers who are specifically dedicated to the US or Great Lakes region. There is also a number of papers included who investigate the agricultural sector in particular. Therefore one can conclude that the main findings in this chapter are applicable to this thesis and provide relevant insights.

5. Agricultural commodities in Michigan

The state of Michigan is one of the larger agricultural producing states in the US. In 2012 the economic value of agricultural production reached almost $8.7 billion in the state, ranking it the 18th state in the country (2015 State Agricultural Overview). The processing of crops has the largest share in total production with over $5.5 billion of economic value while the meat and dairy industry make up for the other $3.2 billion.

Growing over 300 different crops and producing all sorts of meat, flowers and dairy products, the state of Michigan has a diversified agricultural sector and the nation's second most diverse commercial crop base. The agricultural sector in Michigan generates over $96 billion annually in economic activity. Besides production, these economic activities include industries as processing, transportation and marketing. The agricultural sector, including all related activities, employs nearly one million Michigan residents, accounting for 22% of the state's workforce (Working Together To Reach The World, MDARD).

The agricultural diversification and the sector's significant contribution to the state's economy have several reasons. To begin with there is an abundance of natural resources in Michigan. The state is surrounded by fresh water, has a wide variety of soils and a moderate climate is present. Secondly, the established manufacturing sector has resulted in infrastructure investments which benefit both in and outer state connections. Moreover, Michigan's academic and government institutions foster an environment that supports agricultural production, research and development.

This chapter will continue with describing both the production and transportation of agricultural commodities in Michigan in more detail. By doing this, the most valuable and important commodities can be identified which is useful in order to answer the research questions of this thesis. Current transportation routes are identified as well. The third paragraph assesses the trade balance of Michigan in order to investigate what agricultural commodities and other goods are currently imported and exported. Finally an overall conclusion of the findings will be provided.

5.1 Production of agricultural commodities in Michigan

The term of agricultural commodities is carefully chosen since this usually does not include the livestock and dairy industry. This thesis will also not focus on fruits, vegetables or flowers. The main focus will be on grain and oilseeds which from now on will be referred to as agricultural commodities. When the whole range of agricultural products is being referred to, the term agricultural products is used.

The reason for taking this definition of agricultural commodities and the downsized research scope has two foundations. First, as mentioned earlier the focus of this thesis is on bulk goods because of the availability and activity of dry bulk ships in the Great Lakes area. Moreover, livestock products, dairies and fruits are usually transported in containers and in several cases also refrigerated containers are needed. Since container shipping on the Great Lakes is hardly existent, it makes the waterborne transportation of these products out of West Michigan less applicable.

Above all, the most prominent reason to focus specifically on agricultural commodities is derived from the fact that preliminary research learned that grains are the most exported agricultural products in terms of both value and quantity in the state of Michigan. To research possibilities of creating a new transportation hub in West Michigan one should take into account what is already produced and transported in the region in order to make the study as applicable as possible.

The top 5 of Michigan exported agricultural products is given below in table 2. Note that these exports are out of state and not per se shipped to international markets.

Table 2: Exported agricultural products out of Michigan: 2014

Commodity/product	Value in millions of dollar
Soybeans	578.9
Dairy products	332.2
Corn	255.0
Feeds and other feed grains	224.6
Wheat	136.5

Source: US Department of Agriculture, Economic Research Service (2016)

As seen in table 2, four out of the five most exported agricultural products out of Michigan are grains which can be transported in bulk. Dairy exports are of a substantial amount but this type of product is not suited for unrefrigerated bulk transport. In addition the ‘feeds and other feed grains’ category consists of several grains which are not specified in the data of the US Department of Agriculture and are hard to account for in other data sets and calculations.

Therefore, the focus will be on the other three most exported agricultural products of Michigan: soybeans, corn and wheat. Not only are these commodities the most exported products, they also account for the majority of agricultural goods which are produced in Michigan.

The following subparagraphs will elaborate more on all the three agricultural commodities individually. The average selling price per bushel in 2015 will be given as well as the 2015 value of production. A bushel is a common measurement standard for agricultural products all over the world and is derived from an old bucket measurement with a volume of 35.24 litres. All data is retrieved from the Crop Values 2015 Summary which is published by the USDA National Agricultural Statistics Service.

5.1.1 Soybeans

Following from table 2 soybeans are the most valuable agricultural export commodity in Michigan although in volume of production they are ranked second after corn. Specific export markets for each Michigan grown crop are hard to retrieve but USDA statistics (2016) show that Canada, Mexico, Japan, South Korea and China are the top export markets for Michigan’s agricultural commodities. Table 3 gives an overview of the production of soybeans in the state of Michigan.

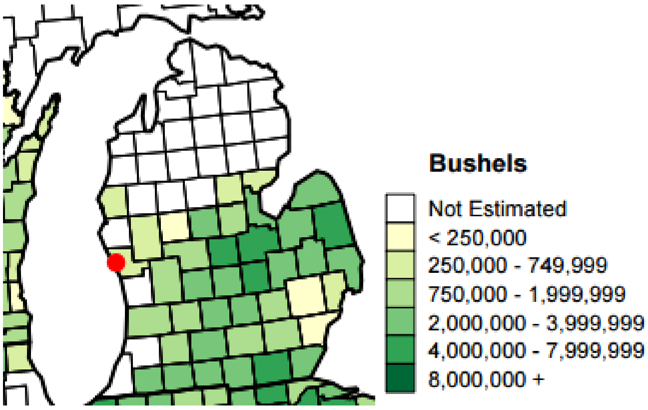
Table 3: Overview of soybean production in Michigan: 2015

Average price per bushel	$8.60
Average price per bushel in US	$8.80
Total value of production	$851,228,000
Percentage of total US value	2.46%

Source: USDA Crop Values 2015 Summary

The production of soybeans is concentrated in the Southeast region of the state. Figure 3 provides an overview of the production per county. The county of Muskegon is represented by the red dot.

Figure 3: Soybean production per county in 2015



Source: US Department of Agriculture, Economic Research Service

5.1.2 Corn

Corn is the most produced commodity in the state of Michigan. This is not only the case for Michigan but across the whole US. In the last decade 50% of the world corn was produced in the US. About 41.5% of the Michigan produced corn is exported outside the state, the majority of this corn is transported to the Southeast region of the US where it is fed to livestock (Corn Uses, Michigan Corn). Another major use of Michigan corn is the production of ethanol which accounts for 25% of the state's corn use. The feed industry is with a usage percentage of 19.4% the 3th largest market for Michigan corn followed by other purposes (6.6%), distiller grains (4.2%) and lastly the production surplus (7.2%). Table 4 provides an overview of the production of corn in the state of Michigan.

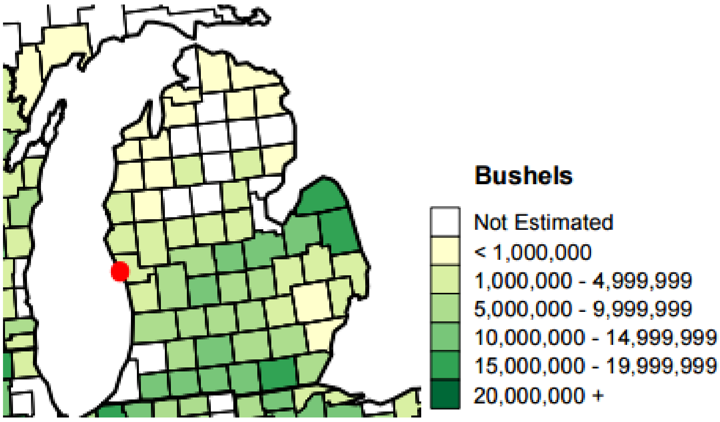
Table 4: Overview of corn production in Michigan: 2015

Average price per bushel	$3.50
Average price per bushel in US	$3.60
Total value of production	$1,173,690,000
Percentage of total US value	2.39%

Source: USDA Crop Values 2015 Summary

As is the case with soybeans, the production of corn is concentrated in the Southeast part of the state. In addition, the northern counties have a small share in corn production as well. Figure 4 provides an overview of the production per county. The county of Muskegon is again represented by the red dot.

Figure 4: Corn production per county in 2015



Source: US Department of Agriculture, Economic Research Service

5.1.3 Wheat

Of the three commodities under investigation, wheat is the least produced and exported one. An important distinction regarding the production of wheat is the growing season, the US Department of Agriculture makes the distinction between winter wheat and wheat that is grown during the whole year. The amount of wheat grown in winter and other seasons may vary significantly per season across states. Minnesota for example produced a total value of $422 million of wheat crops in 2015 while winter wheat only accounted for just over $10 million in value. Other states mainly produce winter wheat and the value of winter wheat is therefore the same as the total value of wheat production. Michigan is one of those states. Table 5 gives an overview of the production of total wheat production in the state of Michigan.

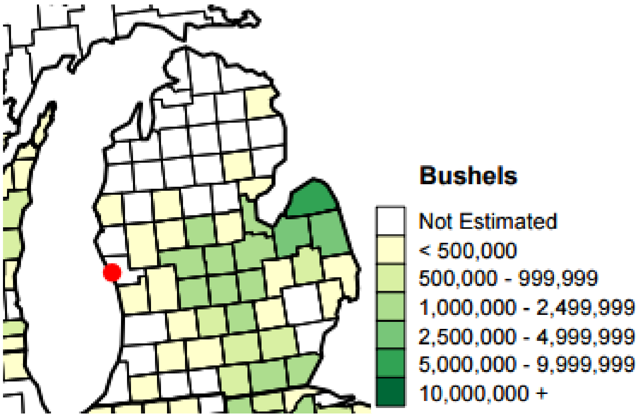
Table 5: Overview of total wheat production in Michigan: 2015

Average price per bushel	$5.65
Average price per bushel in US	$5.00
Total value of production	$217,384,000
Percentage of total US value	2.12%

Source: USDA Crop Values 2015 Summary

The production of wheat is more concentrated than those of soybeans and corn and particularly takes place in the mid-eastern counties of Michigan. Figure 5 provides an overview of the production per county. The county of Muskegon is depicted by the red dot.

Figure 5: Wheat production per county in 2015



Source: US Department of Agriculture, Economic Research Service

5.1.4 Conclusion

The export of agricultural goods out of Michigan is dominated by fives sectors: soybeans, dairy, corn, feed grains and wheat. Because of their ability to be transported in bulk, their significant production numbers and contribution to the state’s agricultural economy, the focus in this thesis will be on soybeans, corn and wheat.

Soybeans and corn show a number of similarities regarding their production. Both commodities are mainly produced in the south-eastern counties, have an annual price per bushel which is a fraction under the nationwide average and both represent approximately 2.4% of total US production value. The share of wheat in the national production value is of the same magnitude and therefore at just a fraction of the absolute value of both corn and soybeans. Moreover, wheat is mainly produced in the central and eastern counties while the annual wheat price in Michigan was 13% higher in 2015 than the national average.

The fact that most grain and soybean crops in Michigan are grown in the southern part of the state is partly due to the fact that the climate is colder in the north. This make the growing season shorter and circumstances less favourable.

Following from figures 3 to 5 one can conclude that the majority of the agricultural commodities in Michigan is produced east or south of Muskegon. In general Michigan's agricultural commodities travel from north to south heading for transhipment or export markets in Chicago, Toledo or other destinations. These findings may not be favourable for Muskegon since the majority of agricultural commodities geographically already passed Muskegon and have to make a detour when being shipped through the port of Muskegon.

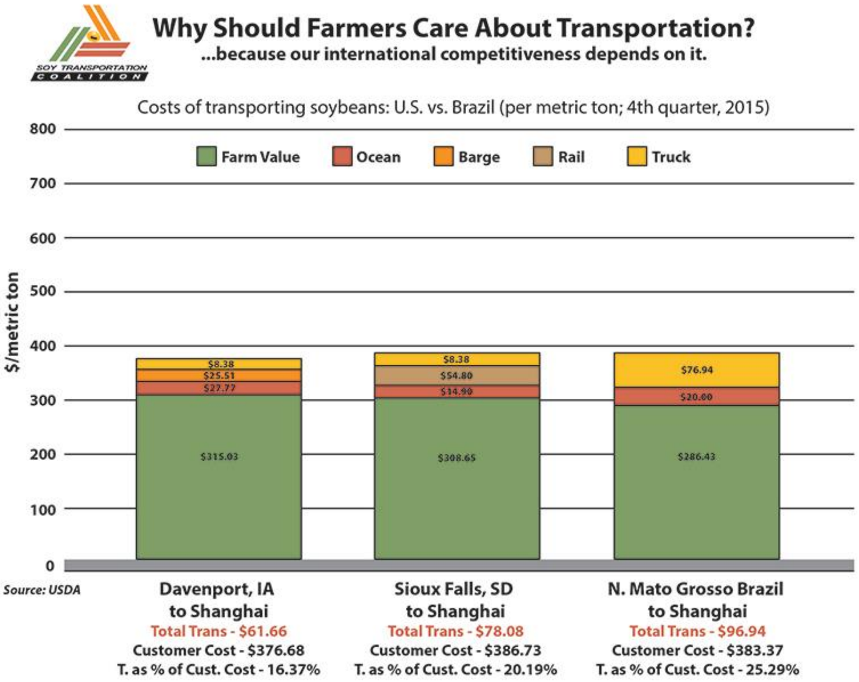
Interviews with field experts also learn that the Muskegon region is a net consumer of grains and feed grains since production is low and demand is relatively high because of the livestock and poultry industry in the area. Some developments in the Muskegon region involve the emergence of non-Genetically Modified Organic (GMO) grown crops but volumes are relatively low and not interesting for export markets yet.

5.2 Transportation of agricultural commodities in Michigan

Transportation is an essential part of the agricultural marketing process. Especially in the highly competitive global environment of agricultural commodities the logistical process can be determining for the international market position. For example, the 2013 per-bushel production cost for soybeans in the US Midwest averaged $9.26 while in Argentina this was only $7.14 per bushel and $7.68 in Brazil (O'Neil, 2015). Southern-American countries are therefore rapidly enlarging their market share on the international grain and oilseeds market. Nevertheless, the US is still able to be competitive since transportation costs from point to production are lower for US produced commodities.

This is also depicted in figure 6 which breaks down the consumer costs of a metric ton of soybeans in Shanghai in the fourth quarter of 2015. The soybeans are either delivered from two locations on the US Upper Plains or from Brazil. Figure 6 confirms the relative large share of transportation cost in the agricultural market which in this specific case fluctuates between the 16 to 26 percent.

Figure 6: Breakdown of consumer costs in Shanghai for a metric ton of soybeans (Q4, 2015)



Source: Soy Transportation Coalition, 2016

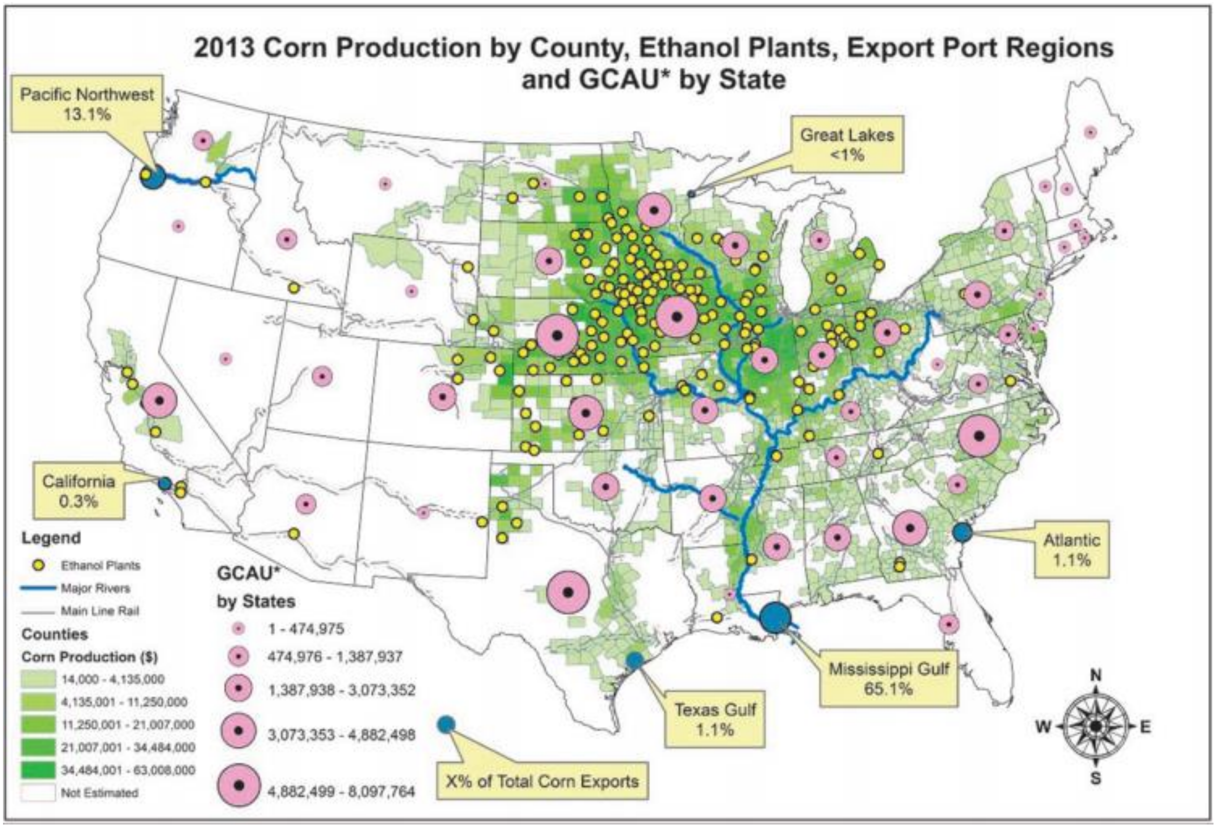
In the following sub paragraphs general background information is given on the transportation of agricultural commodities in the US. Michigan specific practices will be elaborated on subsequently.

5.2.1 Agricultural transportation in the US

The majority of agricultural commodities in the US is produced in the Midwest while being transported and consumed both domestically and internationally. The share of production which is exported internationally is different for every commodity. The value of export differs annually and depends on factors as domestic demand, weather conditions and harvest yield. The share of exports compared to domestic consumption also differs for the three commodities under investigation, especially for corn compared to the other two. The share of production that is exported for the three commodities is 16.9%, 54.8% and 54.6% for respectively corn, soybeans and wheat (USDA Crop Values 2015 Summary).

Figure 7 gives an impression of the corn production and the major export ports. Soybeans have a similar concentration of production and transportation. Wheat however is also produced in the central states and north-western part of the US. The connectivity of the port of Muskegon to the inland US waterway system will be explained in chapter 6.

Figure 7: Corn production, transportation system and export ports



Source: USDA Agricultural Marketing Service analysis of data from USDA National Agricultural Statistics Service State and county level statistics 2013 and Federal Grain Inspection Service port inspection data

Two major observations on US agricultural transportation flows follow from figure 7. First the major share of international exports that flow through the Mississippi Gulf region and secondly the importance of inland waterways considering those exports. Keeping the scope of this thesis in mind it is also interesting to note the small share of the Great Lakes region regarding corn exports. Corn exports from the Great Lakes region mainly flow to Canada but overseas shipments from Duluth, Superior, Milwaukee and Toledo to European, Northern African and Asian ports are also seen (USDA statistics, 2016).

While investigating the modal share of US grain exports, the importance of waterways for grain transportation out of the country is confirmed since barge transportation accounts for 55% of the total transported grain designated for international exports. This means that 55% of the total US grain exports travel the inland waterway system by (barge) vessel before being transhipped onto ocean-going vessels in seaports. The modal share of both international grain exports and domestic shipments is given in table 6. The grain category consists of corn, soybeans, wheat, barley and sorghum. The latter two are only of small relevance whereas corn is dominating both the domestic and export volumes.

Table 6: Modal share of total US grain transportation, both domestic shipments and international exports, year: 2013

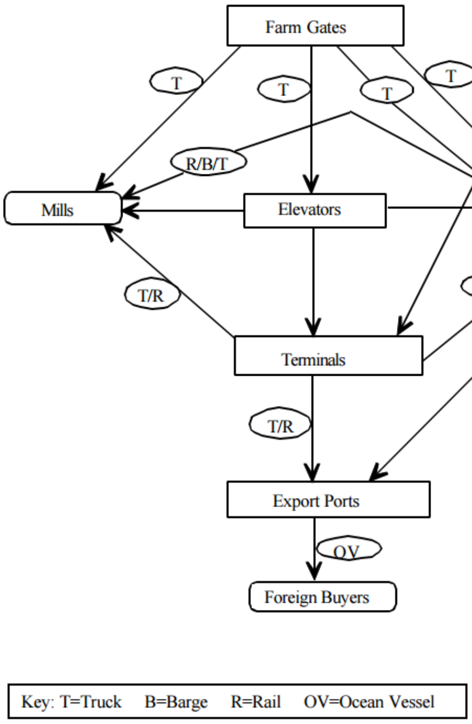
Destination	Rail	Barge	Truck
Domestic	21%	1%	78%
International	35%	55%	20%

Source: Transportation of US Grains: A Modal Share Analysis (Sparger and Marathon, 2015)

Truck transportation is the dominant mode for domestic grain shipments while internationally this mode of transportation is the least popular one. The opposite transportation characteristics are found when inland water transportation is considered whereas railroad transportation has both domestically and internationally a substantial share. These numbers and figures specifically apply to the US grain market and provide a good indication of the general transportation structure of agricultural bulk commodities in the US.

Agricultural commodities usually go through several transhipment hubs or terminals before reaching their final buyer's destination. Transportation from farm to final destination, including all intermediate stops, are commonly executed by more than one transportation mode. Park and Woo (2001) identify the general logistical structure of grain commodities which is depicted in figure 8.

Figure 8: General logistical structure of grain transportation in the US



Source: US/Canada Grain Handling and Transportation systems (Park and Koo, 2001)

5.2.2 Agricultural transportation in Michigan

The modal split that is observed in domestic grain transportation is also representative for the modal split in the state of Michigan considering agricultural goods. Truck transportation accounts for 89.5% of all agricultural transportation within Michigan while train transportation makes up for the remaining 10.5% since the share of waterborne transportation is negligible (Freight White Paper, 2016). Although these numbers regard all agricultural products, it provides an estimation of the modal split considering the three agricultural commodities under investigation.

Nevertheless there is some waterborne transportation of agricultural products out of Michigan. Data of the Freight Analysis Framework (2015) shows that a certain amount of agricultural products (including animal feed products and soybean products) is shipped from the east-side of Michigan to the state of New York before being transhipped onto ocean going vessels which generally head for destinations in South-East Asia, Europe and South-America. Specific ports are not named in the data but since Saginaw is the only port in Michigan with a grain elevator, this is probably the place of origin together with possible containerized shipments from Detroit in Michigan. Similar reasoning leads us to Buffalo (Lake Erie) and Rochester (Lake Ontario) as transhipment hubs in New York where the commodities set sail for their final destination overseas.

An overview of agricultural related commodities that leave Michigan via water is given in table 7. The commodity categories are very broad but 'other ag. products' includes soybeans and their processed products. Grains as corn and wheat have their own category but are not in the top 5.

Table 7: Waterborne agricultural commodities transported out of Michigan, all shipped to domestic hubs before overseas exports (year: 2015)

Destination	Domestic transhipment hub	Commodity	Value (millions)	Volume (kilotons)
Rest of Americas	New York (state)	Other ag. products	$4.28	5.09
South-East Asia	New York (state)	Other ag. products	$3.60	7.29
Eastern Asia	New York (state)	Animal feed	$2.57	9.94
Europe	New York (state)	Animal feed	$1.77	0.75
Europe	New York (state)	Other ag. products	$1.62	1.76

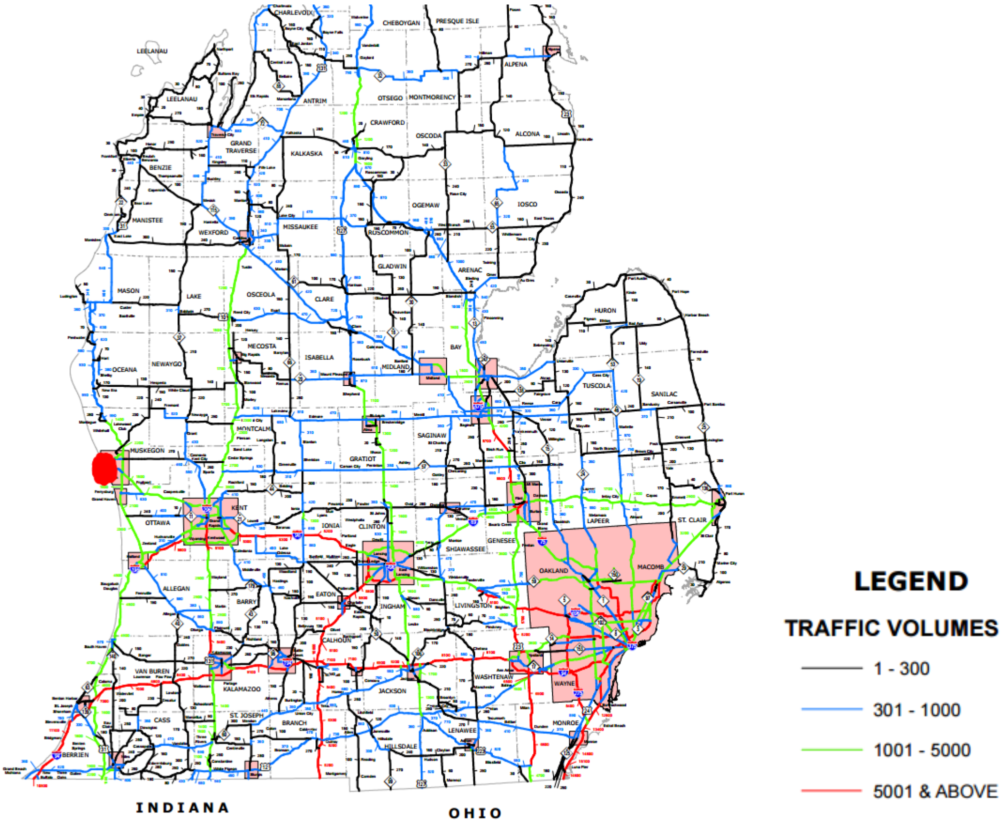
Source: Freight Analysis Framework (2015)

The fact that all agricultural products which are shipped via water out of Michigan are heading east is not beneficial for the Muskegon case. Combine this with the fact that most of the agricultural commodities are also produced in the south-east region and shipping from Muskegon will yield both extra miles travelled over land to reach the port of Muskegon plus three extra days on water to sail around Michigan before arriving in Lake Erie. Paragraph 6.3 will elaborate more on this disadvantage.

Grain transportation via the Great Lakes is also not very common these days considering that only 1.8% of total US grain exports flows through the Great Lakes – St. Lawrence Seaway system while the majority of production takes place in the GLSLS region. Moreover Michigan has only one port, located in Saginaw at the eastside of the state, with a grain elevator (Greenwood's Guide to Great lake Shipping, 2013). The Lion's share of waterborne grain exports through the GLSLS system is shipped out of Duluth, Superior, Toledo and Milwaukee (U.S. Dept. of Agriculture, 2015). According to interviewed field experts, waterborne transportation is indeed the least popular transportation mode for Michigan's agricultural exports.

As already suggested by figures 3 to 5, the majority of agricultural commodities is transported in the southern part of the state since these commodities are produced there and usually have southbound export flows. Figure 9 confirms this and shows the commercial road traffic volumes in the state of Michigan, the county of Muskegon is marked with a red dot.

Figure 9: Commercial road traffic volumes in Michigan, year: 2013



Source: Michigan Department of Transportation, 2013 commercial ADT maps

Further public information is hardly available on this specific topic but interviews with field specialists learn that most of the agricultural commodities are indeed shipped out of state by train and foremost truck. The grain transportation of agricultural commodities which stays within the state is dominated even more by trucks while intra-state train usage is negligible.

Train transportation becomes more attractive on longer distances out of state and the majority of Michigan train exports flows to south-eastern states as Virginia, North Carolina, South Carolina and Georgia for the use in de feed industry (State Rail Grain Statistical Summary, 2013). This data also reveals that train transportation rates in Michigan are the highest in the US. The high train transportation costs are confirmed by both public available train rates and field experts. They argue that these high rates are the result of monopolistic market power of one train operator. Additionally, the location of Michigan as a peninsula state with few state-borders and natural crossings is also driving the train rates up.

Out of state destinations also include major transhipments hubs as Chicago or Cincinnati through which grains eventually flow to the Mississippi River via respectively the Illinois River or Ohio River before ocean transhipment in the Gulf region. The available data does not provide any specific numbers on the flow of Michigan grown agricultural commodities through these major transhipment hubs but field experts argue that the quantities are moderate.

A large number of soybeans flow directly by train to the Gulf region. In 2010 more than 400,000 tons of soybeans were shipped out of State to the Gulf region by train. The largest export market for these soybeans are China, Japan and Europe (Farm To Market – A Soybean's Journey, 2012).

As for the three commodities of interest, they are also shipped directly out of Michigan to a number of foreign export markets. However these export volumes are not very high. As expected soybeans are the most exported commodities and a substantial portion finds its way to Canada by either truck or train. A limited amount of soybeans also flow directly to Japan, Indonesia and Thailand by marine vessel. Almost all the corn that is directly exported out of Michigan finds its destination in Canada via train, truck or marine vessel. Wheat is significantly the least direct exported commodity under investigation and is exported to Vietnam by marine vessel or via land or water to Canada (USDA statistics, 2016).

5.2.3 Conclusion

Transportation of agricultural commodities in the US has different characteristics for domestic and international destinations. In the former case trucking is the dominant transportation mode while barge transportation is of major importance in exporting agricultural commodities internationally. In both cases agricultural commodities are hardly transported directly from the farmer to the final buyer. Multiple intermediate stops are made and transportation modes differ between those stops.

The general findings considering domestic US grain transportation also apply for Michigan since truck transportation is dominant while railroads have a substantial share and waterborne transportation is almost non-existent. The high train rates in Michigan surge both inner and out of state truck transportation levels. The small amount of direct international exports out of Michigan are executed by all three modes of transportation. Despite the fact that Michigan is surrounded by water, the use of waterborne transportation is very limited.

5.3 Trade balance of Michigan

In order to assess the possibilities of a port revitalization, the macro-economic environment has to be investigated as well. This will be done by analysing import and export figures of Michigan. Agricultural imports and exports will also be assessed. All data is retrieved from the United States Census Bureau (2016) unless otherwise stated. Moreover, only international trade is under investigation.

5.3.1 General imports and exports

The well-established automobile manufacturing sector in the Detroit area flourished the Michigan economy in the early and mid-decades of the last century. Despite setbacks in the last decades and most recently during the 2008 financial crisis, the automotive industry still puts a large mark on the state’s economy. This is also shown in the export and import figures.

In 2015 Michigan accounted for a total export value of $54 billion of which the lion’s share is automotive related, 22 out of the 25 top exported commodities are related to the automotive industry. Silicones, natural gas and nickel ores are the only exceptions. Major export partners are Canada ($23.5 billion), Mexico ($11.8 billion), China ($3.2 billion), Germany ($1.9 billion) and Japan ($1.2 billion). Approximately 95% of the total exports originated from the greater Detroit area.

The 2015 Michigan import figure is with $124.2 billion significantly higher than the value of exports. However, drawing the conclusion that the state of Michigan faces a major trade deficit is not per se correct since the Census Bureau statistics do not account for re-exports and re-imports. This implicates that a number of goods from Canada only enter the US via Michigan while being re-exported to other states. Because Michigan and especially Detroit are important trade links for the US with Canada, this deficit may be smaller when correcting for this shortcoming.

Michigan imports are even more dominated by the automotive industry since crude oil is the only commodity in the top-25 that is not directly related with automotive manufacturing. The most important origins of import are Canada ($45.8 billion), Mexico ($43.9 billion), China ($9.2 billion), Germany ($4.4 billion) and Italy ($3.4 billion). The presence of Italy in this list is a sparkling example of the major impact the automobile industry has on the Michigan economy. Since the merger of Detroit based Chrysler and the Italian Fiat Group in 2014 (Wayland, 2014), imports from Italy into Michigan quadrupled in 2015.

5.3.2 Agricultural imports and exports

Paragraph 5.1 and table 2 already provide an introduction with respect to the export of Michigan produced agricultural products. However, these are out of state exports and this paragraph only investigates international exports. In this analysis, the data is retrieved from the USDA Foreign Agricultural Service.

The total international export value of Michigan produced agricultural products reached $1,870 million in 2015. The product categories with an export value of more than $100 million consist of prepared foods ($383 million), beef products ($168.4 million), fresh vegetables ($158.8 million), poultry products ($128.1 million), forest products ($174.8 million) and soybeans ($112.8 million). Except for soybeans all other export categories represent a broad number of specific products. This justifies the focus on soybeans since it is the most exported single product category.

As is the case with general Michigan exports, most of the agricultural exports find their destination in Canada with an annual value in 2015 of $1,089 million. Other top export destinations include Mexico ($115 million), China ($101.8 million), Japan ($91.7 million), South Korea ($75.7 million) and Thailand ($71.6 million).

Data on imports are retrieved from the Freight Analysis Framework (2015) and is less specific categorized than United States Census Bureau or USDA data. The top-5 of agricultural import categories consists respectively of other foodstuffs ($2,011 million), milled grains ($1,379 million), meats ($760 million), other agricultural products ($453 million) and animal feed ($311 million).

Corn, soybeans and wheat are grouped under other agricultural products, together with several other commodities. One can therefore conclude that the commodities of interest are not imported on a major scale into the state of Michigan. However, specific data is missing.

The data also shows that all of the above categories plus other major agricultural imports into the state of Michigan reach the state border from Canada to Detroit by truck. This finding is biased since only direct imports are accounted for and re-exports to or re-imports from other domestic destinations are not corrected for.

5.3.3 Conclusion

The general trade balance of Michigan is characterized by the automobile industry which accounts for the majority of both imports and exports. Moreover the trade balance shows a severe deficit. Although this may partially be due to not correcting for re-imports, the deficit is very substantial and has grown in the 2012-2015 period while total exports decreased with 5.2% and imports rose 6.9%. Another trend is the reduced trade with the state's primary trade partner: Canada. Especially considering imports into Michigan, Canada may lose her position as top importer since imports fell 7.5% between 2012 and 2015 while Mexican imports grew 15.5%. Mexico is now only $1.8 billion behind Canada and chances are that this backlog is cleared on short term.

Agricultural international exports are dominated by brought categories which are meat or vegetable related while soybeans is the only single product category in the top exports. Data on agricultural imports is not very detailed but dominated by brought categories as well. Like the general trade balance, the agricultural balance shows a deficit too. On the contrary the agricultural deficit is smaller and has been declining in the last years.

Canada and Mexico are the most important trade partners considering both imports and exports for general trade as well as agricultural trade. Asian and European countries are relevant secondary markets.

5.4 Conclusion

This chapter provides a number of findings which are useful in order to assess the research questions. First of all the majority of agricultural commodities in Michigan are produced south-east of Muskegon and are transported further south. This challenges the possibility of Muskegon to become an agricultural transportation hub.

From chapter 5.2 it follows that transportation costs are very important in the marketing of agricultural commodities. This partially results in the preference of barge transportation for long distance grain exports in the US while train and especially truck follow with substantial distance. On the contrary, domestic bound grain transportation is dominated by road transportation, followed by train transportation. The share of domestic waterborne transportation is almost negligible.

Agricultural transportation in Michigan has the same characteristics as US domestic grain transportation. Therefore waterborne transportation out of Muskegon is first of all a challenger of the status quo and may have the best option of succeeding when focussing on already existing barge movements down the Mississippi River or overseas exports.

The trade balance of Michigan finds itself in a growing deficit. As for agricultural products this deficit is also present but is slowly declining in the recent years. Nevertheless the state of Michigan is a net exporter of corn, soybeans and wheat. Focussing on this strength while trying to market and distribute these commodities with better infrastructure might benefit both the agricultural and general trade balance of Michigan.

6. Possibilities of waterborne transportation routes out of Muskegon

In order to assess the possibilities of waterborne transportation from the port of Muskegon several steps will be undertaken. First the Great Lakes – St. Lawrence Seaway will be investigated since the port of Muskegon is connected to this inland water basin. Subsequently the Chicago Area Waterway System will be elaborated on because this is a major waterborne transportation hub in the vicinity of Muskegon. Lastly the possible waterborne transportation corridors out of Muskegon will be investigated. These corridors will be the starting point of the economic analysis.

6.1 The Great Lakes – St. Lawrence Seaway

Completed for deep draft ships in 1959, the St. Lawrence Seaway connects the Canadian and US Great Lakes with the Atlantic Ocean. Originally the St. Lawrence Seaway was designed to carry grain from the North American prairies to markets in Europe and the Soviet Union. Both political and economic factors reduced the grain demand in those markets in the subsequent years (GLSLS Study, 2007). Alternative grain buyers are nowadays found in the Pacific region and iron ore replaced grain as the main commodity to be transported in the Great Lakes – St. Lawrence Seaway (GLSLS) region.

The GLSLS waterway stretches over 3,700 kilometres from the Atlantic Ocean to the most western point: Duluth, Minnesota. This makes the GLSLS system the world longest deep draft commercial waterway (Annual Corporate Summary 2015-2016). Its 15 locks will eventually elevate ships 183 metres from sea level on Lake Superior. The maximum draft on the St. Lawrence Seaway is 8.15 metres which allows ships of approximately 30.000 tons into the Great Lakes basin. The cargo transportation within the GLSLS is of vital importance for both the Canadian and US economy. A study by Martin Associates (2011) shows that the GLSLS cargo transportation supports $35 billion in economic activity, 227,000 jobs and $14.6 billion in wages.

Together with more than 110 other ports the port of Muskegon is part of the GLSLS system. The port is located in the state of Michigan, approximately halfway on the east side of Lake Michigan. Together with lakes Ontario, Huron, Erie and Superior these five lakes plus the Gulf of St. Lawrence make up for the GLSLS region. The US states that adjacent to the Great Lakes are originally referred to as the 'Manufacturing Belt' because of the heavy industries that are located in the area. Since the mid-20th century however, heavy industries are declining because of increased automation, moving industries to the west side of the country, free trade agreements and outsourcing of jobs (Washington D.C.: Congress of the United States, 1980). This deterioration led to the region's new nickname 'Rust Belt' and also has consequences for both in- and outbound transportation on the St. Lawrence Seaway. In the heydays during the 1960's and 1970's an average of 53 million tons of cargo was transported annually on the St. Lawrence Seaway compared to 36.25 million tons in 2015 (The St. Lawrence Seaway Traffic Report: 2015).

When breaking up this annual tonnage of cargo it appears that mine products as iron ore, salt and coal are the most important commodities (15.88 million tons). Agricultural products are secondly ranked (10.86Mt) and dominated by wheat followed respectively by soybeans, corn and rapeseed. Processed products (9.50Mt) are the third category of shipped commodities and mainly consist of iron and steel, petroleum products and chemicals.

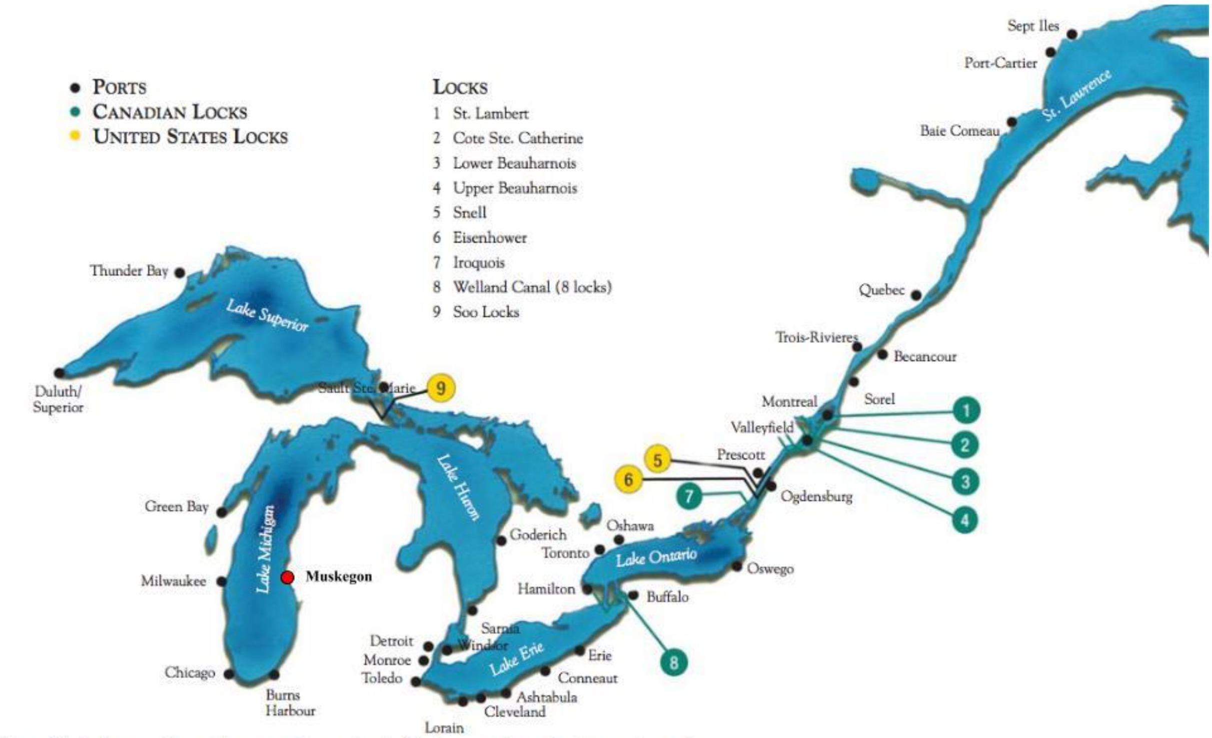
The lion's share of these commodities is shipped in bulk or break-bulk carriers while petro-chemicals are shipped by tankers. Container shipments in the GLSLS system are rare and only 0.2% of total commodities are shipped in containers (The St. Lawrence Seaway Traffic Report: 2015).

Although the above figures provide a good indication of waterborne transportation in the Great Lakes – St. Lawrence Seaway area, it does not account for cargo that is shipped within the Great Lakes itself.

The total cargo tonnage moved on both the Great Lakes and St. Lawrence Seaway reached over 164 million metric tons in 2010 (Martin Associates, 2011). This leads to the conclusion that the majority of shipped cargo on the Great Lakes has both his origin and destination within the GLSLS area itself. This conclusion is supported by Taylor and Roach (2009) who notice a shift from ocean-going commerce towards intra-lake commerce. Iron ore is the major component of the cargo shipped within the GLSLS system; between 1995 and 2003 the average annual tonnage shipped was 261 million metric tons of which 103 million consisted of iron ore loadings. The top 5 cargo's in this time period is complemented with respectively stone (51Mt), coal (37Mt), grain (17Mt) and steel (8Mt).

An overview of the Great Lakes - St. Lawrence Seaway is given below in figure 10. The port of Muskegon is added to the original figure because of the scope of this research.

Figure 10: overview of the Great Lakes - St. Lawrence Seaway



Source: The St. Lawrence Seaway Management Corporation, the Saint Lawrence Seaway Development Corporation

A drawback of shipping on the Great Lakes and St. Lawrence Seaway is the cold weather during winter which results in icing and closure of the waterway system. The GLSLS usually closes for commercial traffic at the end of December and reopens at the end of March. This results in an average number of approximately 280 operating days per year (The St. Lawrence Seaway Traffic Report: 2015). During the closure goods that normally move via the St. Lawrence Seaway do not move at all or via alternative modes and routes. Specialized ice breaking vessels are also able to make water transportation possible during the winter but high costs are involved.

Observations from the GLSLS Study (2007) predict a growing global economy with more trade and more cargo transportation on both Canadian and US high- and railways. Combine this with the fact that the GLSLS system currently operates at only half of its capacity and the region's marine transportation mode can increase the region's transportation capacity while reducing congestion in both the highway and railway system. Conditions for this perspective situation include a good integration of the waterway system with highway and railway networks plus a research and development agenda which focuses on new technologies to improve port efficiency and linkages to other transportation modes.

6.2 Chicago Area Waterway System

The Chicago Area Waterway System, depicted in figure 11, is part of the greater Chicago area transportation hub which is the largest inland port in North America. Its annual container volume throughput of 12.85 million TEU's exceeds those of Los Angeles/Long Beach and New York/New Jersey (OECD, 2012). Because of its central location 46% of all US intermodal transportation touches the port of Chicago while connecting the US East Coast, West Coast and Gulf of Mexico.

Figure 11: Overview of the Chicago Area Waterway System

Source: US Army Corps of Engineers (2011)

Freight movements in the greater Chicago area are dominated by road (67%) and train (30%) transportation while air and waterways only account for a small portion of transported freight (Go To, 2040). Nevertheless both road and train transportation face major problems which are mainly congestion related. The total road congestion in the greater Chicago area costs more than $7 billion each year in lost fuel and productivity. The regional railroad infrastructure which hosts six out of seven Class 1 North American railroads also faces major congestion problems while rail freight traffic can take up to 30 hours to move through Chicago (Clott and Hartman, 2016). Despite this congestion problems the value of regional train freight is expected to grow with 89% by 2035 since crude oil shipments, agricultural products and intermodal transportation are significant rail growth drivers.

Although waterborne transportation in the Chicago area is relatively of small importance it is non negligible and the Chicago Area Waterway System (CAWS) is the only regional connection of the Mississippi River with the GLSLS system and the Atlantic Ocean. Once it was the preferred way of shipping of a wide variety of goods in and out the greater Chicago area but evolvement of the transportation system resulted in a sharp decline of the waterborne transportation share. Nevertheless, the CAWS remains important for especially bulk goods over longer distances because of competitive low transportation prices. This is also found when investigating the top commodities that are shipped through the CAWS which are all relatively low-value bulk goods. Table 8 provides an overview of the top waterborne commodities transported in the CAWS.

Table 8: Top waterborne commodities in the Chicago region, 2012 tonnage

Commodity	Volume (kilotons)
Coal	9,785
Gravel	7,165
Non-metallic minerals	6,656
Basis chemicals	3,162
Cereal grains	2,360
All other	2,331
Total	**31,729**

Source: Chicago Metropolitan Agency for Planning analysis of 2012 FAF date

The majority of the above commodities are shipped through the Illinois River and Mississippi River before departing from or arriving in the CAWS. As seen in subparagraph 5.2.1 most of the agricultural commodities are transhipped in the Mississippi Gulf region for international exports.

Shipping goods from Chicago to Muskegon or vice versa is no problem although hardly any goods move on this route. Shipping goods through the CAWS to Muskegon however, is not possible. This is due to the fact that US Coast Guard regulations prohibits river barges from moving into the Great Lakes basin. Some exceptions are made but strict conditions have to be met and the route to Muskegon is not included in those restrictions. The next paragraph will elaborate more on the US Coast Guard regulations regarding this topic.

6.3 Possible waterborne transportation routes for agricultural commodities

From the literature review in chapter 4 it follows that waterborne transportation offers a number of advantages compared to road and rail transportation. Especially for lower value bulk goods which are not very time sensitive, such as grains and oilseeds, transportation by marine vessel may be favourable.

To assess whether waterborne transportation from the port of Muskegon offers substantial transportation advantages compared to current non-waterborne transportation, certain specific corridors must be investigated. This paragraph provides information on the five corridors which are going to be assessed more thoroughly. The corridors and corresponding routes all flow via Muskegon and have four different destinations. In order to assess the economic analysis to its full extent in chapter 7, a comparison has to me made to already existing transportation modes and routes. Table 9 provides an overview of the five (partial) waterborne corridors and routes under investigation, including the benchmark routes whom they will be compared to.

Table 9: Five corridors from Muskegon to their destination, including investigated routes

Corridor	Route originating from Muskegon	Benchmark route
Muskegon - Chicago	Barge to Chicago	Train/truck to Chicago
Muskegon – New Orleans	Direct barge through Mississippi River	Train/truck to Chicago – river barge + direct train shipment
Muskegon – Canada – Asia	Laker vessel to Thunder Bay – Train to Prince Rupert – ocean vessel	Train/truck to Chicago – train to Seattle – ocean vessel
Muskegon – Quebec – Asia	Laker vessel to Quebec – ocean vessel	Truck to Chicago – barge to New Orleans – ocean vessel
Muskegon – Quebec – Europe	Laker vessel to Quebec – ocean vessel	Truck to Chicago – barge to New Orleans – ocean vessel

The first four routes have eventual south or westbound destinations. The reason of excluding north-bound destinations is the fact that Canada is the only export market in that region. Canada is a major producer and exporter of wheat and to a smaller extent soybeans and corn (Canadian Grain Exports, 2015). Besides, the vast majority of agricultural products that flow from Michigan to Canada are shipped by truck via eastern-located Detroit (Freight Analysis Framework, 2015). Therefore shipping agricultural commodities from western-located Muskegon by water to Canada will have very little potential to be successful.

Following from table 7 some agricultural goods are exported by marine vessels via transhipment hubs in New York before moving to multiple destinations all over the world. These east-bound shipments all originate from the east-side of Michigan because of the presence of a container plus grain port and the fact that the agricultural goods are mainly produced in this part of the state. Successful waterborne shipments from Muskegon to these east-bound transhipments hubs are therefore very challenging. The majority of agricultural products, which are produced in the south-east region of the state, first have to travel some extra miles with truck to reach the port of Muskegon before sailing three extra days on Lake Michigan and Lake Huron in order to reach the Michigan and Ohio ports who are located on the east side.

This detour is depicted in figure 12. The capital of the state, Lansing, which is located in the hearth of state's grain production is taken as starting point and is marked with the blue dot. The land route to Detroit is depicted in green while the route via Muskegon is indicated with the red line. The two transhipment ports in the state of New York, Buffalo and Rochester, are indicated with purple dots.

Figure 12: East-bound routes originating from Lansing, Michigan via Muskegon (red line) and Detroit (green line).

Source: Searates.com, route explorer

Although the east-bound routes may not seem feasible to operate from the port of Muskegon compared to the eastern located ports as Detroit and Toledo, waterborne shipments to Europe and Asia via the GLSLS will be investigated. This follows from the fact that Muskegon offers some advantages as non-congested intermodal connections and the lack of a port authority which results in the absence of port fees. When an overall port authority will be initiated in Muskegon, port fees will probably be introduced fairly quickly. If they are similar to the fees used in Milwaukee (Port of Milwaukee, 2015), the transportation costs per metric ton will be influenced depending on the length of the route. An introduction of port fees will increase the total transportation rate from Lansing to Chicago for example with approximately 5% while rates on longer overseas routes will increase with less than 0.5%. However, the introduction of a port authority and initiation of port fees is a long term scenario and will therefore not be accounted for in the economic analysis. Besides these moderate advantages the assessment of the east-bound routes is foremost included to make this thesis assessment as comprehensive and thoroughly as possible.

Including two routes to Asia may seem senseless. However, Asia is the largest US agricultural export market and commodities flow through multiple corridors since producers and shippers have different preferences for transportation modes or routes. Assessing two routes with different characteristics is therefore of added value to the economic analysis. Moreover, the Michigan grain exports via the west side of North America are mainly transported by train while the route via Quebec is dominated by waterborne transportation. This distinction in main transportation mode justifies the assessment of both routes.

Having set the focus of the transportation flows, each corridor flowing through Muskegon will now be discussed more in detail. Both characteristics and reasoning of a possible economic feasibility of the route are provided.

6.3.1 Muskegon – Chicago – New Orleans

Following from chapter 5 a portion of the Michigan grown agricultural commodities is shipped to Chicago by truck or train for further transportation. Most of these commodities originate south of Muskegon and therefore do not flow naturally by Muskegon since Chicago is also located south of Muskegon, this results in extra transportation miles. On the other hand there are some advantages which include the heavy road and rail congestion in the greater Chicago area and the fact that truckloads within the state of Michigan itself are allowed to be twice as heavy compared to interstate transportation to Chicago (MDOT Intermodal Policy Division, 2013). These practical advantages plus possible cost advantages make this route worth investigating.

Another interesting finding in chapter 5 is the major importance of the Mississippi River and Gulf regarding the export of grains. A major share of the Midwest produced grains are moved through the Mississippi River before being transhipped to international ocean-going vessels. Grains originating from Chicago also move on this route after being loaded on a river barge via the Illinois River. US Coast Guard Regulations prevent these river barges to move directly into the Great Lakes basin because of the lack of a load line. This makes direct shipment from Muskegon to the Mississippi Gulf impossible since the grains have to be transhipped in Chicago on proper river barges. This transhipment results in extra cost and transit time.

Nevertheless successful efforts have been made to allow a river barge into Lake Michigan. Situated across Lake Michigan from Muskegon, the port of Milwaukee operates such a river barge line for more than 20 years. They are allowed to do so since a number of strict conditions are met and route specific characteristics are favourable. The restrictions include a transportation maximum of three barges at one time, the age of the barge must not exceed 10 years, the route must be operated within 5 miles of the shore, only non-hazardous dry cargoes may be transported and the weather conditions must be sufficient.

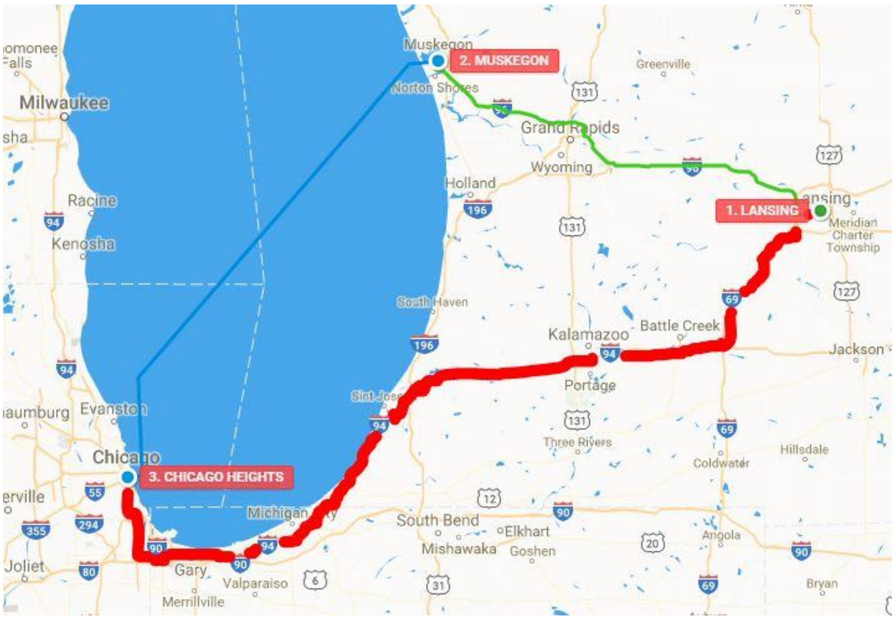
Efforts have also been made by Muskegon authorities but turned out not to be successful yet, mostly because of route specific characteristics which are less favourable compared to the Milwaukee route. The US Coast Guard points out that the weather conditions on the eastern side of Lake Michigan are more severe than on the west side. Non-load lined river barges may be less stable than lake barges and are therefore less safe to operate on the east side of the lake. Moreover, in case of changing weather conditions the ports of refugee on the Chicago – Muskegon route are not sufficient according to the US coast guard (Federal Register, 2015). Only three ports may be used to shelter and the longest distance between two of them is 47 nautical miles compared to 33 nautical miles on the Chicago – Milwaukee route. Additionally the absence of both an economic analysis and a risk assessment have made the US Coast Guard to deny the petition for exemption of river barges on the Chicago – Muskegon route on April 21, 2015.

The direct access from Lake Michigan into the US inland river system and therefore access to the largest US grain export hub at the Mississippi Gulf may offer substantial advantages for Muskegon originated grains. It is therefore that a hypothetical direct barge operation to the Mississippi River with New Orleans as transhipment destination will be investigated. Moreover, one of the main arguments of the US Coast Guard to decline the request for direct barge access from Muskegon to the inland river system was the lack of an economical assessment of this route. This thesis may contribute to overcome the lack of such an assessment.

In addition, a direct barge line from Muskegon with final stop in Chicago will also be investigated. Grains on this line are either terminated in Chicago or further shipped to destinations by means of train or truck. This route is assumed to be operated by a load lined hopper barge which is allowed under current regulations. A field expert however notes that covered hopper load line barges are very scarce within the GLSLS system since most grains are transported by dry bulk carriers.

A sketch of the of the current grain transportation to Chicago by land, originating from south-east Michigan and the waterborne alternative is provided in figure 13. The red line depicts the direct truck transportation route while the green line indicates the truck route to Muskegon, followed by the blue line which represents the waterborne route.

Figure 13: Comparison of current land transportation of grains from Michigan to Chicago and waterborne option originating form Muskegon



Source: Searates.com, route explorer

The economic characteristics of these routes will be compared to current practices which both involve train and truck transportation from Michigan to Chicago. Considering the shipments further down the Mississippi River, the transhipment in Chicago and corresponding barge rates will be taken into account.

6.3.2 Muskegon – Canada – Asia

After Canada, Asian countries are the top export markets for Michigan originated agricultural products. As stated in sub paragraph 5.3.2 Mexico is also among the top export markets. However, considering the three commodities under investigation Mexico is ranked number eight after Canada and six Asian countries. A comment on this finding is that USDA Statistics (2016) do not fully account for re-exports. This means that states which are home to major export markets as Louisiana and California account for more exports than they produce and agricultural producing states as Michigan and other Midwest states have a smaller amount of exports than they actually produce and export. Therefore the USDA Statistics (2016) data only provide an estimation of top export markets instead of representing actual numbers. Nevertheless, taking an Asian-bound route under investigation makes sense as it also is the largest export market for US grains in general.

There are a number of possible corridors and transportation routes which transport Michigan grown commodities to Asian markets. The common factor of these routes is the final ocean-going outbound shipment which generally takes place in the port of New Orleans, several ports in the Pacific Northwest (PNW) or Los Angeles for containerized goods. All these ports are major links in the agricultural export structure of the US, especially to Asian markets. Data of the Freight Analysis Framework (2016) also shows that a number of agricultural goods flow from Michigan to the port of Norfolk, Virginia before being shipped to Asia. The fact that the majority of these goods are shipped by truck and Norfolk is located on the east coast makes this flow of goods irrelevant for comparison.

Freight Analysis Framework data further reveals a number of direct truck shipments of processed agricultural products to the ports of Seattle and Los Angeles before final shipment to Asia. Both train and barge operations are hardly present in this dataset and because of that, Louisiana is hardly present in these figures as well. Most likely this is due to the fact that the majority of Michigan grains are consolidated in Chicago before being shipped on barge or rail to New Orleans or by means of train transportation to either the Pacific Northwest region or Los Angeles. Interviews with field specialists confirm that an amount of Michigan grains are consolidated in the greater Chicago area before further transhipment to any of these three ports.

Since the south-bound corridor to New Orleans is already introduced in sub paragraph 6.3.1 and will further be assessed in chapter 7, the waterborne shipment possibility out of Muskegon to Asian markets will be compared to train transportation out of Chicago to Seattle. While Los Angeles is also a large export hub for agricultural products heading for Asia these exports are almost all containerized movements. Since the focus in this thesis has been put on bulk transportation the benchmark port is Seattle since this port exports more than three million metric tons of grains and oilseeds to Asian markets in bulk annually (April, 2013).

As stated in paragraph 4.2 one of the main advantages of waterborne transportation is the lower cost compared to road and rail transportation. An important criteria for Asian-bound grain transportation out of Muskegon is therefore a route that has a relative long waterborne haul. The second criteria that the route should fulfil is the transhipment possibilities in a port with road or rail connections to a seaport which is able to ship the grains overseas to Asia.

Taking these two conditions into account, the port of Thunder Bay (Canada) is a good option since it is located 945 kilometres (587 miles) north-west of Muskegon and has the largest grain storage capacity in Canada (Thunder Bay Port Authority 2015 Annual Report). Moreover the port is connected by railway to both Prince Rupert and Vancouver which are two major Canadian gateways for Asian bound grains. When determining a specific route out of Muskegon only one of these gateways can be taken into consideration. Both of these ports have advantages but Prince Rupert is located closer to the Asian markets and has the largest grain elevator on the Canadian Westcoast which is directly connected to the railroad system. In comparison to the US railroad connections to Los Angeles and Seattle, Prince Rupert also offers advantages since the rail line to this port is significantly less elevated which results in shorter haulage times and less fuel consumption. In addition, there is less congestion which stimulates efficiency and might lower costs (Rail Connectivity, www.rupertport.com).

The port of Prince Rupert is therefore the designated ocean going transhipment hub for the Asian-bound grains originating from Muskegon. An overview of the transportation route is given below in figure 14. The waterborne route via Lake Michigan and Lake Superior is indicated with the blue line while the railroad is depicted in green. Alternatives of land transportation routes to both Los Angeles and the benchmark route of Seattle via Chicago are marked with red dots and black arrows.

Figure 14: Intermodal route from Muskegon via Thunder Bay to Prince Rupert versus rail connections to Seattle and Los Angeles via through Chicago

Source: Searates.com, route explorer

6.3.3 Muskegon – Quebec – Asia

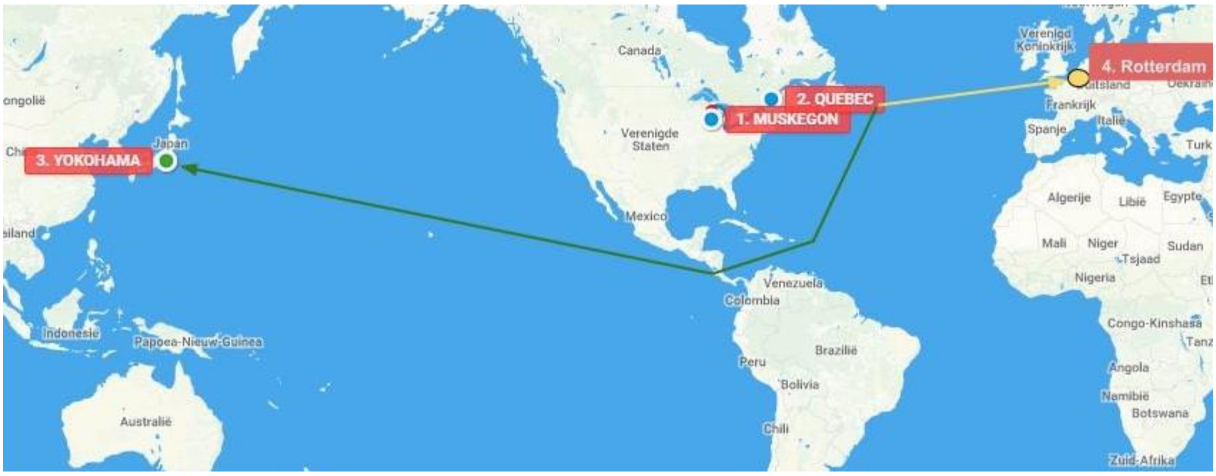
Direct shipments from Michigan to Asia are hardly operated but a small amount of animal feeds and processed grains is shipped from Detroit to Asia (Freight Analysis Framework, 2016). The possibilities for these east-bound shipments are, as stated earlier in this chapter, very limited for the port of Muskegon but some advantages are present. In order to assess the waterborne possibilities out of Muskegon as thoroughly as possible this Muskegon – Asia route through the GLSLS is investigated. Since this route is mainly over water the waterborne advantages as identified in chapter 4 are now maximal benefited from.

Shipping grains directly from the Great Lakes to Asia has some implications and is not common in for most of the ports in the region. Especially for a small port with limited throughput as Muskegon, a number of problems occur. First the amount of grains available to ship must be large enough since most of the ocean going grain bulkers out of the Great Lakes have a capacity of 20,000 to 30,000 metric tons. Considering the limited agricultural production in West Michigan and the absence of an established agricultural commodity infrastructure in Muskegon, loading a seaway-max grain bulker in Muskegon is not very likely.

A more feasible option is to ship the grains out of Muskegon to a larger port in the GLSLS system by means of a smaller dry bulk carrier. Expert interviews learn that these vessels usually have a capacity of 10,000 to 14,000 metric ton. The Muskegon originating grains can then be consolidated at a large grain terminal before being shipped internationally on a large grain bulk carrier. Several ports would be able to function as transhipment hub for Muskegon grains but the Canadian port of Quebec is assumed to be the specific port of transhipment. This stems from the fact that with an annual throughput of 2.2 million metric tons of grain and oilseeds it is the largest agricultural export hub in the St. Lawrence Seaway, partially due to its deep draft which can accommodate large ocean vessels (Canadian Grain Exports, 2012).

The benchmark route of this Muskegon – Quebec – Asia route is truck transportation out of Michigan to Chicago before trans loading the grains on river barges. These grains are then transhipped onto ocean vessels in the Mississippi Gulf. This route is very common for Asian-bound grains originating out of the Midwest. Since the cost analysis for the grain transportation out of Michigan to New Orleans is already described in sub paragraph 6.3.2, adding the sea transportation rate from New Orleans to Asia will make the assessment of this benchmark route complete. Figure 15 depicts the waterborne route from Muskegon via Quebec to two overseas destinations. The Asian-bound route is depicted with the green line and is assumed to flow through the Panama Canal. In the next sub paragraph more information on the European export route will be provided.

Figure 15: Two routes via Great Lakes and Quebec to Asia and Europe



Source: Searates.com, route explorer

6.3.4 Muskegon – Quebec – Europe

As is the case with the Asia corridor via the GLSLS, very little agricultural shipments from Michigan to Europe are currently operated. There are a number of grain shipments out of the Great Lakes region to Europe but interviews with field experts reveal that shipping processed steel from Europe to Great Lakes ports as Milwaukee and Duluth are the initial reason for this. The general cargo ships which bring these steel products to the Great Lake region load grains on board for a relative low backhaul rate. The fact that no European goods are shipped to Muskegon makes this direct shipment not feasible. Interviews have also learned that these backhauls are fully loaded so calling the port of Muskegon in order to fill the remainder of available space in a vessel hold is no option.

For this reason, and others already indicated in the previous sub paragraph, a transhipment of the Muskegon originating grains will take place in Quebec. The seaborne route to Europe is depicted in figure 15 with a yellow line.

Because the Gulf of Mississippi is also a large export hub for European-bound grains (April, 2013), the benchmark route will be the river barge line from Chicago to New Orleans before trans loading the grains on an ocean vessel. Adding the New Orleans – Europe sea rate to the already assessed Mississippi route in sub paragraph 6.3.1 will complete this benchmark assessment.

7. Economic analysis

This chapter provides an economic analysis of the possible waterborne transportation routes of Michigan grown grains via Muskegon to both domestic and international destinations. Five corridors will be under investigation and have already been introduced in paragraph 6.3:

- Muskegon – Chicago
- Muskegon – New Orleans
- Muskegon – Canada – Asia
- Muskegon – Quebec – Asia
- Muskegon – Quebec – Europe

In order to do the economic analysis and make comparisons, the next paragraph will provide a number of general assumptions which are used throughout the whole analysis. Subsequently specific analyses on the transportation rate, transit time and CO2 emission will be provided in individual paragraphs. All the five corridors and corresponding routes will be elaborated on and compared with one and other. There is also a sensitivity analysis included regarding the oil price. The final paragraph provides a conclusion on the economic feasibility of waterborne transportation of agricultural commodities out of Muskegon.

7.1 General assumptions

Doing an economic analysis on specific routes requires a number of assumptions that have to be made in order to do a comparison and gain corresponding outcomes. For this reason a number of assumptions is now provided.

7.1.1 Start and end points of specific corridors

The first assumption involves the point of origin of the Michigan grown commodities. As found in paragraph 5.1 most of the Michigan grain commodities are produced in the south-east region of the state. The capital of the state, Lansing, is situated in this region and is well connected to other parts in and out of Michigan. Moreover, major grain companies as ADM and The Andersons are situated in the Lansing area. Additionally, field experts agree on this consideration and confirm Lansing as a good origination point for Michigan grown grain and oilseeds.

Having determined the point of origin for all transportation routes, a final destination has to be chosen as well. For the first two domestic corridors this is relatively simple. The Muskegon – Chicago corridor will have Chicago as final destination for both land and water transportation. More specifically the Nidera and Cargill grain terminal on the Calumet River, located 6 kilometres inland from Lake Michigan, will be set as destination point. An advantage of this location is the intermodal connection since rail, road and water transportation options are present. Both lake and river barges are able to reach this terminal as well.

The second corridor heading to the Gulf of Mississippi has the port of New Orleans as its final destination. This port is the major agricultural export hub of the US while being supplied by hundreds of river barges from the Midwest region every week (Grain Transportation Report, 2016). Whatever the origin or mode of transportation is, all the grains flowing through this corridor are being transhipped onto ocean-going vessels in the port of New Orleans. All major grain firms are active in the port of New Orleans and are connected to both the railway and water system. Therefore no specific point in the port has to be chosen.

Considering the third transportation route via Thunder Bay to Prince Rupert, a specific Asian destination must be designated. This follows from the fact that a comparison is made with Seattle which implies different ocean transit times for the two routes originating from Muskegon. Following from chapter 5, soybeans are the most exported agricultural commodities of Michigan. Taking into account that Japan is one of the largest importers of US soybeans makes Japan a logical final destination. Additionally Japan is currently the fourth largest importer of total Michigan agricultural commodities and together with China the largest Asian export market for both US and Michigan grown agricultural commodities. Specifically the ports of Yokohama and Kobe are chosen since these are large ports on which information is available throughout public sources and field experts. The port of Yokohama is not only the largest container port in Japan but also a large grain import hub of Japan (Outline of the Port of Yokohama, n.d.). The Asian-bound route via the GLSLS and Quebec have the port of Kobe as final destination. This port is located 300 miles from Yokohama at the east side of Japan and is one of the larger Japanese ports. Because of the relative small distance between the two ports a comparison between the obtained rates is validated.

The European market is assumed to be served via either the port of Amsterdam or Rotterdam. Not only are they among the largest ports in Europe but a substantial amount of dry bulk and grains flows through both ports each year. Both ports are also home to a number of agricultural related firms. Since information on rates was only available for one or the other, it is assumed that ocean rates to both ports is equal. While they are located in each other proximity this assumption is permissible. In addition, field experts state that it is also common to express overseas rates to these two ports combined with Antwerp as the ARA-region (Amsterdam-Rotterdam-Antwerp region).

7.1.2 Unit of measurement

The second set of assumption regards measurement units that will be used. As for the unit of transportation, bulk shipping is set as standard. Agricultural commodities are traditionally shipped in bulk but as mentioned in paragraph 4.3, containerization of these commodities is emerging. Nevertheless interviews with field experts learn that the containerized transportation in the Great Lakes area and Michigan is hardly present. Thus, bulk shipments are the unit of transportation. Rates will be expressed in metric tons (MT) which is equal to 2,205 US pounds or 1,000 kilograms.

Because this thesis focuses on a US case study, the US dollar is taken as currency unit of measurement. When rates are provided in other currencies a conversion will be done in order to perform accurate calculations and comparisons. More information on specific currency conversions can be found in appendix 1.

Finally, the unit of measurement for distances is the statute mile, also known as land mile, which is equivalent to 1,609.34 metres. The statute mile will be the default distance unit of measurement throughout the whole analysis. It will be specifically stated if kilometres or nautical miles are used.

7.1.3 Trade-off between truck and train on short distances

Paragraph 5.2 already highlighted the extraordinary high train rates in the state of Michigan. Preliminary research confirms these high rates and their small degree of competitiveness within the state. Therefore one may argue that the relevant small distance route between Michigan and Chicago would be useless to investigate for train transportation. Nevertheless the train transportation option from Lansing to Chicago will be assumed possible for the completeness of this study and will be assessed for this reason.

On the other hand, grain haulages from Lansing to the port of Muskegon are assumed to be handled by trucks only. This follows from the short distance (109 miles) and the fact that the port of Muskegon is not directly linked to a major railroad operator which makes transportation rates extra high but also hard to verify. In addition it is assumed that these truckloads to Muskegon can carry the double amount of grain in comparison to Chicago since trucks within Michigan are allowed to weigh 164,000 lb where in Illinois this is only 80,000 lb (MDOT Intermodal Policy Division, 2013). Specific assumptions on this topic are elaborated on more in appendix 1.

7.1.4 Equality of the three commodities

While the three different commodities under investigation have more or less the same transportation characteristics corn weights less than soybeans and wheat. One ton of corn requires more physical space and therefore the stowage factor of this commodity is smaller. A field expert points out that corn requires 7.15% more space than wheat or soybeans. While this difference is small in relative terms and may be negligible regarding truck- and train loads, the effect on large capacity waterborne shipments may be worth accounting for.

In general field experts have confirmed the equality of rates for all three the commodities regarding truck, train and waterborne transportation. Considering the large capacity on maritime vessels, no field expert was able to comment on the sea rates but the both the weekly and quarterly grain transportation updates of the United States Department of Agriculture do not make a distinction between the commodities either. Thus, they support the equality in rates too. Moreover, both inland water and sea transportation rates provided by other sources do not make a distinction between any of the three commodities as well.

As for train transportation, different rates are quoted per commodity but no systematics is found. Sometimes corn has the highest rates while on different routes another commodity is more expensive to transport. Because of this and the fact that field experts agree on the equal treatment of the commodities no distinction is made for train transportation either.

Concluding corn, soybeans and wheat are assumed to all have the same transportation characteristics and transportation rates. Some more specific assumptions are done in the following paragraphs. A number of additional assumptions can be found in appendix 1.

7.2 Transportation rate analysis

The importance of transportation costs in the global market of agricultural commodities is highlighted in chapter 4. This paragraph will provide an overview of the transportation rates of all the five corridors of interest and their corresponding routes and transportation modes. Current practices will be compared to a possible waterborne route via Muskegon. First a number of important cost related assumptions are made while the cost of transportation for every route is provided afterwards.

7.2.1 Specific cost related assumptions

Pricing of services is dynamic in nature, this is also the case for transportation rates. One field expert indicates that the introduction of waterborne shipment from Muskegon may trigger truck and railroad firms who currently transport grains in Michigan to lower transportation rates in order to stay competitive or even to supplant the new waterborne operator. For this reason an additional assumption and analysis will be done. If waterborne transportation via Muskegon turns out to be the most economical option, it is assumed that a maritime operator will launch this service. Subsequently, truck and train operators are assumed to lower their rates by 10% as a reaction. The result of this analysis will be discussed briefly for every corridor in which waterborne transportation via Muskegon is the most economic option.

An important cost factor of the total transportation rate is transhipment or trans loading. When the commodities have to be trans loaded from one mode of transportation to another, handling time and cost are involved. Public information on these rates is not available but experts in the field were able to provide useful insights. The major determinant of the trans loading rate is the amount of volume. When large quantities are trans loaded the rates per unit are generally lower. Thus, trans loading from a barge to truck or train, or vice versa, is cheaper than trans loading from train to truck since this normally involves less volume. In the case of trans loading grains onto ocean-going vessels the rates of trans loading are assumed to be incorporated in the transportation rate since efficient dedicated terminals are present and large volumes are handled. The presence of large dedicated terminals also lowers the cost of trans loading. In addition, all the routes which include a seaport have to account for possible trans loading costs in the port. While all the sea ports under investigation are of substantial size and host multiple grain elevators, the possible trans loading rates are assumed to be equal. Because of this equality the possible cost do not matter in order to do an analysis which focuses on comparisons.

Appendix 1 provides more details on these assumptions. The gained insights lead to the following tans loading related costs assumptions:

- Trans loading costs from truck to barge in the port of Muskegon where no dedicated grain terminal is present: $5 per metric ton
- Trans loading costs in Chicago and Thunder Bay where dedicated terminal are present: $3 per metric ton for every mode of transportation
- Trans loading costs in the sea ports are set to zero since dedicated grain terminals and large volumes are present. Moreover trans loading costs are usually already incorporated in sea rates or are assumed to be equal and therefore negligible in order to do a comparison.

The truck rate of shipping from Lansing to Muskegon involves another important assumption. The general truck rates which can be found in appendix 1 are assumed not to be fit for this specific route. This is due the fact that that a field expert explained that general rates apply to general routes with a certain amount of freight volume. Considering Michigan already being a peninsula state, the relative short distance and the low volume of commercial traffic in the Muskegon region (see also figure 9), a premium on this specific route is in order. Details are provided in appendix 1.

7.2.2 Muskegon – Chicago corridor

The waterborne route of Michigan grown grains via Muskegon to Chicago will be compared to a direct route from the Lansing area to Chicago. Both of the truck and railroad options are included for the Lansing – Chicago trip. All rates are presented in table 10 and rates are given per metric ton, additional information can be found in appendix 1.

Table 10: Waterborne Muskegon – Chicago route. Two direct routes by truck and train are set as benchmark

Cost per ton / Route	Lansing – Muskegon – Chicago (barge)	Lansing – Chicago (truck)	Lansing – Chicago (train)
Truck cost	$7.94	$17.65	-
Train cost	-	-	$28.89
Inland water cost	$12.00	-	-
Trans loading cost	$5.00	-	-
Total cost per ton	**$24.94**	**$17.65**	**$28.89**

Table 10 shows that the transportation of Michigan grown grains to Chicago are transported at the lowest cost via truck transportation. This outcome corresponds with paragraph 5.2 which states that agricultural transportation in Michigan is dominated by truck. The high rail rate prices are also confirmed. In comparison with waterborne shipping, rail transportation is still more expensive which may create opportunities for a barge operation to take away some market share of train transportation.

7.2.3 Muskegon – Chicago – New Orleans corridor

Since the majority of US agricultural exports flow through the inland waterway system to the Gulf of Mississippi a waterborne route via Muskegon to New Orleans is now assessed. The hypothetical direct waterborne route from Muskegon to New Orleans will be compared to two routes. First a direct train operation from the Lansing area is investigated while barge transportation from Chicago to New Orleans is also assessed. On the Lansing – Chicago haul both train and truck transportation will be taken into account. All rates per metric ton are presented in table 11. Additional information can be found in appendix 1.

Table 11: Partially waterborne Muskegon – Chicago – New Orleans routes. Three alternative routes and transportation modes are set as benchmark

Cost per ton / Route	Lansing – Muskegon – New Orleans	Lansing – Chicago – New Orleans (truck/barge)	Lansing – Chicago – New Orleans (train/barge)	Lansing – New Orleans (train)
Truck cost	$7.94	$17.65	-	-
Train cost	-	-	$28.89	$52.99
Inland water cost	$35.85	$24.85	$24.85	-
Trans loading cost	$5.00	$3.00	$3.00	-
Total cost per ton	**$48.79**	**$45.50**	**$56.74**	**$52.99**

From table 11 it follows that truck transportation to Chicago and trans loading the commodities on river barges obtains the lowest rate of transporting the commodities to New Orleans. A direct barge operation is only 7% more expensive. Some shippers may be willing to pay this premium in order to avoid the congestion and trans loading in the Chicago area. Moreover, the direct barge rate is calculated by adding two separate rates for the Muskegon – Chicago haul and Chicago – New Orleans haul while applying a small discount on the Muskegon – Chicago rate. Applying a larger discount leads to a favourable position for the direct barge option. The two routes including rail transportation are not interesting to consider from an economical perspective.

7.2.4 Muskegon – Canada – Asia corridor

A relatively long distance on the Great Lakes will be sailed on the route from Muskegon to Thunder Bay, Canada before trans loading the grains on a railcar to the sea port of Prince Rupert. Here the grains will be shipped to their final destination in Japan. The two benchmark routes will flow through Seattle where the grains are trans loaded on ocean-going vessels. Both direct train and truck shipments from Lansing to Seattle are excluded since no direct train connection is available and truck transportation on such a large distance is not feasible for low-value bulk goods. Therefore routes which include Chicago as transportation hub are assessed. Again, the Lansing – Chicago haul is investigated for both truck and train transportation.

In contrast to the New Orleans route, ocean rates are now also taken into account since the port of Prince Rupert is situated closer to the Asian continent and therefore both transportation rates and time are different compared to the port of Seattle. All rates are presented in table 12 and are expressed per metric ton, additional information can be found in appendix 1.

Table 12: Partially waterborne Muskegon – Canada – Asia corridor. Two alternative routes and transportation modes are set as benchmark

Cost per ton / Route	**Lansing – Muskegon – Canada - Asia**	**Lansing – Chicago – Seattle (train/train) - Asia**	**Lansing – Chicago – Seattle (truck/train) - Asia**
Truck cost	$7.94	-	$17.88
Train cost	$90,56	$121.51	$92.62
Inland water cost	$19.50	-	-
Ocean rate	$22.50	$17.88	$17.88
Trans loading cost	$8.00	$3.00	$3.00
Total cost per ton	**$148.50**	**$142.39**	**$131.14**

Transporting the grains by truck to Chicago and moving them to Japan via Seattle by train provides the lowest transportation rate in this corridor. The ocean rate from Thunder Bay to Japan is higher than the Seattle – Japan rate which is somehow surprising because of the shorter distance. Other factors as frequency and amount of throughput which both are higher in Seattle may be at stake. Besides the higher ocean rates, the fact that the grains have to be trans loaded in both Muskegon and Thunder Bay is also not favourable. Additionally, the fractional lower train cost from Thunder Bay to Prince Rupert is not able to offset the inland water transportation cost from Muskegon to Thunder Bay.

7.2.5 Muskegon – Quebec – Asia corridor

An alternative for the Asia corridor in the previous subparagraph is the option of shipping grains from Muskegon to Quebec before trans loading onto an ocean going vessel. The ocean bulker will then sail via the Panama Canal to the final destination of the port of Kobe, Japan. The benchmark route is also dominated by waterborne transportation since a river barge originating in Chicago will move the grains to New Orleans where they are transhipped to a Japan-headed ocean grain bulker.

While this thesis is of inductive nature, the transportation from Lansing to both the ports of Muskegon and Chicago will be operated by trucks. Train transportation from Lansing to Chicago is assessed in the previous corridors but turned out not to be economical beneficial and is therefore excluded in this assessment. Table 11 also shows that in the corridor to New Orleans waterborne transportation combined with trucking to Chicago is the most economic option and is therefore set as only benchmark route. Total transportation rates of both routes are provided in table 13.

Table 13: Dry bulk vessel to Quebec – ocean vessel to Japan, one barge operated benchmark route

Cost per ton / Route	Lansing – Muskegon – Quebec – Japan	Lansing – Chicago – New Orleans – Japan
Truck cost	$7.94	$17.65
Train cost	-	-
Inland water cost	$24.50	$24.85
Ocean rate	$38.00	$29.67
Trans loading cost	$5.00	$3.00
Total cost per ton	**$75.44**	**$75.17**

Comparing the two routes reveals a minor cost advantage for the New Orleans route via Chicago but the transportation rates are perceived as equal. Interesting to note are the almost identical inland waterborne transportation rates from Muskegon to Quebec and Chicago to New Orleans. The longer ocean leg and corresponding costs from Quebec to Japan are offset by a lower truck transportation rate in the Muskegon route. While the transportation rates on both routes are equal it is interesting to compare both routes on different aspects such as transit time, CO2 emission or future oil prices. The next paragraphs will elaborate more on this and might provide interesting findings.

It has to be stated that the transportation rates in this corridor are more than 40% lower than the ones found in the previous Muskegon – Canada – Asia corridor via either Seattle or Prince Rupert. This insight might be useful for shippers and shows the cost advantage of routes who are mainly operated on water instead of railways.

7.2.6 Muskegon – Quebec – Europe corridor

Although the amount of agricultural commodities shipped out of Michigan to Europe is limited , this route exposes the advantages of waterborne transportation the most since the lion's share of this route is on water. In contrast to the Muskegon – Quebec – Asia corridor, no large quantity of extra sea miles is undertaken since Europe is connected to the St. Lawrence Seaway in a straight line, see figure 15.

The port of Quebec is also taken as transhipment point of the grain and oilseeds. The benchmark route will also utilize the river barge route from Chicago to New Orleans and only truck transportation from Lansing to Chicago is considered. Table 14 provides an overview of the total transportation rates of both routes.

Table 14: Dry bulk vessel to Quebec – ocean vessel to the Netherlands, one barge operated benchmark route

Cost per ton / Route	Lansing – Muskegon – Quebec – Europe	Lansing – Chicago – New Orleans – Europe
Truck cost	$7.94	$17.65
Train cost	-	-
Inland water cost	$24.50	$24.85
Ocean rate	$18.50	$16.25
Trans loading cost	$5.00	$3.00
Total cost per ton	**$55.94**	**$61.75**

The Muskegon – Quebec – Europe corridor is the only one in which the waterborne route via Muskegon offers a cost advantage. Lower truck costs to Muskegon are the main reason for the favourable transportation rate while all other cost components are of comparable magnitudes. Although cost advantages are present on this route, the amount of potential throughput to capture for the port of Muskegon may be limited. This follows from the fact that Europe is not a large importer of Michigan grown agricultural commodities. Moreover, ports as Detroit and Toledo offer a 3-day advantage while being located closer to many production farms compared to Muskegon.

As stated earlier in this paragraph the introduction of waterborne shipment from Muskegon may trigger truck and railroad firms who currently transport grains in Michigan to lower transportation rates in order to stay competitive. Therefore it is likely that they will lower their rates. However, in order for the benchmark route to offer the same transportation rate, the trucking rate has to decrease with $5.81 which implies a 33% discount. This is a very substantial discount rate and is more than the 10% earlier suggested. Thus, the waterborne route via Muskegon remains competitive even when Michigan based truck operators lower their rates up to 33%.

7.3 Sensitivity analysis of oil prices

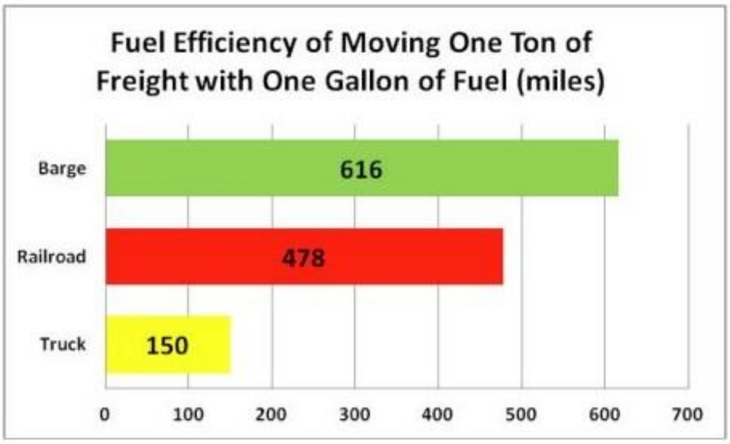
Oil prices and their movements have a considerable impact on the US transportation system. This is not different for the agricultural sector where transportation rates may even be more important considering the competitiveness of the relatively low-value bulk commodities. It is estimated that oil prices impact as much as 20 to 50 percent of the total agricultural production costs where for the manufacturing industry this number ranges between the 10 and 20 percent (Impact of High Oil Prices on Freight Transportation, 2008).

In the year 2000, when the crude oil price per barrel quoted around $20, the share of fuel costs represented in general only 20% of the total costs made in the transportation sector. When oil prices reached their peak in 2008 at more than $150 per barrel the share of fuel represented 50% of total operation cost in the transportation industry. A $200 per barrel price may even surge this share to 70%.

Generally speaking transportation firms are passing through these higher fuel prices to their customers. This is done in several ways: operators work for example with a fuel surcharge which is applied afterwards and shipping firms will eventually incorporate the higher oil prices in the standard freight rates. In certain cases as transcontinental shipping this passing through of the higher fuel prices is not always possible since rail operators’ competitiveness also depends on the rates which ocean carriers charge for all-water movements. Therefore, transportation firms are not always able to charge their customers for the full amount of oil price increases.

Higher fuel prices have a larger impact on long distance haulages than short distance movements. Moreover, the effect of higher fuel prices is not the same for every mode of transportation. A number of studies recognize that the impact on truck transportation rates is the largest since this is the least fuel efficient mode of transportation. Railroad and water transportation are perceived to be significantly more fuel efficient per unit of transportation and in most cases waterborne shipments needs the least amount of fuel for a transportation haul per unit. This is also found by the Texas Transportation Institute (2012) during a US based case study. The results on fuel efficiency are depicted below in figure 16.

Figure 16: Fuel efficiency of truck, barge and rail



Source: Texas Transportation Institute (2012)

As already identified in chapter 4, the cost of shipping is the most important decision making variable. Combine this with the importance of fuel prices on the total cost of the agricultural production process and movements of fuel prices cannot be ignored in the transportation decision making process. Above all, different transportation modes have different fuel efficiencies and therefore the movements of oil prices may affect transportation mode preferences.

This analysis provides an assessment on how fuel prices change the total transportation rate of the five corridors and corresponding transportation modes. Additionally it may reveal changes in the preferred transportation route and corresponding mode.

First the impact of fuel prices on the four modes of transportation have to be determined. Subsequently the impact on the specific transportation rates found in paragraph 7.2 can be determined for each corridor. A number of assumptions and future oil price scenarios are then determined before assessing possible preference shifts in transportation route and mode within each corridor.

7.3.1 Impact of oil prices on transportation rates

From figure 16 it follows that the three transportation modes of interest have different fuel efficiencies per unit. Because of this higher fuel prices may have an effect on the preferences regarding these modes. To determine the impact of oil prices on the rates of specific transportation modes more information is needed. An accurate source is needed which provides the share of oil cost in the total transportation rate of all the modes under investigation. Preferably this source is recent and provides the shares for all the four transportation modes under investigation since the calculations of the fuel share involve a number of assumptions.

The comprehensive US case study 'Impact of High Oil Prices on Freight Transportation' (2008) meets both requirements for the largest part. However, information on ocean vessels misses and the source is to a certain extent outdated. The study is published in 2008 but the base year regarding the data is 2005. Against expectations, this is actually an advantage. The study states that it uses the average diesel price of $2.40 per gallon in 2005 as input for the calculations. When this section of the thesis is completed the average diesel price per gallon in the US is $2.37 per gallon(US Energy Information Administration, 2016). The calculations on which the share of fuel in total transportation rates is based are therefore validated for current oil prices.

The share of fuel prices in ocean rates also have to be taken into account. This follows from the fact that on the Muskegon – Asia and Muskegon – Europe route different seaports with different distances and corresponding fuel consumptions are used. Data on fuel cost as share of total transportation cost is retrieved from a United Nations report (Oil Prices and Maritime Freight Rates: An Empirical Investigation, 2016) and findings are based on the oil prices and sea rates in the 1993-2008 period. Because of this long term perspective this data is perceived to be validated in order to use for a comparison with the other three modes of transportation.

Specific data regarding the fuel cost as share of transportation rate for the 12,000 MT bulk carrier who is assumed to ship grain out of Muskegon to both Thunder Bay and Quebec is unknown. Because of the inland waterway characteristics it is assumed that the fuel share is equal to the tug-barge combination. Table 15 provides an overview of the percentage of fuel costs in the total transportation rate.

Table 15: Share of fuel cost in total transportation rate

Transportation mode	Share of fuel costs
Barge	18%
Railroad	35%
Truck	46%
Ocean vessel	26%

Source: Impact of High Oil Prices on Freight Transportation (2008) and Oil Prices and Maritime Freight Rates: An Empirical Investigation (2016)

Now that the share of fuel cost is known for each transportation mode and paragraph 7.2 provides the transportation rates, future scenarios on fuel prices are the only missing link in doing a sensitivity analysis. The fuel price is directly correlated to the price of a barrel of crude WTI oil which quotes $46.80 at the moment of writing (US Energy Information Administration, 2016). For the long-term scenarios data of the World Bank (2016) is used to set a future normal-case price of a barrel of WTI oil. This data forecasts a price per barrel of $82.60 in 2025 which implies an increase of 76.5% compared to the current price. In addition to this ‘normal-case’ scenario, an ‘optimistic-scenario’, ‘pessimistic-scenario’ and ‘doom’ scenario are assessed which respectively imply halve, double and triple the ‘normal-case scenario’ increase.

Moreover, the transportation modes under investigation do not consume crude oil but mostly processed diesel oil. The bunker oil for ocean vessels is processed differently but is related to the price of diesel. Therefore the increase of diesel prices should be taken into account instead of crude oil prices. In order to do so the relationship between crude oil prices and diesel prices has to examined.

Diesel fuel prices are heavily correlated with the price of crude oil but other cost factors as taxes, marketing, distribution and refining are also at stake. Data from the US Energy Information Administration (2016) shows that in the past ten years the crude oil price comprised on average 57% of the total diesel fuel price. Therefore the increase in WTI crude oil prices are multiplied by this percentage to obtain predictions on future diesel fuel prices for each scenario. Table 16 provides the WIT oil price and both the crude oil and diesel price increases for every scenario. For simplicity this assumes that the other cost factors remain on the same level until 2025.

Table 16: Oil price scenarios for 2025, percentages are increases of 2016 WTI crude oil level and corresponding diesel increases

Scenario	WTI oil price	Increase	Diesel price increase
‘optimistic’	$64.82	38.25%	21.80%
‘normal’	$82.60	76.50%	43.61%
‘pessimistic’	$109.04	133.00%	75.81%
‘doom’	$154.21	229.50%	130.82%

Source: World Bank (2016) and US Energy Information Administration (2016)

These four scenarios will now be applied to the current transportation rates in combination with the share of oil cost in the total transportation cost for each mode and corridor.

7.3.2 Impact of oil prices on transportation rates per corridor

For each of the five corridors a table will be provided with all the routes and total transportation cost per metric ton in each oil price scenario. Comparing the current rates to future rates in the different scenarios will reveal whether preferences for transportation modes change if oil prices rise. Per scenario the route with the lowest transportation rate is highlighted in green.

Table 17: Total transportation rate per metric ton for different oil price scenarios: Muskegon – Chicago

Oil price scenario / Route	Lansing – Muskegon – Chicago (barge)	Lansing – Chicago (truck)	Lansing – Chicago (train)
Current	$24.94	$17.65	$28.89
Optimistic	$26.20	$19.42	$31.09
Normal	$27.47	$21.19	$33.30
Pessimistic	$29.34	$23.80	$36.56
Doom	$32.54	$28.27	$42.12

Shipping grains from Lansing to Chicago by truck is economically the best option, also in the case of higher oil prices. However, when the oil price surges to higher levels the gap between the direct truck option and waterborne transportation becomes smaller. This implies that very high oil prices may stimulate a modal shift in this particular corridor towards waterborne shipping.

Table 18: Total transportation rate per metric ton for different oil price scenarios: Muskegon – New Orleans

Oil price scenario / Route	Lansing – Muskegon – New Orleans	Lansing – Chicago – New Orleans (truck/barge)	Lansing – Chicago – New Orleans (train/barge)	Lansing – New Orleans (train)
Current	$48.79	$45.50	$56.74	$52.99
Optimistic	$50.99	$48.24	$59.92	$57.03
Normal	$53.19	$50.99	$63.10	$61.08
Pessimistic	$56.44	$52.04	$67.80	$67.05
Doom	$62.00	$58.97	$75.82	$77.25

In the Muskegon – New Orleans corridor the route via Chicago by truck and transhipment to a river barge remains the route with the lowest transportation rate during all oil price scenarios. In contrast to the Muskegon – Chicago corridor, the gap between the lowest rate route and second lowest route rate is not becoming smaller. This is due to the fact that the largest part of both routes is operated by a tug-barge combination which is the most fuel efficient transportation mode. This makes both routes not very sensitive for oil price movements.

Table 19: Total transportation rate per metric ton for different oil price scenarios: Muskegon – Canada – Asia

Oil price scenario / Route	Lansing – Muskegon – Canada - Asia	Lansing – Chicago – Seattle (train/train) - Asia	Lansing – Chicago – Seattle (truck/train) - Asia
Current	$148.50	$142.39	$131.14
Optimistic	$158.24	$152.67	$141.00
Normal	$167.99	$162.96	$150.85
Pessimistic	$182.39	$178.15	$165.40
Doom	$206.98	$204.10	$190.25

None of the future oil price scenarios is able to initiate a modal shift in this corridor. The main reason is the fact that all routes have a large share of both train and waterborne transportation whereas the fuel inefficient truck transportation mode is of little importance in this corridor.

Table 20: Total transportation rate per metric ton for different oil price scenarios: Muskegon – Quebec – Asia

Oil price scenario / Route	Lansing – Muskegon – Quebec – Japan	Lansing – Chicago – New Orleans – Japan
Current	$75.44	$75.17
Optimistic	$79.35	$79.60
Normal	$83.26	$84.02
Pessimistic	$89.04	$90.56
Doom	$98.90	$101.73

In this alternative corridor from Michigan to Asia the higher fuel prices do favour a modal shift towards waterborne shipping out of Muskegon. The shift is mainly caused by the longer truck haul from Lansing to Chicago compared to the Lansing – Muskegon trip. Despite the favourable rates on the Muskegon route, it is questionable if a modal shift will take place in reality. While the cost advantage is at maximum 4%, other costs such as switching costs and the premium of convenience must also be taken into account.

Table 21: Total transportation rate per metric ton for different oil price scenarios: Muskegon – Quebec – Europe

Cost per ton / Route	Lansing – Muskegon – Quebec – Europe	Lansing – Chicago – New Orleans – Europe
Current	$55.94	$61.75
Optimistic	$58.74	$65.42
Normal	$61.55	$69.08
Pessimistic	$65.69	$74.50
Doom	$72.77	$83.75

While the fuel inefficient truck leg on the Muskegon route is shorter than the benchmark route, the already lower transportation rate becomes only more favourable after fuel prices rise. The current cost advantage of 9.5% rises to 13.1% in the doom scenario.

7.3.3 Conclusion

Higher oil prices may only stimulate a modal shift in one out of the five corridors. This shift takes place in the Muskegon – Quebec – Asia corridor while transportation rates are almost equal and the short truck leg to Muskegon eventually results a lower transportation rate when oil prices go up. This is also experienced in the Muskegon – Quebec – Europe corridor where waterborne transportation via Muskegon becomes more attractive with higher oil prices.

A key factor in this fuel price scenario analysis is the truck distance per route. While this mode of transportation is substantially less fuel efficient compared to train and water transportation, the road distance has a large influence in this analysis. In reality this implicates that production sites of agricultural commodities which are located closer to the port of Muskegon have a larger incentive to utilize the port if oil prices will rise in the future. Finally other factors as switching costs, convenience of current practices and transit time must also be taken into account.

7.4 Transit time analysis

Besides cost, time of transportation is also of influence in the decision making process of choosing both a transportation route and mode. From chapter 4 it follows that lower value goods as agricultural commodities who are not perishable are less time sensitive. Therefore the transit time of soybeans, corn and wheat may not be very valuable for the shippers. On the other hand, in the globalizing agricultural commodity market in which transportation rates are converging, an efficient transportation structure with lower transit time may be the competitive edge shippers are looking for. Thus, the transit times of all the corridors under investigation are assessed and taken into account in order to draw a final conclusion.

All the assumptions and details regarding distances, shipping speeds, trans loading times and calculations can be found in appendix 2. The total transit time for all five corridors will now be presented in individual tables. All transit times are in hours and rounded, unless otherwise stated.

Table 22: Total transit time: Muskegon – Chicago

Transportation mode / Route	Lansing – Muskegon – Chicago (barge)	Lansing – Chicago (truck)	Lansing – Chicago (train)
Truck	2	4	0
Train	0	0	80
Inland water	15	0	0
Transhipment	24	0	0
Total time	**41**	**4**	**80**

As is the case considering the transportation rate, the truck option in the most favourable one in the Muskegon – Chicago corridor. In addition to being the most expensive mode, train is also substantially the slowest mode of transportation. Expert interviews learn that this is due to high number of stops and changes in railyards in the Michigan and Chicago area. Waterborne transportation is considerably faster than train transportation but cannot compete road transportation, both in terms of costs and time.

Table 23: Total transit time: Muskegon – New Orleans

Transportation mode / Route	Lansing – Muskegon – New Orleans	Lansing – Chicago – New Orleans (truck/barge)	Lansing – Chicago – New Orleans (train/barge)	Lansing – New Orleans (train)
Truck	2	4	0	167
Train	0	0	80	0
Inland water	520	504	504	0
Transhipment	12	12	12	0
Total time (days)	**22.7**	**21.7**	**24.8**	**7**

The direct route by train is clearly the fastest way of shipping grains and oilseeds from Muskegon to New Orleans. As suggested in chapter 4, waterborne transportation is slower than train transportation and all the routes who use barges have a transit time of three times the one of train transportation. Since the commodities under investigation are not very time sensitive, it is unclear if the longer transit time will outweigh the 16.5% cost advantage of the lowest rate route compared to the fastest route. Following from chapter 5 a substantial amount of soybeans is shipped by train out of Michigan to New Orleans. It is very well possible that the short transit time is the reason for this and may indicates that soybeans are more time sensitive than the other two commodities under investigation.

Table 24: Total transit time: Muskegon – Canada – Asia

Transportation mode / Route	Lansing – Muskegon – Canada - Asia	Lansing – Chicago – Seattle (train/train) - Asia	Lansing – Chicago – Seattle (truck/train) - Asia
Truck	2	0	4
Train	220	404	324
Inland water	39	0	0
Ocean	271	303	303
Transhipment	48	12	12
Total time (days)	**24.2**	**30**	**26.8**

In contrast to the transportation rate analysis, the waterborne route via Muskegon is the preferred route if only transit time is accounted for. The advantage in time is mostly gained during the shorter train transport and ocean haul from Prince Rupert to Japan. The 2.5 day advantage of the Muskegon route will probably not offset the cost difference of 13.28% since the grains are not highly perishable and the transit time advantage is not that substantial.

Table 25: Total transit time: Muskegon – Quebec – Asia

Transportation mode / Route	Lansing – Muskegon – Quebec – Japan	Lansing – Chicago – New Orleans – Japan
Truck	2	4
Train	0	0
Inland water	98	504
Ocean	782	647
Transhipment	24	12
Total time (days)	**37.7**	**48.6**

The route via Muskegon offers a substantial time advantage while the slow inland barge leg is replaced by a shorter and faster route in the GLSLS system. Since the current transportation rates are almost equal this 11 day advantage in voyage time may trigger shippers to use the port of Muskegon instead of the inland river system.

Table 26: Total transit time: Muskegon – Quebec – Europe

Transportation mode / Route	Lansing – Muskegon – Quebec – Europe	Lansing – Chicago – New Orleans – Europe
Truck	2	4
Train	0	0
Inland water	98	504
Ocean	216	341
Transhipment	24	12
Total time (days)	**14.2**	**35.9**

In the European corridor the avoidance of the inland river system results in an even larger transit time advantage. While Quebec and Europe are connected in a straight the route via Muskegon and the GLSLS is more than 21 days faster than the benchmark. Together with the lower transportation rate found in paragraph 7.2, this time advantage contributes to the feasibility of waterborne transportation out of Muskegon to Europe.

7.5 Emission analysis

The world is becoming more aware of the carbon footprint that it has put on the environment in the last decades. The negative effects of industrialization, globalization and transportation on the environment are nowadays widely acknowledged and the urge for more sustainable solutions is large. The sparkling example of this recognition is the Kyoto Protocol which was adopted in 1997 by the United Nations in order to fight climate change and reduce negative externalities as greenhouse gasses (UN Framework Convention on Climate Change, 2016). A more recent example includes the Paris Agreement adopted by 195 countries in December 2015 which involves the firs-ever universal, legally binding global climate deal (European Commission, 2016b).

The freight transportation sector is a substantial contributor to these negative externalities and 9% of total CO2 emissions in the US are caused by freight transportation (Comer et al, 2010). This figure is 23 percent up from 1990 levels, primarily due to increasing emissions from trucking (U.S. Environmental Protection Agency, 2008). From chapter 4 it follows that waterborne transportation has environmental advantages over road transportation and to less extent over railroad transportation. This advantage, together with the urge for a more sustainable world, provides a favourable position for a modal shift towards waterborne transportation. However, as mentioned in chapter 4 as well, the price of transportation is the most important decision making variable in the freight transportation industry. Making the emission output of transportation modes quantifiable and charging an emission fee might be able to stimulate a modal shift.

This paragraph identifies the emissions per ton mile for every mode of transportation. In addition every route under investigation will be assessed with respect to emissions and a hypothetical emission fee will be put into place. Subsequently an analysis will be done for each route in order to see if such a fee will stimulate a modal shift and may favour waterborne shipping.

7.5.1 Emissions of transportation modes

Fuel consumption and emissions are closely related to each other. Therefore the three transportation modes of interest have different amounts of emissions. In a comprehensive US based analysis, the Texas Transportation Institute (2012) identifies the emissions per ton-mile of trucks, railroads and inland barging. The results of this study are set as guidelines in this thesis and are summarized in table 27.

Table 27: Emission per ton-mile in grams for all three transportation modes

Transportation mode	HC	CO	NOx	PM	CO2
Tug-barge	0.014	0.043	0.274	0.008	16.41
Railroad	0.018	0.057	0.354	0.010	21.14
Truck	0.10	0.37	1.45	0.06	171.83

Source: Texas Transportation Institute (2012)

Appendix 1 provides more information on table 27, including the abbreviations. Since carbon dioxide (CO2) is one of the emissions with the highest impact on the environment this greenhouse gas will be the focus of the remainder of this paragraph. The majority of policy making and legislation on sustainable transportation solutions is also focused on CO2 and to less extent on the other emissions.

Since the corridors under investigation include a sea haul from North America to Japan or Europe, the CO2 emission of this route should also be taken into account. As with the sea transportation rates, a handymax dry bulk ship is assumed to operate this route. A study by Psaraftis and Kontovas (2009) provides the CO2 emission for specifically handymax bulk carriers in ton-kilometres. Converting this figure to miles results in a CO2 emission per ton-mile of 10.14 grams.

The waterborne shipments from Muskegon to the Canadian ports of Thunder Bay and Quebec are assumed to be operated by a 12,000 MT bulk carrier. Specific details on CO2 emission output are not available for this vessel but since it is designed for inland waterways. As with the oil price scenario-analysis it is assumed to have the same CO2 output as the tug-barge combination.

7.5.2 Emission fee scenario

Legislation and policy making with respect to emissions differ per country and within the US also per state. The common factor in all policies is the focus on making engines more fuel efficient and less polluting. The European Union initiated for example a penalty payment for car manufactures who excess emission standards regarding engines (European Commission, 2016). Although this aim may be the best long term solution and is economical beneficial for both shippers and consumers, the current cost of CO2 emissions are not internalized.

Putting a price tag on a gram of CO2 is hard and several studies have been investigating this topic. In most cases the purpose of such a study is to assess a possible modal shift to less polluting transportation modes as railroads and waterborne shipping. Apart from increasing the fuel taxes, which also affect the consumer, one policy measurement to internalize emission costs is to let shippers pay a so called emission tax on the amount of CO2 that they produce on a freight haul. When environmental unfriendly transportation modes are used, such an emission tax might stimulate shippers in using newer and other transportation modes with lower emissions and corresponding costs. Using cleaner fuels as LNG can also be a possible outcome. This possible trigger in modal choice is also the aim of this paragraph. With the information of table 27 the total CO2 emission per route will be assessed, subsequently a hypothetical fee per ton of CO2 will be set in place. Finally the total costs per route will be recalculated to see if the internalization of emissions will initiate a modal shift.

Numerous studies try to identify the cost of CO2 emission, usually expressed in metric tons of CO2. The European Union Marco Polo projects who aim to stimulate an environmental friendly modal shift use data from the European IMPACT study (Maibach et al, 2008) and determine an average CO2 cost of €31 per metric ton. A more recent study from the US government obtained a total social cost of CO2 of $56 per metric ton (US Environmental Protection Agency, 2015). Since this study is recently conducted and based in the US the analysis in this paragraph will set the cost of a metric ton of CO2 at $56. This will also be the fee which is charged on every route for a metric ton of CO2. More information on the 2015 US Environmental Protection Agency can be found in appendix 1.

7.5.3 Assessment of five corridors

All five corridors and corresponding routes will now be assessed individually. In the next tables the total transportation rate per ton is given without CO2 emissions being accounted for, then the hypothetical fee of $56 per ton of CO2 is applied and the new rate is also provided. For every corridor it is briefly discussed whether the initiation of a CO2 emission fee will shift the preference of shipper towards more fuel efficient modes of transportation. In addition, the amount of metric tons of CO2 per metric ton of cargo is provided for every route. The lowest transportation rate per corridor is highlighted in green.

Table 28: Total transportation rate per metric ton, in and -excluding CO2 fee: Muskegon – Chicago

Transportation rate / Route	**Lansing – Muskegon – Chicago**	**Lansing – Chicago (truck)**	**Lansing – Chicago (train)**
Excluding CO2 fee	$24.94	$17.65	$28.89
Metric ton of CO2	0.02	0.04	0.01
Including CO2 fee	$26.09	$19.66	$29.18

Taking the cost of CO2 into account does not change the preferred mode of transportation in the Muskegon – Chicago corridor. Considering the transportation rates, trucking remains the favourable option. The gap between the truck route and other two routes using more sustainable modes of transportation becomes smaller after initiating an emission fee.

Table 29: Total transportation rate per metric ton, in and -excluding CO2 fee: Muskegon – New Orleans

Transportation rate / Route	Lansing – Muskegon – New Orleans	Lansing – Chicago – New Orleans (truck)	Lansing – Chicago – New Orleans (train)	Lansing – New Orleans (train)
Excluding CO2 fee	$48.79	$45.50	$56.74	$52.99
Metric ton of CO2	0.05	0.06	0.03	0.03
Including CO2 fee	$51.32	$48.89	$58.41	$$54.60

Initiating a CO2 emission fee will not change the preferred transportation route and mode in the Chicago – New Orleans corridor. The CO2 fee raises the lowest rate with 7.5% while the nearest competing route through Muskegon only increases 5.2% after a CO2 emission tax. This implies that a larger fee rate may stimulate a preference shift towards waterborne transportation in this particular corridor. The increase in the emission fee however has to be unlikely high in order to initiate such a modal shift.

Table 30: Total transportation rate per metric ton, in and -excluding CO2 fee: Muskegon – Canada - Asia

Transportation rate / Route	Lansing – Muskegon – Canada - Asia	Lansing – Chicago – Seattle (train/train) - Asia	Lansing – Chicago – Seattle (truck/train) - Asia
Excluding CO2 fee	$148.50	$142.39	$131.14
Metric ton of CO2	0.13	0.11	0.14
Including CO2 fee	$155.63	$148.41	$138.90

While all the routes in the Muskegon – Canada – Asia corridor have a similar amount of CO2 emissions the introduction of a CO2 fee will not stimulate a modal shift. The difference between all the rates after the introduction of a CO2 fee remains for this reason also almost unchanged.

Table 31: Total transportation rate per metric ton, in and -excluding CO2 fee: Muskegon – Quebec - Asia

Transportation rate / Route	Lansing – Muskegon – Quebec – Japan	Lansing – Chicago – New Orleans – Japan
Excluding CO2 fee	$75.44	$75.17
Metric ton of CO2	0.17	0.17
Including CO2 fee	$84.88	$84.48

Introducing an emission fee will not cause a modal shift since both routes have an almost identical amount of CO2 emission and corresponding fee per metric ton. This is due to the fact that both routes have a very long sea leg and both the truck and inland water transportation trips are of similar length. The total transportation rates remain for this reason almost equal.

Table 32: Total transportation rate per metric ton, in and -excluding CO2 fee: Muskegon – Quebec - Europe

Cost per ton / Route	Lansing – Muskegon – Quebec – Europe	Lansing – Chicago – New Orleans – Europe
Excluding CO2 fee	$55.94	$61.75
Metric ton of CO2	0.08	0.12
Including CO2 fee	$60.21	$68.27

Since the waterborne route via Muskegon and Quebec is well connected to the European mainland, the shorter distance compared to the route via New Orleans results in an advantage for Muskegon after introducing a CO2 emission fee. That is, the already lower transportation rates becomes relatively even lower compared to the benchmark route.

7.6 Conclusion

The economic analysis is done on the basis of five corridors. All of these corridors include a waterborne route originating from Muskegon and a minimum of one benchmark route. These routes are first assessed on the transportation rate per metric ton, subsequently the transit time is also calculated. Future oil price scenarios are also taken into account and finally a hypothetical CO2 emission fee is initiated to investigate the environmental impact of each route.

While chapter 4 indicates that price is the most important decision making variable in the transportation route and modal choice process, especially for lower value bulk goods, the rate per route is also the most important factor in the analysis while transit time is secondary.

In the three corridors with Chicago, New Orleans and Asia as destination, the waterborne route via Muskegon is not able to provide a cost advantage. Although transportation rate differences sometimes become smaller, future oil price scenarios and initiating a CO2 emission fee do not make Muskegon the most economic option in either of the this three corridors. The alternative corridor to Asia which flows via Quebec has approximately the same transportation rate for both the Muskegon- and benchmark route. While the CO2 emission fee does not change this situation, higher oil prices favour the Muskegon route to a small degree. The fifth corridor to Europe is currently already attractive for waterborne transportation via Muskegon since the transportation rate is almost 10% lower compared to the benchmark route. Higher oil prices and an emission fee only enlarge this cost advantage.

Although in two of the five corridors waterborne transportation via Muskegon may offer a cost advantage and lead to a higher feasibility of exporting agricultural commodities out of the port, other factors are also at stake. Besides variables as frequency, reliability and port efficiency, the shift of switching to another mode of transportation also comes at a cost. This cost of switching is set around 14%. Additionally current providers may lower their transportation rates in order to stay competitive and a certain amount of throughput has to be obtained in order to make waterborne transportation via Muskegon possible. It is questionable if these hurdles can be offset by the moderate cost advantage Muskegon offers in two corridors.

The second variable which is part of the analysis is transit time. In the two inland river system corridors to Chicago and New Orleans no time advantage is obtained if the Muskegon route is compared with the lowest transportation rate route. On the other hand, the waterborne route via Muskegon offers a faster transit time in both the Asian corridors and to Europe. This time advantage favours the already two competitive corridors. On the other hand it is not likely that it will stimulate a modal shift on the Asian corridor via Thunder Bay since low-value bulk commodities as grain and oilseeds are not very time sensitive and the transportation rate is not the lowest.

Table 33 provides an overview of a comparison of the waterborne Muskegon route to lowest transportation rate route. For each of the five corridors it is stated if there is an advantage for the Muskegon route on one of the variables of the economic analysis. If the Muskegon route is able to provide an advantage it is also stated between brackets how many transit days this route is faster or what the cost advantage is percentage-wise compared to the most economic benchmark route. As for the oil price scenario, only the ‘doom scenario’ is taken into account.

Table 33: Overview of possible advantage that the route via Muskegon has to offer in comparison with the lowest transportation rate route

Variable / corridor	Muskegon – Chicago	Muskegon – New Orleans	Muskegon – Canada – Asia	Muskegon – Quebec – Asia	Muskegon – Quebec – Europe
Current rate	No	No	No	Equal	Yes (9.8%)
Transit time	No	No	Yes (2.5 days)	Yes (11 days)	Yes (21.5 days)
CO2 fee	No	No	No	Equal	Yes (11.8%)
Oil price scenario	No	No	No	Yes (2.8%)	Yes (13.1%)

Following from table 33 the largest possible cost advantage the port of Muskegon has to offer in any of the corridors is 13.1%. This is still smaller than the switching costs of 14% identified earlier. While the transit time is significantly faster in this corridor, it is concluded that the Muskegon – Quebec - Europe route has the most chance of providing opportunities for exporting agricultural commodities through the port Muskegon but a modal shift is not likely to appear on the short term.

8. Combining transportation of agricultural commodities with other goods

Exporting agricultural commodities through the port of Muskegon is in the current market conditions not economical feasible for most corridors under investigation. Reasons include the relative large distance from the port to the heart of production and the unfavorable location at the west side of Michigan. Combining the transportation of agricultural commodities with other sorts of shipments may change this. The cost of transportation can namely be lower if multiple goods are combined in one shipment.

This chapter will investigate the options and potential of combining multiple goods for shipments through the port of Muskegon. Both the advantages and obstacles regarding the situation in Muskegon are presented followed by an assessment of the possibilities of combining agricultural commodities with other goods for each corridor. Depending on these findings a number of calculations with possible discount rates are done after the agricultural commodities are combined with other goods. An overall conclusion will finalize this chapter.

8.1 Advantages of combined shipments

Combining agricultural products with other sorts of goods in one shipment may benefit the feasibility of exporting goods through Muskegon in two ways. First of all the throughput can be enlarged which makes the possibility of waterborne transportation out of Muskegon more likely since the amount of grains shipped out of the port might be limited. Not only can the combination of multiple commodities help to reach the minimum quantity of cargo needed to establish a waterborne service, it can also help to improve the frequency of waterborne shipments out of Muskegon. As identified in chapter 4, a higher frequency increases the willingness of shippers to utilize a certain transportation mode or route.

Secondly, the cost of transporting agricultural commodities via the port of Muskegon can be lower after combining multiple type of goods in one shipment. The lower transportation rate can be established via two mechanisms. Economies of scale may be in place when for example not two but three barges are shipped at once from Muskegon to Chicago or New Orleans. Fixed costs can then be divided among more goods and the transportation rate for agricultural goods is able to decrease.

In the case of using other types of vessels than tug-barge combinations, the advantages of economies of scale are more limited since the dry bulk carrier has already a large capacity. This vessel is namely five times as large as two barges combined. Moreover, few goods other than grain are suited to be transported in combination with the grain itself. Reasons include the fact that the vessel has two holds and only lower value dry bulk commodities can be shipped in the second hold. On the other hand, economies of scale are applicable to container ships. However, this type of vessel is not assumed to ship grains out of Muskegon and assessing this option is therefore beyond the scope of this research.

The other possible cost advantage is derived from the fact that high value goods are able to bear higher transportation costs compared to low-value goods such as grain and oilseeds. This third-degree price discrimination creates an environment in which two different prices are charged for the same service, in this case waterborne transportation out of Muskegon. The pricing mechanism is based on the price elasticity which is high for low-value goods and low for high-value goods. In order to practice third-degree price discrimination three conditions must be met (Coyle et al, 2016). First, buyers of transportation services must be able to be divided into sub-markets according to their different price elasticity characteristics. Secondly, the seller of the service must be able to prevent the price inelastic buyer of the service to operate in the lower price market. Lastly, the seller has to possess some degree of monopoly power.

A logical fourth condition involves the fact that there has to be both a low-value and high-value type of good to be transported from the port of Muskegon. Because the agricultural commodities represent the low-value goods, high-value goods are assumed to be available for further assessment. This assumption will hold during the remainder of this chapter.

The other three conditions which are identified by Coyle et al (2016) have to be met as well for the Muskegon case. Considering the first condition this might not be a problem since the provider of waterborne transportation must be able to make a distinction between transportation services for agricultural bulk commodities and high-value goods such as semi- and finished goods which simply cannot be transported in bulk but only in containers. This directly fulfills condition number two since the buyer of high-value good transportation cannot operate in the low-value bulk market while this type of transportation is not qualified for these goods. The third condition regarding the monopoly power is also achievable since the port of Muskegon has currently a very limited amount of waterborne transportation providers, especially regarding the export market.

Overall the economic advantages of combining multiple goods in one shipment may be present for agricultural commodities originating from the port of Muskegon. However, the advantages are most likely to be present on the barge operated routes where both economies of scale and third-degree price discrimination can be exercised. Additionally, the conditions regarding the third-degree price discrimination can be fulfilled for the Muskegon case. Economies of scale while using dry bulk carriers or container ships are not present or relevant in this specific case.

8.2 Obstacles of combined shipments

One of the main obstacles regarding the combination of agricultural commodities with other goods is the absence of current outflow through the port of Muskegon. Following from chapter 2 only 63,488 short tons of slag was shipped out of the port last year. As identified in the previous paragraph it is of vital importance for low-value bulk commodities that they can be combined with high-value goods in order to take advantage of the combination of transportation flows. Besides the fact that the throughput of slag is not substantial, it is also not a high-value commodity.

Thus, for further assessment it has to be assumed that there is at least one type of high-value good shipped through the port of Muskegon. A major drawback of this assumption is the current actual lack of such an outbound flow. Reasons of this absence may include the distance between the port of Muskegon and production sites, the absence of inbound container shipments and corresponding infrastructure and slower transit time of waterborne transportation. In addition it is also not proven that waterborne shipping from the port of Muskegon for high-value goods is more cost efficient than current practices. Chapter 4 learns that the value of time for high-value goods is also higher compared to low-value bulk goods. This may also play a role regarding the reluctance of using slow waterborne transportation.

This disadvantage of longer transit times is also one of the reasons why container on barge services is not popular in North America since it is perceived as too slow compared to trucks or trains. Nevertheless containers on barges can be very economical and in Europe this kind of service, especially as feeder service to Rotterdam, is popular among shippers (TEMS/RAND Corporation, 2007). While the barge operations from Muskegon have the highest potential to benefit from combining multiple goods, the negative attitude in North America towards containers on barges is perceived as an obstacle.

The characteristic of high-value goods which involve a relative low price elasticity may also underlie the absence of transportation out of Muskegon. It can very well be that waterborne shipping offers some price advantages compared to current transportation practices of semi- and finished goods produced in Michigan but these advantages may not be substantial enough to offset other decision variables such as transit time, convenience or switching costs. Therefore the price inelasticity of high value goods which is identified in paragraph 8.1 as a condition for agricultural commodities to benefit from combined transportation, is at the same time also an obstacle.

A final obstacle of combining agricultural goods with high-value goods is the required alignment of the destinations of both. If transshipment or final destinations are not the same, there are no opportunities for the combination of both type of goods. The next paragraph will provide more information regarding this matter.

8.3 Possibilities in the port of Muskegon

For the assessment of combining the agricultural commodities with other goods, the five corridors investigated in chapter 7 will function as starting point. While these corridors are the base of the assessment, it is important to look at the type of vessels that are assumed to be used for these corridors in order to investigate which type of good can be combined within each corridor.

Following from chapter 7 and appendix 3, two different type of vessels are assumed to operate from the port of Muskegon. First, the three routes via Canada are all served by a dry bulk carrier who sails to either Thunder Bay or Quebec for further trans loading. On the two routes to Chicago and New Orleans a tug-barge combination is used.

From paragraph 8.1 it follows that high-value goods are of interest for the combination with agricultural commodities. High-value type of goods involve both semi- and finished products and are normally transported in containers (Rodrigue, 2013). Goods with a very high value as medicines or highly advanced technological devices are shipped by air and are excluded from this assessment. While high-value goods are not shipped in bulk, the combination with agricultural commodities on a dry bulk carrier in the corridors through Canada is impossible.

Excluding the three corridors who pass Canada leave only the two barge-operated corridors to Chicago and New Orleans open for a combination of cargo types. While a tug-barge vessel can handle different sorts of barges at once, this type of vessel is able to transport containers. A possible scenario would be a barge operation from Muskegon to New Orleans with two hopper barges for grain and one flat barge which is able to transport containers. This way not only third-degree price discrimination may be in place but economies of scale as well. This follows from the default assumption of two hopper barges while now three barges are operated during a trip.

The two barge-operated corridors will therefore be of focus in the following sections. The remainder of this paragraph will elaborate more on Michigan manufactured semi- and finished goods and their destinations. The next paragraph focuses on calculations assuming a discount rate for the agricultural commodities when combined with high-value goods in the two corridors of interest.

8.3.1 Specific export flows per corridor

In order to identify specific goods that can be combined with agricultural commodities on barge shipments, the current export flow out of Michigan are now assessed. This assessment builds on findings from paragraph 5.3 and uses export data from the Freight Analysis Framework (2015). By investigating these flows, the feasibility of combining multiple goods out of Muskegon can be determined.

As found in paragraph 5.3 the export of Michigan is dominated by the automotive industry. Since the majority of the automobiles and car parts are produced in the Detroit area located at the east side of Michigan this industry is not included in the assessment. Moreover it is assumed that because of the large volumes these type of goods have well integrated supply chains and are not likely to utilize the port of Muskegon. It might also be the case that special infrastructure is required such as accommodation of a RoRo car vessel. In addition, paragraph 5.3 reveals that Canada is the major importer of Michigan goods. These export flows are also excluded since the assumed dry bulk vessel who operates the route from Muskegon is not qualified for transportation of high-value goods.

Only the export flows who reach their final domestic destination by water are included in this current data assessment. The fact that these goods have a relative long water haul means that they are not very time sensitive and not highly perishable. This make them qualified for waterborne transportation out of Muskegon which usually implies longer transit times compared to current practices.

Table 34 provides the top 5 export commodities, ranked by export value, which are produced in the entire state of Michigan and fulfill the conditions. In appendix 5 a complete overview of the 40 most valuable export flows out of Michigan who satisfy the conditions can be found.

Table 34: Top 5 of selective export flows out of Michigan, ranked by value (year: 2015)

Destination	**Foreign mode**	**Domestic destination**	**Type of good**	**Domestic mode**	**Value in millions of dollars**
Eastern Asia	Water	California	Basis chemicals	Truck	332.97
Eastern Asia	Water	California	Machinery	Truck	250.76
Eastern Asia	Water	California	Transport equip.	Multiple	232.22
Eastern Asia	Water	California	Basis chemicals	Rail	187.05
Eastern Asia	Water	California	Chemical prod.	Truck	182.21

Source: Freight Analysis Framework (2015)

A number of findings can be derived from both the table above and appendix 5. First of all, the major export market is Eastern Asia and to less extent other parts of Asia and Europe. Moreover, the amount of exports is substantial and reaches well over a billion US dollars while California is the main waterborne export hub for Michigan manufactured goods. Lastly, the type of goods are all semi- or finished goods and mainly chemical or manufactured related. Considering the finding in paragraph 5.3 regarding silicon as one of the top 25 overall export products of Michigan, this comes as no surprise.

The above findings are supportive for the case of combining agricultural commodities with other types of goods. The amount of export is namely substantial and the type of goods are qualified to be transported in containers. This implies that the ‘basic chemicals’ category might be more advanced than the name suggests since they are transported by truck and have a long water haul to Asia. Moreover the goods are of higher value than agricultural commodities and may bear higher transportation costs. This follows from Appendix 5 which shows that all of the goods in table 34 have a value of at least $5 per kilogram which is multiple times higher than the agricultural commodities of interest. Finally, the main destinations, Asia and Europe, are also common destinations through which goods from the New Orleans region flow. Concluding, the potential for combining agricultural commodities with manufactured goods and chemicals on barges is present in the Muskegon – New Orleans corridor.

Having determined that this corridor is qualified, it may be interesting to look at current export flows from Michigan through New Orleans. Table 35 provides an overview of these flows. The amount of goods who originate in Michigan and flow via New Orleans is limited and shows little similarities to the major export flows in table 34. Reasons might include the substantial longer transit time of barge transportation to New Orleans versus truck transportation to California. Nevertheless, transporting combined flows from Muskegon by water via New Orleans is assumed as possible.

Table 35: Top 5 of selective export flows out of Michigan via New Orleans, ranked by value (year: 2015)

Destination	Foreign mode	Domestic destination	Type of good	Domestic mode	Value in millions of dollars
Rest of Americas	Water	New Orleans	Other foodstuffs	Truck	10.97
Rest of Americas	Water	New Orleans	Chemical prod.	Multiple	7.55
Rest of Americas	Water	New Orleans	Precision instru.	Multiple	3.42
Europe	Water	New Orleans	Plastics/rubber	Truck	3.16
Rest of Americas	Water	New Orleans	Machinery	Truck	1.71

Source: Freight Analysis Framework (2015)

The second corridor which might be operated by a barge vessel involves the short Muskegon – Chicago route. An overview of the five most exported products from Michigan to Chicago are provided in table 36. As is the case with the other corridor under investigation, motorized vehicles and related goods are excluded. However, all modes of transportation are now included since there is no foreign outbound flow. Appendix 5 provides a more complete overview of the 40 most exported goods from Michigan to the Chicago area.

Table 36: Top 5 of selective export flows from Michigan to Chicago area, ranked by value (year: 2015)

Destination	Type of good	Domestic mode	Value in millions of dollars
Chicago area	Base metals	Truck	760.73
Chicago area	Other foodstuffs	Truck	620.41
Chicago area	Machinery	Truck	561.95
Chicago area	Milled grain prod.	Truck	433.32
Chicago area	Plastics/rubbers	Truck	348.01

Source: Freight Analysis Framework (2015)

While the flow of goods from Michigan to the Chicago area is very substantial and involves mainly semi- and finished goods, this corridor is also qualified for combining agricultural commodities with higher valued goods. Table 36 also confirms the popularity of truck transportation in Michigan which was already found in chapter 6.

No specific type of good is identified as having the largest potential to be shipped out of Muskegon together with the agricultural commodities. Nevertheless it is clear that high-value goods which are shipped in containers have the largest potential. Especially manufactured goods and silicon may have a chance of success. Considering the most valuable export product from table 36, 'base metals', the same disadvantage for agricultural commodities with respect to transportation via the port of Muskegon occurs: the main production sites are not located in the vicinity of Muskegon. As for steel, the main production areas are Grand Rapids and foremost the Greater Detroit area. On a relative short haul from Michigan to Chicago the detour via the port of Muskegon will yield too much extra costs. This problem is probably also the main reason for the absence of current exports through the port of Muskegon. This implies that goods which are produced in the direct proximity of Muskegon have the largest potential of transportation advantages compared to current transportation practices if combined with agricultural commodities. Because in general the production sites of semi- and finished goods in Michigan are located south of Muskegon the potential of transporting these goods via the port of Muskegon is limited. Notwithstanding, the next paragraph will quantify the possible advantages of combing multiple commodities and assesses the two barge-operated corridors individually.

8.4 Economic analysis

Quantifying a possible cost advantage for the agricultural commodities when combined with other goods is not a straightforward task. Little literature exists on this topic, specifically when it regards barges instead of container vessels. Moreover two different measurement units are used in the Muskegon case. The grain commodities are transported in bulk and priced in metric tons while the higher value goods are both transported and quoted in container units. Using two different measurement units makes it challenging to exercise third-degree price discrimination and apply a discount rate on bulk transportation on forehand.

Nevertheless it is assumed that combining a hopper grain barge with a flat container barge will lower the transportation rate for the agricultural commodities. The lower rate will foremost be the result of third-degree price discrimination of containerized goods. In addition, economies of scale are also in place and will affect the transportation rate as well but to a smaller extent.

While determining a specific discount rate is very hard, two different ones will be applied to the waterborne leg of the routes operated from Muskegon. Recalculations of the total transportation rate will therefore be done using both a 7.5% and 15% discount. These specific rates are chosen since it as assumed that two different mechanisms lower the transportation rate for the agricultural commodities. Setting a discount rate lower than 7.5% is therefore assumed to be too low while discount rates above the 15% represent a very strong ability of price discrimination which might not be realistic. Additionally, the other legs in the transportation chain as truck transportation to the port of Muskegon are held constant. This is also the case for trans loading rates.

The discounted transportation rates will now be calculated individually for both corridors. They will only be compared to the route with the lowest rate which is obtained in chapter 7. It is also assumed that these lowest rates are not subject to the advantages of combining multiple goods. For the truck-operated leg from Lansing to Chicago this makes sense since the trucks are assumed to be fully loaded. However, in the Muskegon – New Orleans corridor the barge leg from Chicago to New Orleans might also benefit when agricultural commodities are combined with other goods. No assessment of this scenario is available and therefore this possibility is ignored.

8.4.1 Muskegon – Chicago corridor

The two discount rates are now applied on the waterborne leg from Muskegon to Chicago. Table 37 provides both the current rates and discounted rates, compared to the most economical route which involves trucking from Lansing to Chicago.

Table 37: Muskegon – Chicago corridor, current transportation rate vs. possible transportation rates with discounted waterborne legs

Cost per ton / Route	**Lansing – Muskegon – Chicago (barge)**	**Lansing – Chicago (truck)**
Current rate	$24.94	$17.65
7.5% discount rate	$24.04	$17.65
15% discount rate	$23.14	$17.65

Combining agricultural commodities with high-value goods does not lead to a modal shift in the Muskegon – Chicago corridor based on transportation rates. This is due to the relative high share of trans loading costs in the port of Muskegon and road transportation haul from Lansing to Muskegon which is already half the distance from Lansing to Chicago. Both of these cost components do not benefit from the combination of multiple goods.

8.4.2 Muskegon – New Orleans corridor

In the Muskegon – New Orleans corridor the discounted direct barge route from Muskegon to New Orleans will be compared to the route which involves truck transportation from Lansing to Chicago and a barge operation from Chicago to New Orleans. Results are given in table 38.

Table 38: Muskegon – New Orleans corridor, current transportation rate vs. possible transportation rates with discounted waterborne legs

Cost per ton / Route	Lansing – Muskegon – New Orleans (barge)	Lansing – Chicago (truck) – New Orleans (barge)
Current rate	$48.79	$45.50
7.5% discount rate	$46.10	$45.50
15% discount rate	$43.41	$45.50

The results show that shipping agricultural commodities out of Muskegon together with high value goods might lead to a modal shift. Whereas a 7.5% discount rate still leaves the truck operated route via Chicago the most economic option, a 15% discount rates results in a favorable position for the waterborne option out of Muskegon. Nevertheless the cost advantage of 4.6% compared to the non-Muskegon originating route is not enough to initiate a modal shift considering the switching cost of 14% found in chapter 4.

8.5 Conclusion

Assessing the possibilities of combining agricultural commodities with other goods to obtain lower transportation rates is the main goal of this chapter. In order to lower the transportation rate, two mechanisms can be used. One is third-degree price discrimination wherefore a number of conditions must be satisfied, the second one is economies of scale.

For the Muskegon case both of these mechanisms can be exercised. However, only the two barge-operated corridors are qualified for benefiting from the combination of multiple commodities. The three corridors via Canada are served by a dry bulk carrier and cannot carry high-value goods. This is a condition for a successful combination of goods in order to lower transportation rates. Using both hopper barges and flat barges with containers makes this combination possible on the corridors to Chicago and New Orleans. Nevertheless the same problem regarding agricultural commodities is encountered for high-value goods: the main production sites are not located in the direct proximity of the port of Muskegon. The road haul to Muskegon yields extra transportation costs which makes the transportation and therefore combination of higher value semi- and finished goods via Muskegon not very likely.

In order to economically assess possible waterborne transportation advantages, two discount rates are set and applied to the waterborne leg originating from Muskegon. In the Muskegon – Chicago corridor the effect of such a discount rate is little and no modal shift is effectuated. Combining agricultural commodities with high-value goods in the Muskegon – New Orleans corridor however leads to a lower rate for the Muskegon route compared to the current most economic option. However, this is only the case when the highest of the two discount rates is applied and the cost advantage of 4.6% is not very substantial. Combining agricultural commodities with higher value goods will not initiate a modal shift based on transportation rates when taking this possible cost advantage and modal switching cost of 14% into account.

Both from a practical and economic perspective the combination of agricultural commodities with other sorts of goods will not benefit the export of agricultural commodities through the port of Muskegon.

9. Conclusion

The purpose of this research is to identify whether waterborne transportation via the port of Muskegon is able to provide substantial advantages over current agricultural transportation practices. The first part of the thesis involves a qualitative research while in the second part a quantitative economic assessment is conducted. Key findings of this thesis will be provided in the next paragraph. Limitations of the research and recommendations for further research are given thereafter.

9.1 Key findings

In order to identify possibilities for Michigan grown agricultural commodities to be exported via the port of Muskegon the following main research question was drafted:

''Does the port of Muskegon has the potential to offer substantial transportation advantages for export flows via the Great Lakes for agricultural commodities in the state of Michigan compared to current non-waterborne transportation practices?''

Answering this question required a number of steps to be taken. First, qualitative research is carried out which identified that cost and transit time are the most important variables on which a transportation mode can offer advantages. Other factors are also at stake but these two variables are set as the most important variables while transportation cost is the primary variable.

Investigating the current practices of agricultural production and transportation in the state of Michigan is the next step towards answering the main research question. Three commodities are identified with the highest potential of transportation through the port of Muskegon: corn, soybeans and wheat. A major disadvantage of these and other agricultural commodities is the location of production. This generally takes place in the south-east part of the state and does not favor Muskegon as exports usually flow further south out of state. Combine this with the dominance of truck transportation and exporting agricultural commodities via Muskegon is a challenger of current practices.

Assessing the main research question from an economic perspective requires specific corridors and corresponding routes to be investigated. Five possible corridors are identified, all originating from Michigan and flowing through the port of Muskegon while at least one benchmark route is designated per corridor. The five corridors are as follow:

- Muskegon – Chicago
- Muskegon – New Orleans
- Muskegon – Canada – Asia
- Muskegon – Quebec – Asia
- Muskegon – Quebec – Europe

Within these corridors different routes are compared with one and other. Current transportation rates are assessed while future oil prices scenarios are also taken into account. CO2 emissions are quantified and assessed as well. Transit time and discount rates following from the combination of agricultural commodities with high-value goods are also part of the analysis. When drawing conclusions it is assumed that only one scenario is present at the time. Thus, the worst oil price scenario and the initiation of a CO2 emission tax will not be present at the same time.

In the first three corridors the port of Muskegon is not able to provide a cost advantage compared to current transportation practices considering all scenario-analyses. Except for the New Orleans corridor where the most prosperous scenario of combining agricultural commodities with high-value goods results in a 4.6% transportation rate advantage. Besides the fact that the combination with higher value goods is unlikely to be accomplished in practice, the cost advantage does not outweighs the switching cost of 14%. As for transit time there are no substantial advantages to be gained within each of these three corridors.

The two waterborne routes out of Muskegon in the corridors to Asia and Europe via Quebec are competitive within current market conditions. Nevertheless, the highest cost advantage during any scenario-analysis is 13.1% in the European corridor. Advantages because of combined shipments with high-value goods are not present in both corridors because of the use of a bulk carrier. Although the European route also offers a significant time advantage other factors must be taken into account as well. That is, the minimum discount rate regarding switching costs is set to 14% and current providers of agricultural transportation in Michigan are likely to lower transportation rates after initiating operations out of Muskegon. In addition, other decision variables identified during the qualitative research cannot be unaccounted for. Since there is currently no agricultural infrastructure in the port of Muskegon, variables as efficiency, reliability and frequency are hard to quantify. The actual absence of agricultural export flows will not benefit these variables compared to current transportation practices.

The maximum cost advantage found in any corridor and scenario-analysis is less than the presumed switching costs while other general factors impede the initiation of waterborne agricultural exports via Muskegon as well. Therefore, the port of Muskegon does not have the potential to offer substantial advantages for agricultural exports out of Michigan compared to current practices.

9.2 Limitations of research

The major limitation of this research involves data gathering and the corresponding willingness of organizations to cooperate on this project. During the first phase of the research the main goal was to identify current transportation practices of agricultural commodities in Michigan. Numerous of relevant firms and organisations were contacted in order to obtain information. The response rate and the amount of information obtained was lower than expected. Nevertheless a number of firms did provide useful information and together with public available information a fair impression of current transportation practices was established.

After the research progressed, data for the economic analysis had to be obtained. Here, input of firms and organizations is even of more crucial importance. This follows from the fact that bulk transportation rates, especially in the Michigan region, are hardly public available. The cost of trans loading and rates on inland water transportation are not publicly available at all. Reluctance of shippers and firms to provide input is therefore more problematic than during the first phase of the research. While eventually for every transportation leg or movement a relevant rate is obtained, in most cases only one rate was available. This makes the input somewhat biased since rates could not be verified to those from other providers. For more solid and less biased results a larger amount of input providers is desirable and therefore the quality of current input is to some extent limited.

During other phases of the research such as assessing the possibilities of combining agricultural commodities with other goods, the lack of response from companies did not favour the research as well. Flowers are for example an interesting industry to investigate on this matter but none of the major flower producers in Michigan responded. In addition, a higher response rate on this and other topics might have provided more relevant insights and guidance during the whole research project.

The reluctance of firms and organizations to cooperate on this project might also indicate their doubts on the advantages that waterborne transportation via Muskegon has to offer. This is also confirmed by a number of interviewees and the results from the overall conclusion are in line with these negative expectations.

Another limitation is the narrow focus of the analysis which includes only three agricultural commodities. Although the selection of these specific commodities is justified, a broader scope can only enhance the research and possible findings on a higher utilization of waterborne transportation out of West Michigan. Including other goods and commodities which are produced closer to Muskegon itself or which are suited for containerized transportation may have provided more opportunities for the port of Muskegon.

The final limitation of this research is the limited amount of benchmark routes included in several corridors. To a certain extent this is the result of the amount of input from firms and organizations on both current transportation practices and rates. Including routes via Detroit, Toledo or the US west-coast ports can only improve the research and corresponding results.

9.3 Recommendations for further research

In this research transportation rates and transit time are set as main variables. Although CO2 emissions and future oil prices are taken into account, including more decision making variables in the economic analysis is recommendable. Further research might include scenario-analyses on efficiency, reliability, frequency, safety and congestion. Quantifying these variables might be a hard task for the Muskegon case but will provide a complete image of possibilities and bottlenecks.

Further research can also focus on modelling demand with respect to outbound port throughput in the Muskegon area. Independent variables as transportation rates for each mode, fuel prices and CO2 emissions can be included in the model. Other variables which are not accounted for in this research can be quantified as well. Suggestions include congestion on highways and railyards, safety issues, frequency, efficiency and reliability. Taking specific distances from the port to production sites of both agricultural commodities and manufactured goods into account is also of value.

10. Management advice to County of Muskegon

It is clear that the waterborne transportation opportunities for agricultural commodities out of Muskegon are generally not promising under current market conditions. Nevertheless certain developments as rising oil prices, greater awareness of environmental advantages and lower waterborne transportation rates by means of nearby production sites or a combination of multiple goods may provide opportunities in the future.

Multiple of these developments must occur at the same time in order for the port of Muskegon to become interesting for agricultural transportation firms. Since this is not likely to happen in the near future no short-term actions are required from the County of Muskegon itself. Longer term actions include the creation of awareness of general advantages of waterborne shipping such as the relative low increase of transportation rates during rising oil prices and lower emissions. Another option is to attract a large agricultural producer or manufacturer to the Muskegon region.

This thesis provides guidance on which kind of routes and producers to target initially in order to get stakeholders interested and create awareness of the advantages and possibilities. A first starting point is to address producers of both agricultural and other commodities who are located in the vicinity of the port. This way, the relative expensive truck haul to the port is as short and economic as possible while advantages of waterborne shipping are maximal utilized. In addition the commodities must not be highly time sensitive since waterborne transportation might involve longer transit times. It is also advisable to focus on longer routes which are more exposed to the advantages of waterborne shipping. Especially the corridor to Europe might be valuable to investigate and promote.

Current conditions do not favour the combination of transporting agricultural commodities with high-value goods. Attracting production sites to the region and creating a stakeholder group will improve these opportunities and eventually might lower transportation rates. Investigating other ways to lower transportation rates as reassuring backhaul cargo might also result from building a network of regional producers and shippers. Finally, emphasizing future scenarios as rising oil prices, greater environmental impact and more congested highways can lead to the interest of potential stakeholders.

The creation of awareness and possible advantages as well as identifying a stakeholder group can be done by the County of Muskegon itself. Another more costly option would be the initiation of a port authority. Because of the current unfavourable conditions for the port of Muskegon it is not advisable to invest in such an authority on the short-term. However, when market conditions change the establishment of a port authority might enhance the chances of success of more exports through the port of Muskegon. State legislators have already been working on a bill which makes the establishment of a port authority possible (Michigan Legislature, 2016).

When conditions change in the long-term a pilot project can be undertaken and initiated by either the County itself or a port authority. This can both be embodied by financially supporting a waterborne operation from the port of Muskegon for a limited period or funding and initiating certain infrastructure. One can think of storage capacity such as a grain elevators, a general warehouse or trans loading facilities.

Before investing in such a project, the County of Muskegon should gauge the willingness among stakeholders towards waterborne transportation and investigate possible levels of throughput. Without sufficient prospects the project of revitalization exports should be put on hold. A recommendation regarding this matter is to set up a public – private partnership in which the government works together with a small number of dedicated businesses who are willing to take an entrepreneurial position towards the port of Muskegon by means of making an investment or commitment to throughput. A port authority would be capable of accommodating such a partnership. In addition, the initiation of a partnership or port authority will also reduce the problem regarding the chicken and egg dilemma on what should come first; the demand for a waterborne service or the service itself?

Similar projects in which the government cooperates with businesses by means of funding or partnerships is not uncommon in the maritime world. The municipality of Rotterdam is for example the major stakeholder in the Port Authority of Rotterdam and the municipality of Cleveland still subsidizes the bi-monthly container service between Cleveland and Europe.

Thus, the current market conditions do not favour agricultural exports via the port of Muskegon and no immediate action can be undertaken to change this. When conditions change in the long-term, first the market potential must be assessed before concrete partnerships and incentives are realized in order to stimulate and accommodate waterborne shipments out of the port of Muskegon.

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Appendix 1: Transportation rates

Truck rates

The truck rates are derived from Grain Transportation and Marketing Programs data which specifically states per mile rates for grains, assuming a maximum total truck weight of 80,000 lbs. and a truckload of 25 metric ton of grains. In addition this data also makes a distinction for different regions in the US. Both Michigan and Chicago are part of the North Central region. The report is updated on a quarterly basis and at the moment of assessment only the first quarter report of 2016 is available. The truck rates are given below in appendix table 1.

Appendix table 1: Grain rate per-mile per truckload, (1st quarter, 2016)

Region	25 miles	100 miles	200 miles
North Central region	$3.28	$2.11	$2.08
Rocky Mountain region	NA	NA	NA
South Central	$2.88	$2.15	$2.02
West	NA	NA	NA

Source: https://www.ams.usda.gov/sites/default/files/media/2016GTORQ1.pdf

As already mentioned in chapter 7 these rates are modified for the Lansing – Muskegon route since this route is not within the vicinity of a major road transportation corridor and only a small distance is travelled. According to field experts a premium of $1.00 is applicable in addition to the rates in appendix table 1. Moreover, the rates on the Lansing – Muskegon route are modified more extensively since trucks with 164,000 lb weight maximum are allowed on Michigan highways (MDOT Intermodal Policy Division, 2013). This leads to a possible double truckload of 50 metric tons of grain instead of 25. However, state fees and fuel consumption are higher compared to the smaller truckloads and therefore the per-mile-rate will be increased with 25% before the premium of $1.00 is applied. This results in a per-mile-rate of $3.64 for a truckload of 50 metric tons on the Lansing – Muskegon route.

In addition, the field expert confirms that these rates are accurate for the Midwest region and cover all of the main expenses. However, fuel surcharges may be applicable but are not accounted for in this analysis. Route specific toll rates are not included and therefore these toll fees are calculated separately. The desktop application of Tollsmart is used for these calculations and small detours incorporated in order to avoid high toll costs. This results in the fact that the Lansing – Chicago route avoids the Chicago Skyway and takes the I-94 out of Indiana. This small detour saves $27,90 in toll fees on a one way haulage.

Finally, an interview with one of the field experts learned that the amount of tons a truck is assumed to carry in this thesis should also be transported in reality. Otherwise the stated rates would not apply. Thus, for the Lansing Muskegon route it is assumed that trucks carry a minimum of 50 metric tons and on the Lansing – Chicago route 25 metrics tons are transported per truckload.

Train rates

In contrast to the truck rates, both train and waterborne rates usually do not have a standard per mile-rate. Reasons for this include the larger infrastructure investments, fewer number of operators and limited amount of specific destinations able to serve. Quotes on train loads are not widely available and the majority of the Class 1 railroad firms do not have any public rates. Canadian National Railway Company (CN) is an exception and offers an online tool which provides a number of domestic and Canadian rail rates, specifically for grains. Moreover, this tool also provides rates for a number of routes the other six Class 1 railroads operate in both the US and Canada. The URL of this online tool is: http://ecprod.cn.ca/velocity/POWCarloadFrontend/public/english/GetCarloadPrice

Union Pacific (UP) also offers semi-public data on train rates. Combining the data of CN and UP offers the possibility to obtain specific grain quotes for all the routes under investigation. The URL for the UP rates is: http://c02.my.uprr.com/pic/jas/priceinquiry.jas

A number of assumptions regarding the CN rate information are made in order to obtain specific rates. First of all, both CN and UP operate a number of different load cars with different characteristics and measurements. Although these do not differ very much, the capacity of metric tons does differ per type of load car. Therefore the average of these car loads, 91 metric tons, is taken. These car loads are specifically for agricultural use since it are covered hoppers.

In addition it is assumed that rail cars of the rail operator itself are used. This is only a small premium in comparison with the case that own equipment is used. A downside of this assumption is the fact that it can be very costly if severe delays occur or the rail car is stuck in a rail yard. In this case the rail operator will charge a fee, approximately $100, for every day of extra use while the rail car in fact stands still. Considering the scope of this thesis these possible extra charges will be neglected.

The rates from both rail operators are a one-way route specific rate per car which are thus assumed to carry 91 metric tons. The given rates exclude reciprocal charges at both destination and origin. In addition to these rates both rail operators also charge a fuel surcharge tariff. UP provides this automatically while CN only provides a per-mile surcharge of $0.023. The total CN fuel surcharge is therefore calculated by multiplication of this rate and the train distance in miles which is obtained from www.distancesfrom.com.

As already stated in chapter 7, all of the grains are assumed to have equal transportation rates. Field experts have verified this for road transportation but train rates turn out to be different for the three commodities under investigation. Both UP and CN provide rates for different commodities, the specific commodity groups that are used in the calculations (if available), including the universal STCC codes are:

- Wheat, not organically grown (STCC code: 0113710)
- Corn, not popcorn, in the ear, not shelled, dried, not organically grown (STCC code: 0113210)
- Soybeans, dried, not organically grown (STCC code: 0114410)

The online rate-tools were able to provide specific train rates for all of the commodities on three out of the four routes. The train rates of the commodities differ somewhere between the 5% and 25% range. It has to be stated that no particular commodity has the lowest or highest train rate on every route so no pattern can be found regarding specific commodities. This justifies the assumption of equality among the commodities.

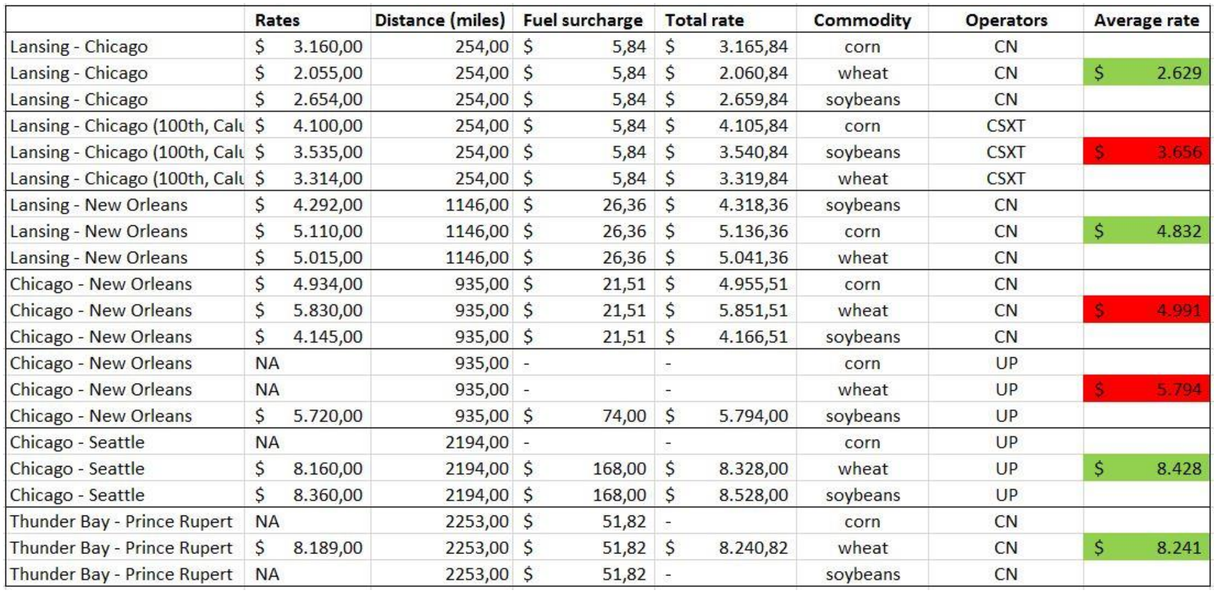
The average of the three commodity rates is chosen as route specific rate. As for the one route where only the rate of one commodity is available, this rate is set as route specific rate. On two routes multiple rates from different operators are available. In this case the cheapest operator is chosen. In addition, all the chosen rates are direct lines with only one operator involved. This enhances the accuracy of the rates and avoids cost of trans loading or switching from operator.

Since the Thunder Bay – Prince Rupert route is entirely situated within Canadian borders, the CN train rate on the route is also provided in Canadian dollars. In order to make accurate calculations this rate is converted to US dollars. The exchange rate is obtained from www.xe.com on Sunday 8-21-2016 and was quoted 1 CAD = 0.7770 USD.

A number of major (rail) transportation hubs as Seattle and Chicago are part of this analysis. Logically these hubs have multiple rail terminals and both the rate tools of CN and UP offer a number of place specific terminals to set as origin or destination. However, no specific terminals or dedicated grain firms are appointed in this thesis. For the simplicity and uniformity of calculations the option of only choosing the city and no specific terminal is used in both the rate tools.

The rail rates are given below in appendix figure 1. The final average rates depicted in green are the one used in the calculations since they are the cheapest alternative.

Appendix figure 1: train rates from origin to destination



	Rates	Distance (miles)	Fuel surcharge	Total rate	Commodity	Operators	Average rate
Lansing - Chicago	$ 3.160,00	254,00	$ 5,84	$ 3.165,84	corn	CN	
Lansing - Chicago	$ 2.055,00	254,00	$ 5,84	$ 2.060,84	wheat	CN	$ 2.629
Lansing - Chicago	$ 2.654,00	254,00	$ 5,84	$ 2.659,84	soybeans	CN	
Lansing - Chicago (100th, Calu	$ 4.100,00	254,00	$ 5,84	$ 4.105,84	corn	CSXT	
Lansing - Chicago (100th, Calu	$ 3.535,00	254,00	$ 5,84	$ 3.540,84	soybeans	CSXT	$ 3.656
Lansing - Chicago (100th, Calu	$ 3.314,00	254,00	$ 5,84	$ 3.319,84	wheat	CSXT	
Lansing - New Orleans	$ 4.292,00	1146,00	$ 26,36	$ 4.318,36	soybeans	CN	
Lansing - New Orleans	$ 5.110,00	1146,00	$ 26,36	$ 5.136,36	corn	CN	$ 4.832
Lansing - New Orleans	$ 5.015,00	1146,00	$ 26,36	$ 5.041,36	wheat	CN	
Chicago - New Orleans	$ 4.934,00	935,00	$ 21,51	$ 4.955,51	corn	CN	
Chicago - New Orleans	$ 5.830,00	935,00	$ 21,51	$ 5.851,51	wheat	CN	$ 4.991
Chicago - New Orleans	$ 4.145,00	935,00	$ 21,51	$ 4.166,51	soybeans	CN	
Chicago - New Orleans	NA	935,00	-	-	corn	UP	
Chicago - New Orleans	NA	935,00	-	-	wheat	UP	$ 5.794
Chicago - New Orleans	$ 5.720,00	935,00	$ 74,00	$ 5.794,00	soybeans	UP	
Chicago - Seattle	NA	2194,00	-	-	corn	UP	
Chicago - Seattle	$ 8.160,00	2194,00	$ 168,00	$ 8.328,00	wheat	UP	$ 8.428
Chicago - Seattle	$ 8.360,00	2194,00	$ 168,00	$ 8.528,00	soybeans	UP	
Thunder Bay - Prince Rupert	NA	2253,00	$ 51,82	-	corn	CN	
Thunder Bay - Prince Rupert	$ 8.189,00	2253,00	$ 51,82	$ 8.240,82	wheat	CN	$ 8.241
Thunder Bay - Prince Rupert	NA	2253,00	$ 51,82	-	soybeans	CN	

Trans loading rates

As stated in the chapter 7 the cost of trans loading grains are not publically available. Interviews with field experts led to useful insights but for the equality of comparison and to simplify input for the calculations a number of assumptions have to made. First of all no trans loading rates are charged for the point of origin in Lansing. While in practice these rates may be present, all investigated routes would carry these costs and therefore these rate can be neglected since the main goal of this thesis is to make a comparison between aspects of certain routes and modes of transportation who differ from each other.

An interview with an employee of one of the largest grain handling firms in the world also learns that trans loading costs are influenced greatly by the fact whether grains are directly transhipped from one mode of transportation to the other, or are first stored in a grain elevator for a number of days. The latter option increases the cost of trans loading significantly while the storage fee of grains can easily be $0.10 per metric ton, per day. Storing grains for a month before further transhipment takes place is not uncommon and therefore increases the trans loading cost by approximately $3.00 per metric ton.

For the simplicity of the calculations it is assumed that the grain trans loading on all the routes of interest is directly done from one transportation mode to another. Thus, possible costs of storage are not accounted for. For some transportation routes this assumption is more likely than others while vessel to vessel trans loading is quite common but train to vessel trans loading is less seen. Nevertheless all routes and transportation modes are excluded from storage rates.

The assumption that trans loading rates onto ocean going vessels are incorporated in the sea rates is quite strong but storage fees may also be applicable to these rates. However, all the routes which include an ocean-bound haul are subject to this. Since all sea ports under consideration (including Quebec) are large grain handling ports, it is assumed that that the trans loading process and therefore likeliness of storage is equal. Because this thesis is focused on comparisons between routes, transportation modes and ports, the possible storage and trans loading costs in seaports are neglected.

Inland waterway rates

Since a large share of the total US grain exports flow from the Midwest through the Mississippi River, a certain amount of information on these barge movements are publically available. The US Department of Agriculture releases a weekly update on the movements and barge rates from several places of origin to New Orleans. However, Chicago is not included as a place of origin. Personal contact with the USDA itself resulted in more detailed information and a barge rate of $24.85 per metric ton (MT) of grain is set from Chicago to New Orleans. This price is based on the data input provided by the USDA on 8-16-2016.

Since the distance between Muskegon and Thunder Bay is 945 kilometres (587 miles) it was suggested by field experts to consider a dry bulk vessel instead of barges since these are more common on this kind of trips and economies of scale lower the transportation rates. The provided transportation rate, using a bulk carrier and load of 12,000 metric ton, is $19.50 per metric ton. Considering the fact that this rate is based on multiple back to back to back shipments while taking the agricultural production rates in West Michigan also into account, the volume needed to establish such a service would be hard to aggregate in Muskegon. On the upside, these bulk carriers are able to carry multiple commodities so different commodity shipments out of Muskegon can be combined.

In addition a barge rate is obtained to verify the higher cost of barging. Assuming a 7,000 ton barge this rate indeed turned out to be $23.00 per metric ton. Therefore the economic analysis on intra-lake shipments will be assessed using dry bulk vessel characteristics.

While the distance between Muskegon and Chicago is relatively short (114 miles) a barge operation is the most logical option for waterborne transportation. Using three barges with a total capacity of 4,000 metric tons, the transportation rate is $12.00 per MT. The local barge operator who provided this rate states that no backhaul is assumed. When a load is available to ship back to Muskegon, the rate per MT would be able to come down to $9.50 per MT.

Two field experts were able to provide insights on the hypothetical direct barge movement from Muskegon to New Orleans. The first one stated that not only the typical barges on the inland waterways differ from those in the Great Lakes basin, but also the tug boats. He suggested that the river barges from Muskegon to Chicago would be shipped by a specific lake tug and in the Chicago area a specialized river barge operator will take over. The main advantage is that the commodities do not have to be trans loaded but only the tug boat is changed. The rates this field expert was able to provide are from 2015 and are therefore not very representative.

The second field expert argued that smaller river barges have to be used of 1,200 MT each. However it is possible to ship those all the way from Muskegon to New Orleans by means of one tug boat. Since no similar operations are done at the moment it is recommended by the field experts to combine the two barge rates from Muskegon to Chicago and Chicago to New Orleans as total rate for the direct route. The main advantage is that no trans loading cost in Chicago have to be accounted for. Moreover, since the trip from Muskegon to Chicago does not have any trans loading time to account for the rate on this rate can be set to $11.00 per MT instead of $12.00 pet MT. The total rate for direct barge transportation from Muskegon to New Orleans will therefore be set to $35.85 ($11.00+$24.85) per MT.

Operations on the route from Muskegon to Quebec are also carried out by the dry bulk carrier with a 12,000 MT capacity. The provided rate is $24.50 per metric ton.

For both the inland and ocean water transportation rates no demurrage costs are included. Although this cost can range from several hundred up to more than thousand US dollar per hour, these costs are to some extent already incorporated in the trans loading rate. To specifically identify which share of the trans loading cost is assigned to demurrage is hard to identify. Therefore possible demurrage costs are not accounted for in this analysis.

It is also assumed that both the inland waterway rates and ocean rates include the corresponding tolls and fees such as for the Panamax Canal or St. Lawrence Seaway. Whereas for the demurrage costs no field expert could provide a detailed comment, the assumption of inclusion of the tolls in the rates is confirmed by multiple field experts from the shipping industry.

Ocean rates

Sea rates for bulk commodities from the Pacific Northwest region to Asia are not always publically available but since a substantial amount of grains and oilseeds is shipped every week on this route, some figures are retrievable. Although no official definition for the Pacific Northwest is known, the region is usually referred to as the majority of the surfaces of the state of Washington, Oregon, Idaho and the Canadian province of British Columbia. Four major agricultural seaports are active in this region: the ports of Tacoma, Portland, Seattle and Vancouver (Canada). While the benchmark route is preferably in the US and has a large annual grain bulk throughput the port of Seattle is chosen as alternative. Moreover data of the Freight Analysis Framework (2015) shows that a number of Michigan grown agricultural commodities is also shipped through Seattle heading for Asian markets. As stated in chapter 7, the Japanese port of Yokohama is set as final destination.

The ocean bulk rates are provided by several agricultural related organisations since shipping firms do not publicize them. All rates are retrieved from weekly reports, published in the week of 15-19 August, 2016. Some of the reports are only available for paid subscribers but a field expert provided the needed rates and information. The reports provide multiple rates on the PNW – Japan route for different sized vessels. Because of economies of scale, larger bulk carriers have lower rates. The handymax ships which can carry between 35,000 and 45,000 metric tons are set as reference point. Although the four different reports which are investigated all assume the same transportation rate characteristics, each one provides a slightly different rate for the PNW -Japan route. This difference is probably due to different specific departure days. Therefore the average of the four rates is taken. Appendix table 2 provides an overview and the mean of all the rates.

Appendix table 2: Sea rates for grains on PNW – Japan route (week of 15-19 August, 2016)

Route	US$ per metric ton (handymax)	Source
PNW - Japan	$19.00	U.S. Wheat Associates
PNW - Japan	$17.00	U.S. Grains Council
PNW - Japan	$15.70	Commodity3 Report
PNW - Japan	$19.80	USDA
Average	$17.88	

While one report states more precise which commodities or grains are included in the rates, all of them are bulk grain rates and equality of three commodities is assumed. Therefore the seaborne transportation rate from Seattle to Japan is set at $17.88 per metric ton.

The same methodology is also applied to obtain the sea rates from the Gulf of Mississippi to both Japan (Yokohama) and the Netherlands (Amsterdam/Rotterdam). Results and average sea rates are presented in appendix table 3 and 4.

Appendix table 3: Sea rates for grains on Gulf – Japan route, (1st quarter, 2016)

Route	US$ per metric ton (handymax)	Source
Gulf - Japan	$30.25	U.S. Grains Council
Gulf - Japan	$29.00	U.S. Wheat Associates
Gulf - Japan	$29.75	USDA
Average	$29.67	

Appendix table 4: Sea rates for grains on Gulf – Europe route, (1st quarter, 2016)

Route	US$ per metric ton (handymax)	Source
Gulf - Europe	$16.25	U.S. Grains Council
Gulf - Europe	-	U.S. Wheat Associates
Gulf - Europe	-	USDA
Average	$16.25	

The rates ocean rates originating from Prince Rupert and Quebec are obtained from one of the largest grain firms in the world who were willing to cooperate on this topic. The rates to the Asian market are set with final destination Kobe, Japan and for the Quebec – Europe route Amsterdam is designated as final destination. The rates apply to handymax ships and are obtained in the first week of September. An overview of the rates per metric ton is given below.

Quebec – Europe (Amsterdam, the Netherlands):	$18.50
Quebec – Asia (Kobe, Japan):	$38.00
Prince Rupert – Asia (Kobe, Japan):	$22.50

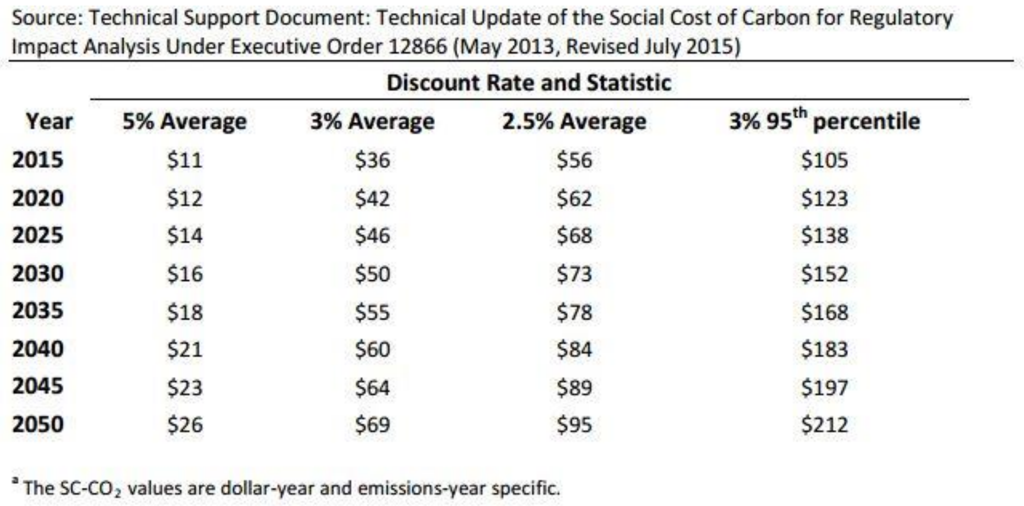
Emission analysis

The information in table 27 is based on a comprehensive US case study conducted in 2009. The fact that the results are relative recently obtained and all the three modes of interest are captured at once in a comprehensive study validates the use of this data in the emissions assessment. The abbreviations of the emissions, including brief background information, will now be provided:

- HC: hydrocarbons, reacts with other polluting chemicals
- CO: carbon monoxide, causes smog and may form other emissions of CO2
- NOx: nitrogen oxides, cause smog and acid rains
- PM: particulate matter, affect human health through lungs and blood streams
- CO2: carbon dioxide, important greenhouse gas which stimulates global warming

Calculations for the modal shift emission analysis are based on the CO2 price per ton obtained from the US Environmental Protection Agency (2015) study. This study takes a large number of variables into account and since a large amount of the negative CO2 effects are only noticeable in the long term, future costs of C02 are taken into account as well. Since future costs have to be discounted against current interest rates, a number of different interest rates and corresponding (future) CO2 costs are provided. Appendix figure 2 depicts these different rates and CO2 costs. This thesis assumes the scenario of a 2.5% interest rate and sets 2015 as base year.

Appendix figure 2: Discount rate and corresponding CO2 cost per metric ton



Source: Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866 (May 2013, Revised July 2015)

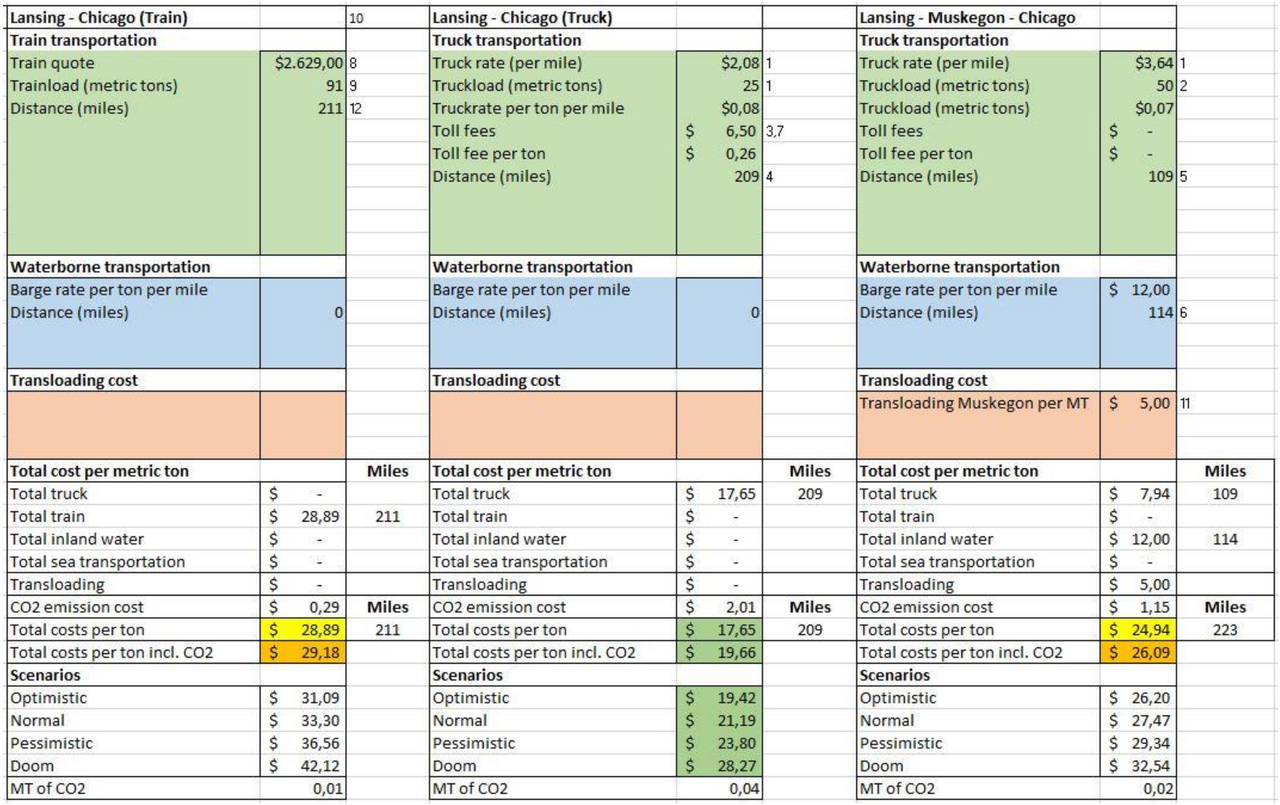
	Discount Rate and Statistic			
Year	5% Average	3% Average	2.5% Average	3% 95th percentile
2015	$11	$36	$56	$105
2020	$12	$42	$62	$123
2025	$14	$46	$68	$138
2030	$16	$50	$73	$152
2035	$18	$55	$78	$168
2040	$21	$60	$84	$183
2045	$23	$64	$89	$197
2050	$26	$69	$95	$212

[a] The SC-CO₂ values are dollar-year and emissions-year specific.

In order to obtain the CO2 emissions and corresponding cost for both train and sea transportation, the distance calculators of respectively www.distancesfrom.com and www.searates.com are used, all distances are calculated in miles.

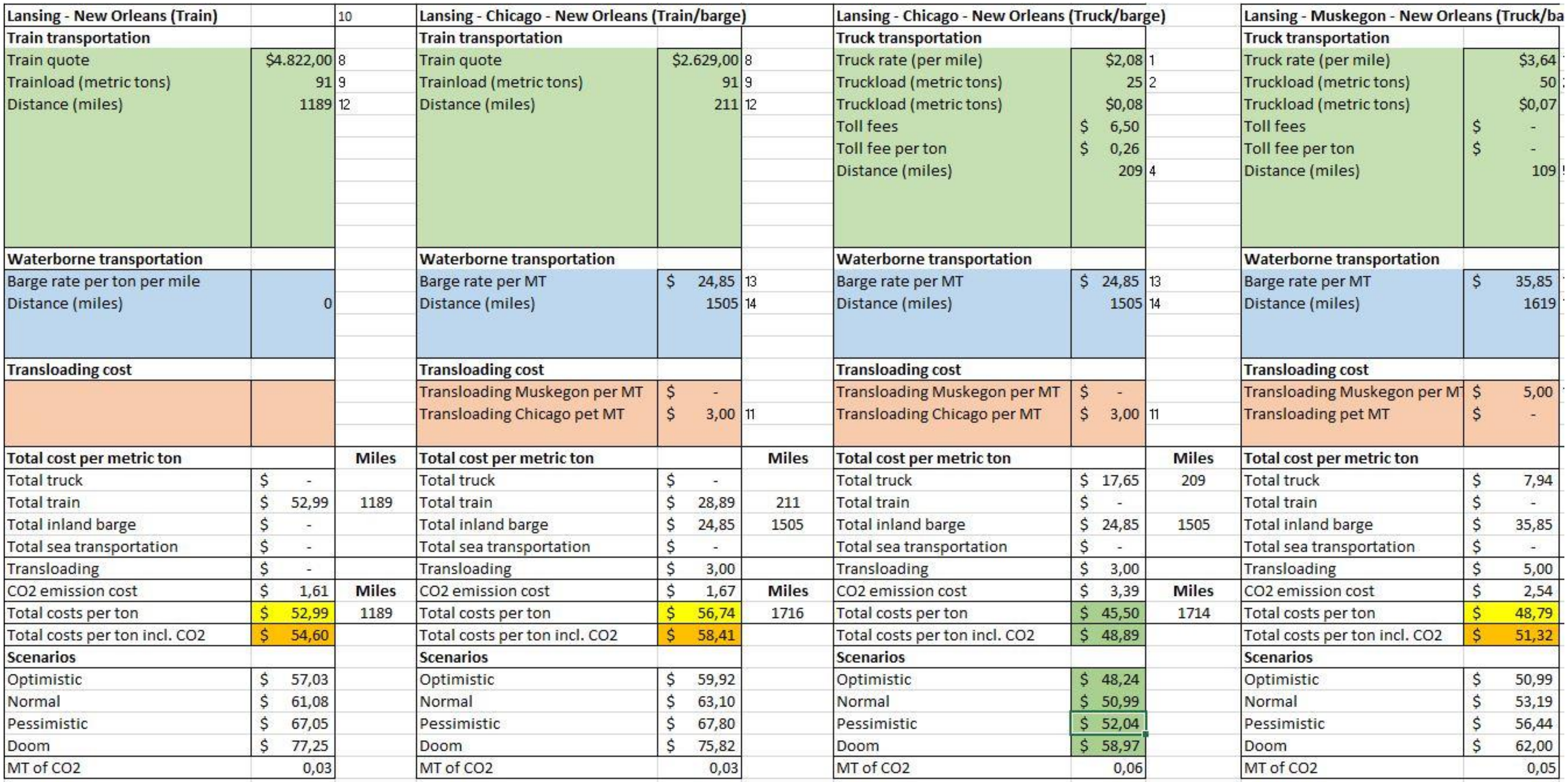
Detailed calculations per corridor (including sensitivity analysis and CO2 emissions)

Muskegon – Chicago corridor



Lansing - Chicago (Train)		10	**Lansing - Chicago (Truck)**			**Lansing - Muskegon - Chicago**		
Train transportation			**Truck transportation**			**Truck transportation**		
Train quote	$2.629,00	8	Truck rate (per mile)	$2,08	1	Truck rate (per mile)	$3,64	1
Trainload (metric tons)	91	9	Truckload (metric tons)	25	1	Truckload (metric tons)	50	2
Distance (miles)	211	12	Truckrate per ton per mile	$0,08		Truckload (metric tons)	$0,07	
			Toll fees	$ 6,50	3,7	Toll fees	$ -	
			Toll fee per ton	$ 0,26		Toll fee per ton	$ -	
			Distance (miles)	209	4	Distance (miles)	109	5
Waterborne transportation			**Waterborne transportation**			**Waterborne transportation**		
Barge rate per ton per mile			Barge rate per ton per mile			Barge rate per ton per mile	$ 12,00	
Distance (miles)	0		Distance (miles)	0		Distance (miles)	114	6
Transloading cost			**Transloading cost**			**Transloading cost**		
						Transloading Muskegon per MT	$ 5,00	11
Total cost per metric ton		**Miles**	**Total cost per metric ton**		**Miles**	**Total cost per metric ton**		**Miles**
Total truck	$ -		Total truck	$ 17,65	209	Total truck	$ 7,94	109
Total train	$ 28,89	211	Total train	$ -		Total train	$ -	
Total inland water	$ -		Total inland water	$ -		Total inland water	$ 12,00	114
Total sea transportation	$ -		Total sea transportation	$ -		Total sea transportation	$ -	
Transloading	$ -		Transloading	$ -		Transloading	$ 5,00	
CO2 emission cost	$ 0,29	**Miles**	CO2 emission cost	$ 2,01	**Miles**	CO2 emission cost	$ 1,15	**Miles**
Total costs per ton	$ 28,89	211	Total costs per ton	$ 17,65	209	Total costs per ton	$ 24,94	223
Total costs per ton incl. CO2	$ 29,18		Total costs per ton incl. CO2	$ 19,66		Total costs per ton incl. CO2	$ 26,09	
Scenarios			**Scenarios**			**Scenarios**		
Optimistic	$ 31,09		Optimistic	$ 19,42		Optimistic	$ 26,20	
Normal	$ 33,30		Normal	$ 21,19		Normal	$ 27,47	
Pessimistic	$ 36,56		Pessimistic	$ 23,80		Pessimistic	$ 29,34	
Doom	$ 42,12		Doom	$ 28,27		Doom	$ 32,54	
MT of CO2	0,01		MT of CO2	0,04		MT of CO2	0,02	

Muskegon – New Orleans corridor



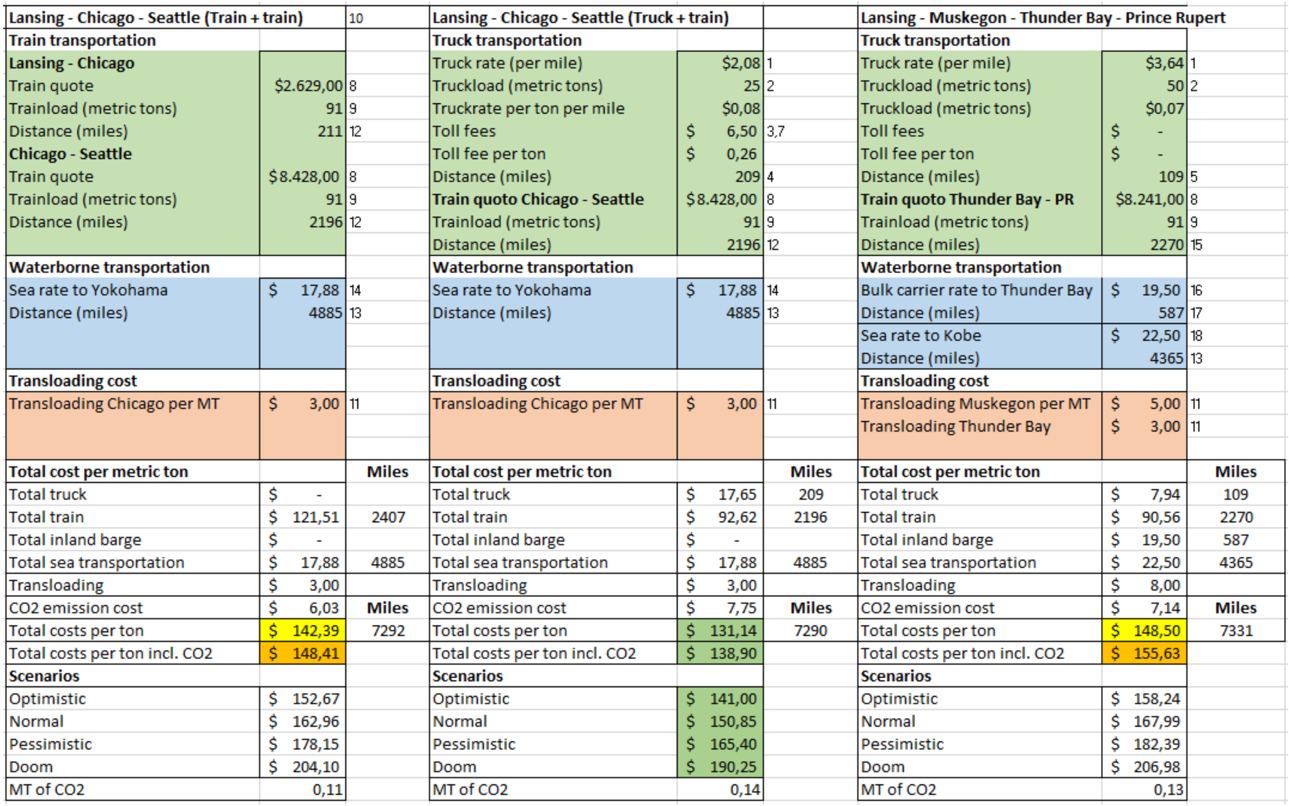
Lansing - New Orleans (Train)		10
Train transportation		
Train quote	$4.822,00	8
Trainload (metric tons)	91	9
Distance (miles)	1189	12
Waterborne transportation		
Barge rate per ton per mile		
Distance (miles)	0	
Transloading cost		
Total cost per metric ton		**Miles**
Total truck	$ -	
Total train	$ 52,99	1189
Total inland barge	$ -	
Total sea transportation	$ -	
Transloading	$ -	
CO2 emission cost	$ 1,61	**Miles**
Total costs per ton	$ 52,99	1189
Total costs per ton incl. CO2	$ 54,60	
Scenarios		
Optimistic	$ 57,03	
Normal	$ 61,08	
Pessimistic	$ 67,05	
Doom	$ 77,25	
MT of CO2	0,03	

Lansing - Chicago - New Orleans (Train/barge)		
Train transportation		
Train quote	$2.629,00	8
Trainload (metric tons)	91	9
Distance (miles)	211	12
Waterborne transportation		
Barge rate per MT	$ 24,85	13
Distance (miles)	1505	14
Transloading cost		
Transloading Muskegon per MT	$ -	
Transloading Chicago pet MT	$ 3,00	11
Total cost per metric ton		**Miles**
Total truck	$ -	
Total train	$ 28,89	211
Total inland barge	$ 24,85	1505
Total sea transportation	$ -	
Transloading	$ 3,00	
CO2 emission cost	$ 1,67	**Miles**
Total costs per ton	$ 56,74	1716
Total costs per ton incl. CO2	$ 58,41	
Scenarios		
Optimistic	$ 59,92	
Normal	$ 63,10	
Pessimistic	$ 67,80	
Doom	$ 75,82	
MT of CO2	0,03	

Lansing - Chicago - New Orleans (Truck/barge)		
Truck transportation		
Truck rate (per mile)	$2,08	1
Truckload (metric tons)	25	2
Truckload (metric tons)	$0,08	
Toll fees	$ 6,50	
Toll fee per ton	$ 0,26	
Distance (miles)	209	4
Waterborne transportation		
Barge rate per MT	$ 24,85	13
Distance (miles)	1505	14
Transloading cost		
Transloading Muskegon per MT	$ -	
Transloading Chicago per MT	$ 3,00	11
Total cost per metric ton		**Miles**
Total truck	$ 17,65	209
Total train	$ -	
Total inland barge	$ 24,85	1505
Total sea transportation	$ -	
Transloading	$ 3,00	
CO2 emission cost	$ 3,39	**Miles**
Total costs per ton	$ 45,50	1714
Total costs per ton incl. CO2	$ 48,89	
Scenarios		
Optimistic	$ 48,24	
Normal	$ 50,99	
Pessimistic	$ 52,04	
Doom	$ 58,97	
MT of CO2	0,06	

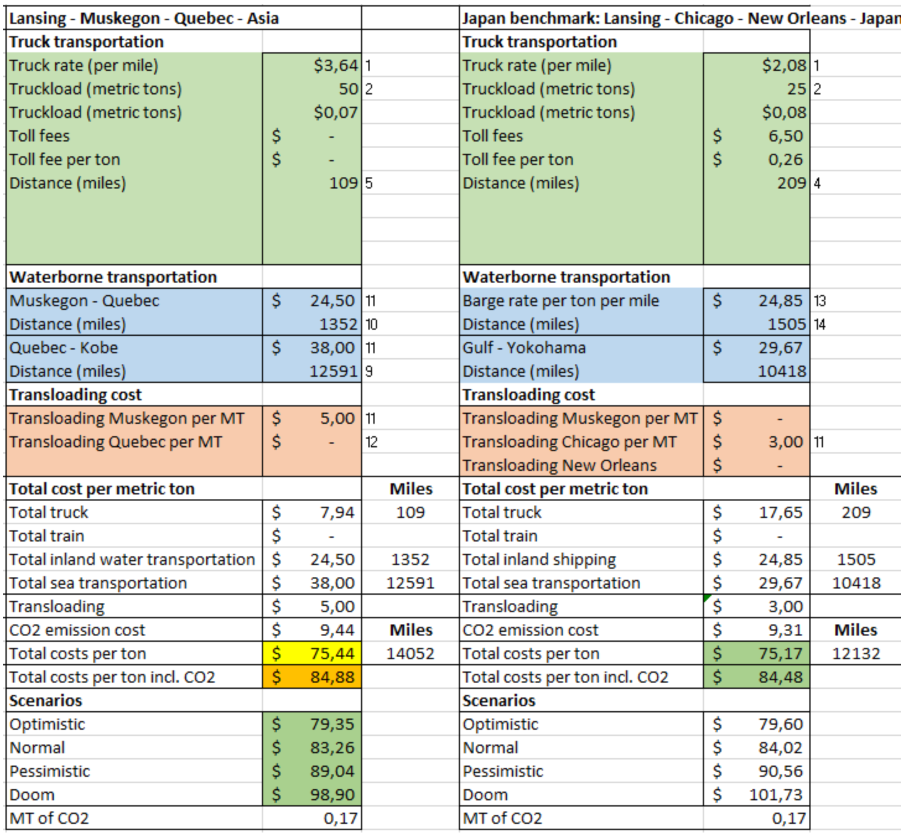
Lansing - Muskegon - New Orleans (Truck/ba	
Truck transportation	
Truck rate (per mile)	$3,64
Truckload (metric tons)	50
Truckload (metric tons)	$0,07
Toll fees	$ -
Toll fee per ton	$ -
Distance (miles)	109
Waterborne transportation	
Barge rate per MT	$ 35,85
Distance (miles)	1619
Transloading cost	
Transloading Muskegon per MT	$ 5,00
Transloading pet MT	$ -
Total cost per metric ton	
Total truck	$ 7,94
Total train	$ -
Total inland barge	$ 35,85
Total sea transportation	$ -
Transloading	$ 5,00
CO2 emission cost	$ 2,54
Total costs per ton	$ 48,79
Total costs per ton incl. CO2	$ 51,32
Scenarios	
Optimistic	$ 50,99
Normal	$ 53,19
Pessimistic	$ 56,44
Doom	$ 62,00
MT of CO2	0,05

Muskegon – Canada – Asia corridor



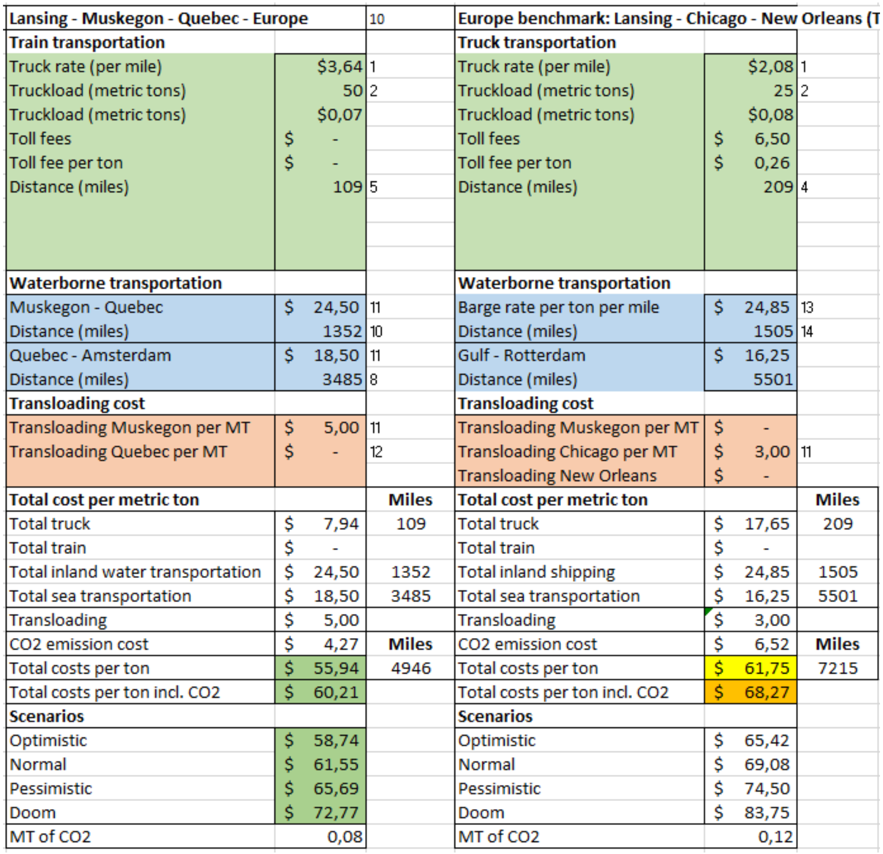
Lansing - Chicago - Seattle (Train + train)		10	**Lansing - Chicago - Seattle (Truck + train)**			**Lansing - Muskegon - Thunder Bay - Prince Rupert**		
Train transportation			**Truck transportation**			**Truck transportation**		
Lansing - Chicago			Truck rate (per mile)	$2,08	1	Truck rate (per mile)	$3,64	1
Train quote	$2.629,00	8	Truckload (metric tons)	25	2	Truckload (metric tons)	50	2
Trainload (metric tons)	91	9	Truckrate per ton per mile	$0,08		Truckload (metric tons)	$0,07	
Distance (miles)	211	12	Toll fees	$ 6,50	3,7	Toll fees	$ -	
Chicago - Seattle			Toll fee per ton	$ 0,26		Toll fee per ton	$ -	
Train quote	$8.428,00	8	Distance (miles)	209	4	Distance (miles)	109	5
Trainload (metric tons)	91	9	**Train quoto Chicago - Seattle**	$8.428,00	8	**Train quoto Thunder Bay - PR**	$8.241,00	8
Distance (miles)	2196	12	Trainload (metric tons)	91	9	Trainload (metric tons)	91	9
			Distance (miles)	2196	12	Distance (miles)	2270	15
Waterborne transportation			**Waterborne transportation**			**Waterborne transportation**		
Sea rate to Yokohama	$ 17,88	14	Sea rate to Yokohama	$ 17,88	14	Bulk carrier rate to Thunder Bay	$ 19,50	16
Distance (miles)	4885	13	Distance (miles)	4885	13	Distance (miles)	587	17
						Sea rate to Kobe	$ 22,50	18
						Distance (miles)	4365	13
Transloading cost			**Transloading cost**			**Transloading cost**		
Transloading Chicago per MT	$ 3,00	11	Transloading Chicago per MT	$ 3,00	11	Transloading Muskegon per MT	$ 5,00	11
						Transloading Thunder Bay	$ 3,00	11
Total cost per metric ton		**Miles**	**Total cost per metric ton**		**Miles**	**Total cost per metric ton**		**Miles**
Total truck	$ -		Total truck	$ 17,65	209	Total truck	$ 7,94	109
Total train	$ 121,51	2407	Total train	$ 92,62	2196	Total train	$ 90,56	2270
Total inland barge	$ -		Total inland barge	$ -		Total inland barge	$ 19,50	587
Total sea transportation	$ 17,88	4885	Total sea transportation	$ 17,88	4885	Total sea transportation	$ 22,50	4365
Transloading	$ 3,00		Transloading	$ 3,00		Transloading	$ 8,00	
CO2 emission cost	$ 6,03	**Miles**	CO2 emission cost	$ 7,75	**Miles**	CO2 emission cost	$ 7,14	**Miles**
Total costs per ton	$ 142,39	7292	Total costs per ton	$ 131,14	7290	Total costs per ton	$ 148,50	7331
Total costs per ton incl. CO2	$ 148,41		Total costs per ton incl. CO2	$ 138,90		Total costs per ton incl. CO2	$ 155,63	
Scenarios			**Scenarios**			**Scenarios**		
Optimistic	$ 152,67		Optimistic	$ 141,00		Optimistic	$ 158,24	
Normal	$ 162,96		Normal	$ 150,85		Normal	$ 167,99	
Pessimistic	$ 178,15		Pessimistic	$ 165,40		Pessimistic	$ 182,39	
Doom	$ 204,10		Doom	$ 190,25		Doom	$ 206,98	
MT of CO2	0,11		MT of CO2	0,14		MT of CO2	0,13	

Muskegon – Quebec – Japan corridor



Lansing - Muskegon - Quebec - Asia			**Japan benchmark: Lansing - Chicago - New Orleans - Japan**		
Truck transportation			**Truck transportation**		
Truck rate (per mile)	$3,64	1	Truck rate (per mile)	$2,08	1
Truckload (metric tons)	50	2	Truckload (metric tons)	25	2
Truckload (metric tons)	$0,07		Truckload (metric tons)	$0,08	
Toll fees	$ -		Toll fees	$ 6,50	
Toll fee per ton	$ -		Toll fee per ton	$ 0,26	
Distance (miles)	109	5	Distance (miles)	209	4
Waterborne transportation			**Waterborne transportation**		
Muskegon - Quebec	$ 24,50	11	Barge rate per ton per mile	$ 24,85	13
Distance (miles)	1352	10	Distance (miles)	1505	14
Quebec - Kobe	$ 38,00	11	Gulf - Yokohama	$ 29,67	
Distance (miles)	12591	9	Distance (miles)	10418	
Transloading cost			**Transloading cost**		
Transloading Muskegon per MT	$ 5,00	11	Transloading Muskegon per MT	$ -	
Transloading Quebec per MT	$ -	12	Transloading Chicago per MT	$ 3,00	11
			Transloading New Orleans	$ -	
Total cost per metric ton		**Miles**	**Total cost per metric ton**		**Miles**
Total truck	$ 7,94	109	Total truck	$ 17,65	209
Total train	$ -		Total train	$ -	
Total inland water transportation	$ 24,50	1352	Total inland shipping	$ 24,85	1505
Total sea transportation	$ 38,00	12591	Total sea transportation	$ 29,67	10418
Transloading	$ 5,00		Transloading	$ 3,00	
CO2 emission cost	$ 9,44	**Miles**	CO2 emission cost	$ 9,31	**Miles**
Total costs per ton	$ 75,44	14052	Total costs per ton	$ 75,17	12132
Total costs per ton incl. CO2	$ 84,88		Total costs per ton incl. CO2	$ 84,48	
Scenarios			**Scenarios**		
Optimistic	$ 79,35		Optimistic	$ 79,60	
Normal	$ 83,26		Normal	$ 84,02	
Pessimistic	$ 89,04		Pessimistic	$ 90,56	
Doom	$ 98,90		Doom	$ 101,73	
MT of CO2	0,17		MT of CO2	0,17	

Muskegon – Quebec – Europe corridor



Lansing - Muskegon - Quebec - Europe		10	**Europe benchmark: Lansing - Chicago - New Orleans (T**		
Train transportation			**Truck transportation**		
Truck rate (per mile)	$3,64	1	Truck rate (per mile)	$2,08	1
Truckload (metric tons)	50	2	Truckload (metric tons)	25	2
Truckload (metric tons)	$0,07		Truckload (metric tons)	$0,08	
Toll fees	$ -		Toll fees	$ 6,50	
Toll fee per ton	$ -		Toll fee per ton	$ 0,26	
Distance (miles)	109	5	Distance (miles)	209	4
Waterborne transportation			**Waterborne transportation**		
Muskegon - Quebec	$ 24,50	11	Barge rate per ton per mile	$ 24,85	13
Distance (miles)	1352	10	Distance (miles)	1505	14
Quebec - Amsterdam	$ 18,50	11	Gulf - Rotterdam	$ 16,25	
Distance (miles)	3485	8	Distance (miles)	5501	
Transloading cost			**Transloading cost**		
Transloading Muskegon per MT	$ 5,00	11	Transloading Muskegon per MT	$ -	
Transloading Quebec per MT	$ -	12	Transloading Chicago per MT	$ 3,00	11
			Transloading New Orleans	$ -	
Total cost per metric ton		**Miles**	**Total cost per metric ton**		**Miles**
Total truck	$ 7,94	109	Total truck	$ 17,65	209
Total train	$ -		Total train	$ -	
Total inland water transportation	$ 24,50	1352	Total inland shipping	$ 24,85	1505
Total sea transportation	$ 18,50	3485	Total sea transportation	$ 16,25	5501
Transloading	$ 5,00		Transloading	$ 3,00	
CO2 emission cost	$ 4,27	**Miles**	CO2 emission cost	$ 6,52	**Miles**
Total costs per ton	$ 55,94	4946	Total costs per ton	$ 61,75	7215
Total costs per ton incl. CO2	$ 60,21		Total costs per ton incl. CO2	$ 68,27	
Scenarios			**Scenarios**		
Optimistic	$ 58,74		Optimistic	$ 65,42	
Normal	$ 61,55		Normal	$ 69,08	
Pessimistic	$ 65,69		Pessimistic	$ 74,50	
Doom	$ 72,77		Doom	$ 83,75	
MT of CO2	0,08		MT of CO2	0,12	

Appendix 2: Transit times

Truck transit times

Truck distances are calculated from the start and ending points described in paragraph 7.1. The distances are obtained from Google Maps with standard settings. Since this thesis is an US based case study the unit of measurement is statute miles which is equivalent to 1,609.34 metres. The statute mile will be the default unit of measurement throughout the analysis unless otherwise stated.

The truck speed is obtained from an US Department of Transportation, Federal Highway Administration document. This document provides the average commercial truck speed on 25 Interstate routes, including one in the Michigan and Chicago area, for the year 2009. The average of all the 25 Interstate routes is used as trucking speed regarding the calculations in this thesis and is set at 56.3 miles per hour. While the two trucking routes under investigation are relatively short routes, 109 miles to Muskegon and 209 miles to Chicago, no pauses are incorporated. Moreover, both the place of origin and the two destinations are well connected to Interstate highways so no corrections are made for slower trucking speeds on secondary roads. The USDOT, Federal Highway Administration document is retrieved from the following URL: http://www.ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/10factsfigures/table3_8.htm

Train transit time

As is the case with transportation the rate, the transit times of train transportation do not have a standard quote per mile. The fact that shipments have to be picked up and deliveries are made during a route at multiple terminals are partly causing this. An alternative would be a dedicated train shuttle, however this usually involves 75 to 110 railcars which is equivalent to more than 7,000 tons of grain.

Therefore, the transit times are obtained from online tools of the Class 1 railroads which provide scheduled transit times per railcar. On the routes operated by CN, the online tool of CN itself was able to provide all the transit times: http://cn.ca/en/our-business/prices-tariffs-transit-times#. The Chicago – Seattle route is operated by multiple Class 1 railroads but UP is the most competitive one in our case study. However they are not able to provide (an estimation) of transit times. BNSF Railways also operates this route and is able to provide a transit time via their online tool: http://www.bnsf.com/bnsf.was6/goaltp/cntrl/qry. Both the CN and BNSF tools provide multiple days of departure and corresponding transit schedules and times may differ. Therefore in all the cases the shortest transit time is chosen, all expressed in hours.

Inland water transit time

Not only the transportation rate for the Chicago – New Orleans route is obtained with help from the USDA but also the transit time is provided by them. They use an online tool from ACL (http://www.acltrac.com/transit_times.asp?cat=bargeinfo) and quote a transit time of 21 days from Chicago to New Orleans. When dividing the distance between Chicago and New Orleans by the average barge speed, this transit time would only be a fraction of the 21 days. However the ACL tool also accounts for other factors as waiting times at locks.

As already stated in the transportation rate sector, the Muskegon – Thunder Bay route will be serviced by a bulk carrier. Interviews with Great Lake shippers learned that this ships average a speed of 12 knots per hour. To calculate the transit time the nautical distance of 945 kilometers (510 nautical miles) will be used which is obtained from the National Oceanic and Atmospheric Administration (NOAA): http://www.nauticalcharts.noaa.gov/nsd/distances-ports/distances.pdf.

The same vessel with the same speed is assumed to ship the grain from Muskegon to Quebec before overseas shipment to Europe or Asia. The distance from Muskegon to Quebec is 1,352 miles and is calculated with help of the route explorer of Searates.com.

The transportation time of the barge operation from Muskegon to Chicago is calculated using an average barge speed of 6.5 knots an hour. This speed is obtained from a field expert and assumes a full load of two barges. The distance between the two ports is set at 114 miles and is also calculate by means of the route explorer tool of Searates.com.

Ocean transit time

The ships which carry the grains from the US and Canadian Westcoast to Japan are assumed to be Handy-max vessels. The design speed of the modern versions is approximately 14 knots per hours (http://marine.man.eu/docs/librariesprovider6/technical-papers/propulsion-trends-in-bulk-carriers.pdf?sfvrsn=16). Where container line shipments have been subject to the recent trend of slow steaming, bulk carriers are perceived not to participate in this trend. Main reason is that the normal cruising speed of container ships used to be 22 to 25 knots per hour and modern slow steaming speeds are around 18 knots per hour. The 14 knots per hour speed of bulk carriers would be classified as ‘super slow steaming’. Therefore, 14 knots per hour is set as shipping speed for handy-max bulk carriers and field experts acknowledge that this is the standard for over a decade in dry bulk shipping.

The distances of the Seattle - Yokohama and Prince Rupert – Yokohama routes are calculated by means of the transit time calculator of Searates.com. In addition the distances from Quebec to Amsterdam and Kobe via Quebec are also calculated via this online tool, as well as their benchmark routes originating from New Orleans. The obtained distances are as follow:

- Seattle – Yokohama: 7,862 kilometres (4,245 nautical miles)
- Prince Rupert – Yokohama: 7,024 kilometres (3,793 nautical miles)
- Quebec – Amsterdam: 5,607 kilometres (3,028 nautical miles)
- Quebec – Kobe: 20,263 kilometres (10,941 nautical miles)
- New Orleans – Rotterdam: 8,852 kilometres (4,778 nautical miles)
- New Orleans – Yokohama: 16,766 kilometres (9,053 nautical miles)

Trans loading time

This thesis does not account for the loading time in Lansing or unloading time in the port of Chicago or other final destinations. The aim of this study is to compare different routes and transportation modes. Thus, the (un) loading of commodities at the place of origin and destination is the same for every route so no difference will be found in the comparisons. While different seaports with each of their own characteristics are under investigation, no difference in trans loading times are assumed. This stems from the fact that all of the four sea ports (Seattle, Prince Rupert, New Orleans and Quebec) are large grain hubs with modern facilities who can trans load up to 4,000 ton of grains in one hour (http://www.rupertport.com/shipping/terminals/prg).

On the other hand, trans loading grains in Muskegon and Chicago are not part of every transportation corridor under investigation and will therefore be taken into account in the analysis. An interview with a field expert learns that trans loading grains in the port of Muskegon will take approximately 24 hours when a barge is involved which can carry up to 1,200 metric tons. This trans loading process can take place from land to barge or truck to barge (vice versa is also possible) using a portable conveyer belt while a dedicated grain elevator is missing in the port of Muskegon. When multiple barges are loaded it is assumed that each barge is has an individual conveyer belt at its disposal.

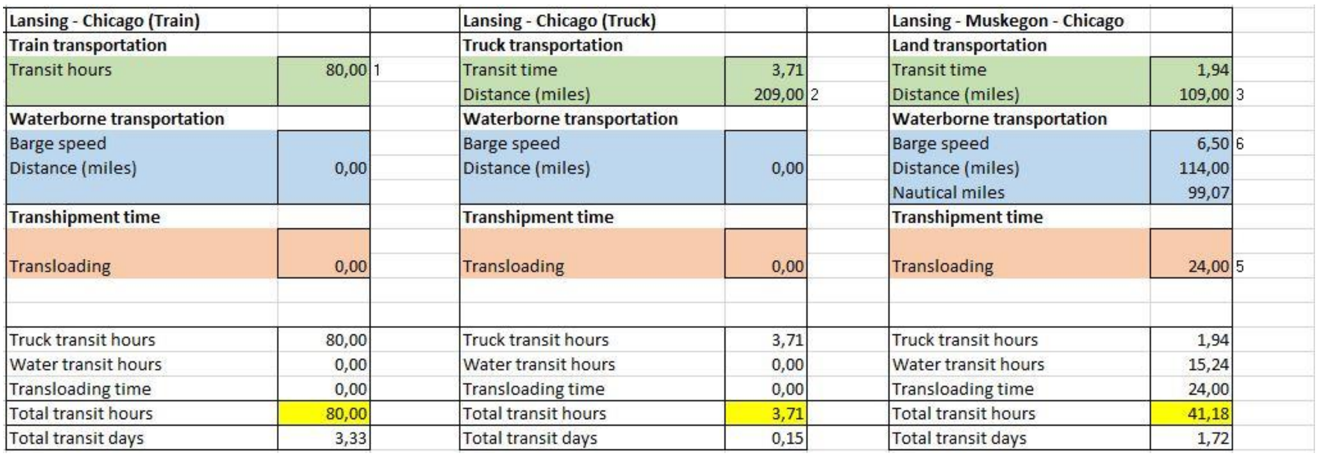
The advantages of larger ports with dedicated equipment become apparent when a field expert states that the trans loading of grains in the port of Prince Rupert will take approximately 24 hours for a bulk carrier loaded with 12,000 metric ton of grains.

No exact times for the trans loading in Chicago are provided by field experts. In the corridors of interest the grains are transhipped from either a truck or train to a river barge which carries 1,200 metric tons. While more sophisticated equipment is present in the port of Chicago than in Muskegon it is assumed that the trans loading time is half of the time in Muskegon. Because of this, the time of trans loading in Chicago is set to 12 hours.

As already stated in the appendix section regarding trans loading rates, direct trans loading from one transportation mode to another is assumed. While in practice grains can be stored for 30 days before being transhipped into a port to their new transportation mode, these possible extra days of transhipment are not accounted for.

Detailed calculations per corridor

Muskegon – Chicago corridor

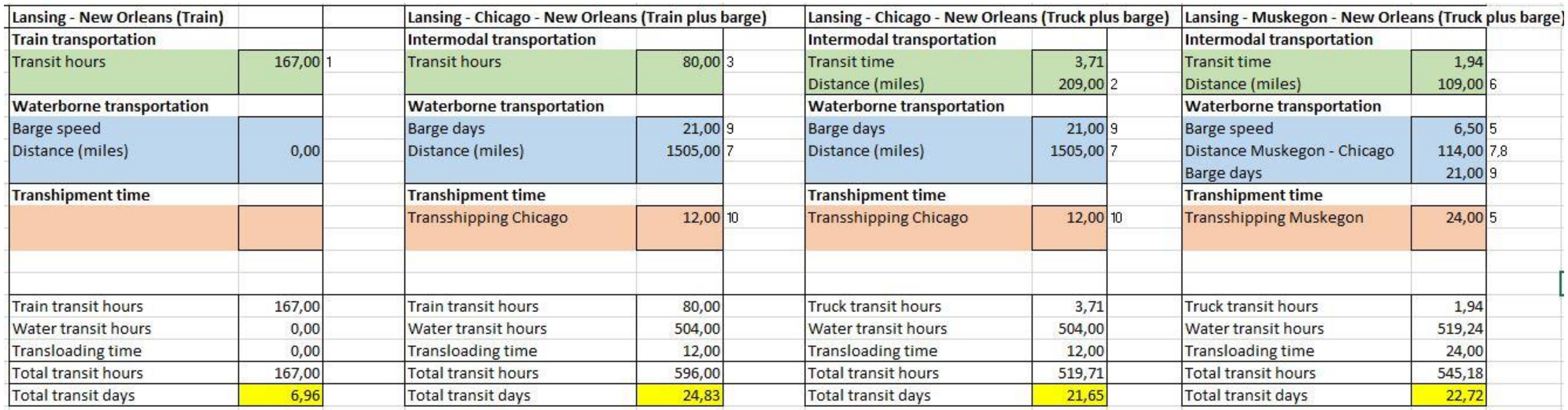


Lansing - Chicago (Train)		
Train transportation		
Transit hours	80,00	1
Waterborne transportation		
Barge speed		
Distance (miles)	0,00	
Transhipment time		
Transloading	0,00	
Truck transit hours	80,00	
Water transit hours	0,00	
Transloading time	0,00	
Total transit hours	80,00	
Total transit days	3,33	

Lansing - Chicago (Truck)		
Truck transportation		
Transit time	3,71	
Distance (miles)	209,00	2
Waterborne transportation		
Barge speed		
Distance (miles)	0,00	
Transhipment time		
Transloading	0,00	
Truck transit hours	3,71	
Water transit hours	0,00	
Transloading time	0,00	
Total transit hours	3,71	
Total transit days	0,15	

Lansing - Muskegon - Chicago		
Land transportation		
Transit time	1,94	
Distance (miles)	109,00	3
Waterborne transportation		
Barge speed	6,50	6
Distance (miles)	114,00	
Nautical miles	99,07	
Transhipment time		
Transloading	24,00	5
Truck transit hours	1,94	
Water transit hours	15,24	
Transloading time	24,00	
Total transit hours	41,18	
Total transit days	1,72	

Muskegon – New Orleans corridor



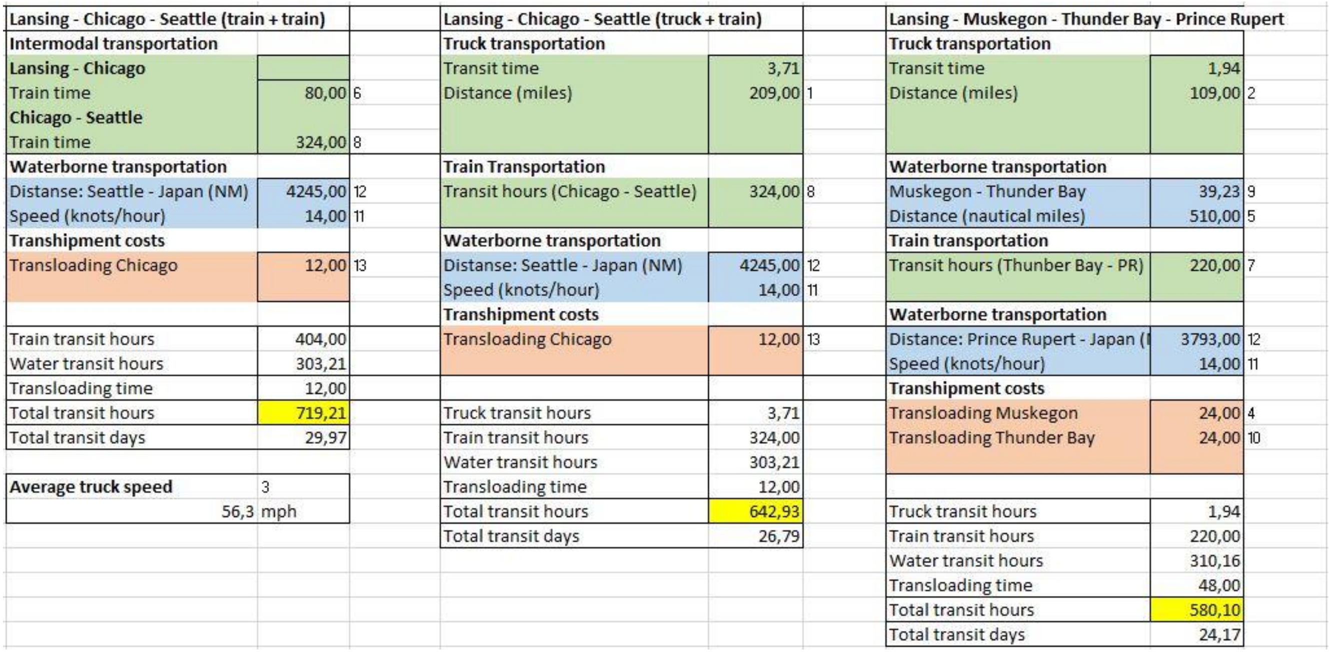
Lansing - New Orleans (Train)		
Train transportation		
Transit hours	167,00	1
Waterborne transportation		
Barge speed		
Distance (miles)	0,00	
Transhipment time		
Train transit hours	167,00	
Water transit hours	0,00	
Transloading time	0,00	
Total transit hours	167,00	
Total transit days	6,96	

Lansing - Chicago - New Orleans (Train plus barge)		
Intermodal transportation		
Transit hours	80,00	3
Waterborne transportation		
Barge days	21,00	9
Distance (miles)	1505,00	7
Transhipment time		
Transshipping Chicago	12,00	10
Train transit hours	80,00	
Water transit hours	504,00	
Transloading time	12,00	
Total transit hours	596,00	
Total transit days	24,83	

Lansing - Chicago - New Orleans (Truck plus barge)		
Intermodal transportation		
Transit time	3,71	
Distance (miles)	209,00	2
Waterborne transportation		
Barge days	21,00	9
Distance (miles)	1505,00	7
Transhipment time		
Transshipping Chicago	12,00	10
Truck transit hours	3,71	
Water transit hours	504,00	
Transloading time	12,00	
Total transit hours	519,71	
Total transit days	21,65	

Lansing - Muskegon - New Orleans (Truck plus barge)		
Intermodal transportation		
Transit time	1,94	
Distance (miles)	109,00	6
Waterborne transportation		
Barge speed	6,50	5
Distance Muskegon - Chicago	114,00	7,8
Barge days	21,00	9
Transhipment time		
Transshipping Muskegon	24,00	5
Truck transit hours	1,94	
Water transit hours	519,24	
Transloading time	24,00	
Total transit hours	545,18	
Total transit days	22,72	

Muskegon – Canada – Asia corridor

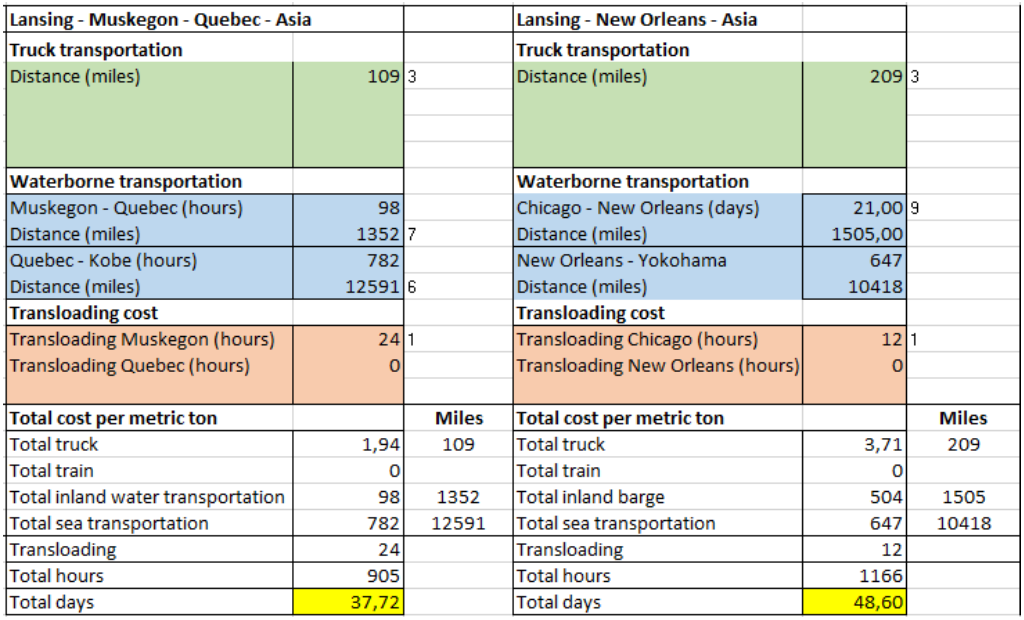


Lansing - Chicago - Seattle (train + train)		
Intermodal transportation		
Lansing - Chicago		
Train time	80,00	6
Chicago - Seattle		
Train time	324,00	8
Waterborne transportation		
Distanse: Seattle - Japan (NM)	4245,00	12
Speed (knots/hour)	14,00	11
Transhipment costs		
Transloading Chicago	12,00	13
Train transit hours	404,00	
Water transit hours	303,21	
Transloading time	12,00	
Total transit hours	719,21	
Total transit days	29,97	
Average truck speed	3	
56,3	mph	

Lansing - Chicago - Seattle (truck + train)		
Truck transportation		
Transit time	3,71	
Distance (miles)	209,00	1
Train Transportation		
Transit hours (Chicago - Seattle)	324,00	8
Waterborne transportation		
Distanse: Seattle - Japan (NM)	4245,00	12
Speed (knots/hour)	14,00	11
Transhipment costs		
Transloading Chicago	12,00	13
Truck transit hours	3,71	
Train transit hours	324,00	
Water transit hours	303,21	
Transloading time	12,00	
Total transit hours	642,93	
Total transit days	26,79	

Lansing - Muskegon - Thunder Bay - Prince Rupert		
Truck transportation		
Transit time	1,94	
Distance (miles)	109,00	2
Waterborne transportation		
Muskegon - Thunder Bay	39,23	9
Distance (nautical miles)	510,00	5
Train transportation		
Transit hours (Thunber Bay - PR)	220,00	7
Waterborne transportation		
Distance: Prince Rupert - Japan (I	3793,00	12
Speed (knots/hour)	14,00	11
Transhipment costs		
Transloading Muskegon	24,00	4
Transloading Thunder Bay	24,00	10
Truck transit hours	1,94	
Train transit hours	220,00	
Water transit hours	310,16	
Transloading time	48,00	
Total transit hours	580,10	
Total transit days	24,17	

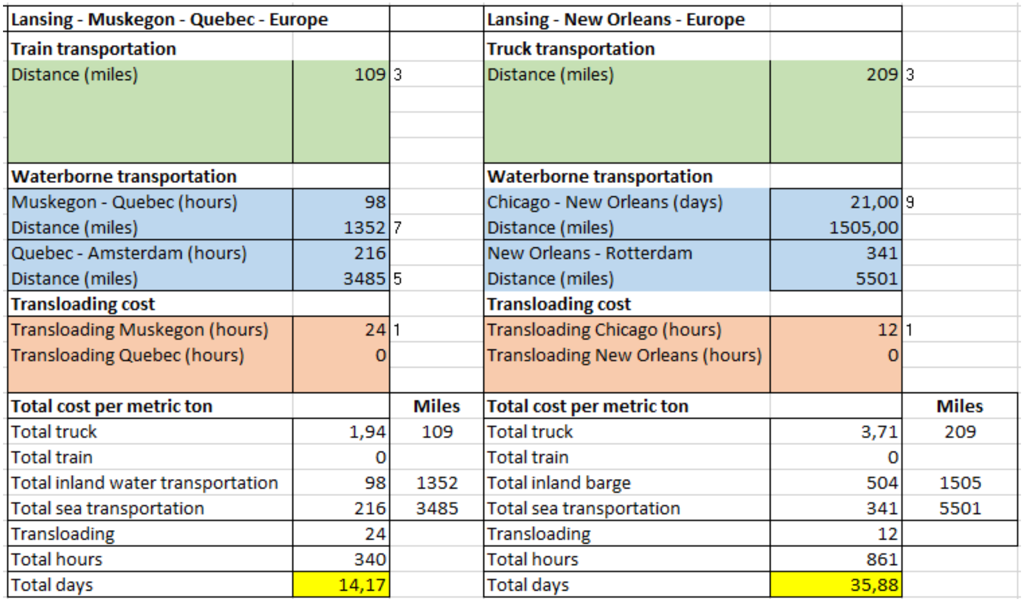
Muskegon – Quebec – Japan corridor



Lansing - Muskegon - Quebec - Asia		
Truck transportation		
Distance (miles)	109	3
Waterborne transportation		
Muskegon - Quebec (hours)	98	
Distance (miles)	1352	7
Quebec - Kobe (hours)	782	
Distance (miles)	12591	6
Transloading cost		
Transloading Muskegon (hours)	24	1
Transloading Quebec (hours)	0	
Total cost per metric ton		**Miles**
Total truck	1,94	109
Total train	0	
Total inland water transportation	98	1352
Total sea transportation	782	12591
Transloading	24	
Total hours	905	
Total days	37,72	

Lansing - New Orleans - Asia		
Truck transportation		
Distance (miles)	209	3
Waterborne transportation		
Chicago - New Orleans (days)	21,00	9
Distance (miles)	1505,00	
New Orleans - Yokohama	647	
Distance (miles)	10418	
Transloading cost		
Transloading Chicago (hours)	12	1
Transloading New Orleans (hours)	0	
Total cost per metric ton		**Miles**
Total truck	3,71	209
Total train	0	
Total inland barge	504	1505
Total sea transportation	647	10418
Transloading	12	
Total hours	1166	
Total days	48,60	

Muskegon – Quebec – Europe corridor



Lansing - Muskegon - Quebec - Europe			**Lansing - New Orleans - Europe**		
Train transportation			**Truck transportation**		
Distance (miles)	109	3	Distance (miles)	209	3
Waterborne transportation			**Waterborne transportation**		
Muskegon - Quebec (hours)	98		Chicago - New Orleans (days)	21,00	9
Distance (miles)	1352	7	Distance (miles)	1505,00	
Quebec - Amsterdam (hours)	216		New Orleans - Rotterdam	341	
Distance (miles)	3485	5	Distance (miles)	5501	
Transloading cost			**Transloading cost**		
Transloading Muskegon (hours)	24	1	Transloading Chicago (hours)	12	1
Transloading Quebec (hours)	0		Transloading New Orleans (hours)	0	
Total cost per metric ton		**Miles**	**Total cost per metric ton**		**Miles**
Total truck	1,94	109	Total truck	3,71	209
Total train	0		Total train	0	
Total inland water transportation	98	1352	Total inland barge	504	1505
Total sea transportation	216	3485	Total sea transportation	341	5501
Transloading	24		Transloading	12	
Total hours	340		Total hours	861	
Total days	14,17		Total days	35,88	

Appendix 3: Vessel types

The port of Muskegon has the possibility to accommodate a large variety of ships since there is a quay of 1,000 feet with a draft of 27 feet. Despite these possibilities, only two types of ships now enter the port of Muskegon on a regular basis: tug-barge combinations and dry bulk lake vessels. The former usually have a draft between 10 and 17 feet while the dry bulk vessel are somewhat larger and require a draft up to 27 feet. This port specific data is retrieved from the US Navigation date center: http://www.navigationdatacenter.us/wcsc/webpub14/Part3_Ports_Tripsby2014.htm.

Because of these possibilities of the port of Muskegon multiple vessels are assumed to have the ability to ship grains out of Muskegon. Two lake-going vessel types will now be discussed as well as the type of vessel that ships the grain overseas.

Tug-barge combination

The most common vessel type on the US inland waterways is the combination of a tug and barge. While the tugboat can both tug or push the barges, the latter option is nowadays the preferred option. Moreover, a tugboat which moves grains on the Mississippi River can push more than 15 barges at once. These barges are all covered hopper river barges designed to ship dry bulk commodities as grains and oilseeds. Expert interviews learn that after proper cleaning other commodities can be shipped in the vessels. As stated earlier the river barges are not allowed to go into the Great Lakes basin because of safety reasons. Weather on the Great Lakes can be much more severe and due to the lack of o load line and other design issues the US Coast Guard prohibits river barges to enter Lake Michigan.

An exemption on this prohibition is the line operated from Milwaukee to Chicago and further down the Mississippi River. One of the conditions that has to be met is the fact that only three barges may be tugged or pushed at once. This is also the maximum number of barges that is assumed on the hypothetical line from Muskegon to Chicago and Muskegon to New Orleans. While barge shipments from the greater Chicago area to New Orleans are completely inland river navigable, the number of towed barges may be larger than this. The number of barges towed by one tugboat influences the fuel efficiency of this transportation mode, however the numbers used in the economic analysis are averages so this is assumed to be accounted for.

A number of general characteristics for the covered hopper barges are now provided:

- Capacity of 1 river barge: 1,200 metric tons
- Draft: 9 feet
- Length x width: 195 feet x 35 feet
- Average speed: 6.5 knots

The above figures are retrieved from a field expert and in addition the following source is used: http://www.globalsecurity.org/military/systems/ship/towboat.htm.

Dry bulk lake carrier

Field experts indicate that grain transportation on longer inter-lake routes is cheaper when bulk vessels are used instead of barges. For this reason it is assumed that the trips from Muskegon to both Thunder Bay and Quebec are operated by a bulk carrier. These ships can carry multiple dry bulk goods, also during one trip since they normally have multiple cargo holds. Since these ships are smaller than ocean going vessels, they are referred to as dry bulk lake carriers.

A number of general characteristics for a dry bulk carrier are now provided:

- Capacity: 12,000 metric tons
- Draft: 25.6 feet
- Length x width: 459 feet x 69 feet
- Average speed: 12 knots

Data is retrieved from a field expert and considers a specific dry bulk vessel. Nevertheless these characteristics also apply in general for a number of dry bulk carriers who operate in the GLSLS system.

Handymax vessel

The ocean hauls under investigation are assumed to be operated by handymax vessels. These relative small ocean vessels are commonly used to transport grains and other dry bulk around the globe. This is also confirmed by the transportation sheets of ocean rates for grains where shipping by handymax vessels is always indicated as standard or extra option. The approximately 1,800 dry bulk handymax vessels who operate worldwide represent 25% of the total dry bulk vessels of the world fleet.

As the dry bulk lake carriers, handymax vessels also are able to ship multiple commodities during one trip since several cargo holds are present. Handymax vessels are not assumed to ship in the Great Lakes basin itself because the draft of the vessel is several feet to deep.

A large number of handymax vessel is operated globally and therefore the specific characteristics differ per ship. General characteristics of a handymax ship are given below.:

- Capacity: 35,000 – 45,000 metric tons
- Draft: 28 – 34 feet
- Length x width: 490 – 660 feet x 70 – 80 feet
- Average speed: 14 knots

Data is retrieved from Psaraftis and Kontovas (2009) plus the website of a shipping firm: http://hudsonshipping.com/?q=node/95.

Appendix 4: List of interviewees

Because of confidentially reasons none of the interviews is named explicitly in this thesis. Appendix table 5 provides an overview of the interviewees by providing a list of the interviewed firms and organizations as well as the position of the representative spoken to.

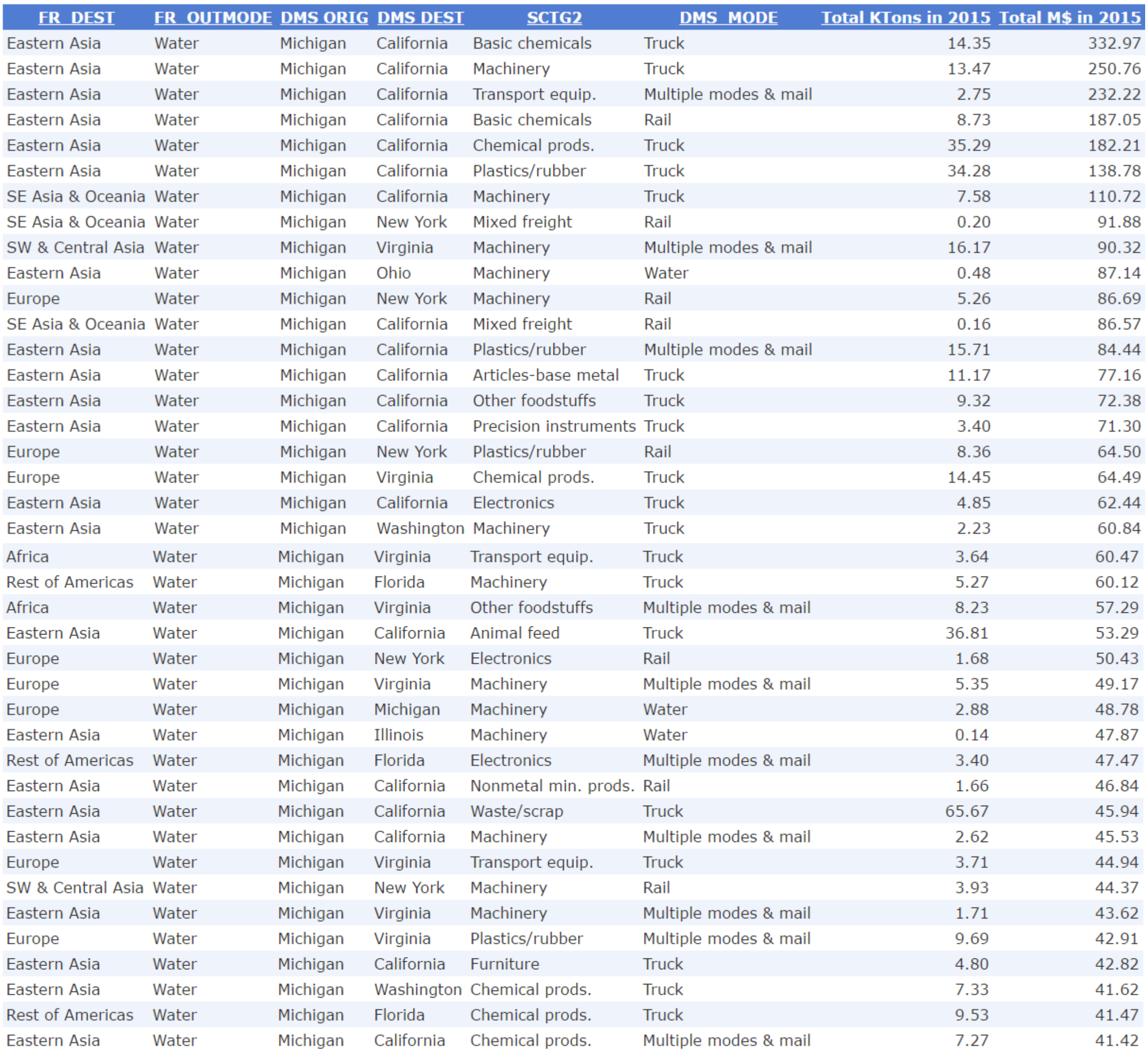
Appendix table 5: List of interviewees

Type of organization	**Description**	**Position of interviewee**
Farmer	Midsize Muskegon area based farmer	General manager
Farmer	Larger multi crop farmer in West Michigan	Transportation manager
Farmer	Operates multiple large grain elevators in the US and Michigan	Plant manager
Processor	Large corn processor which produces ethanol, corn oil and DDGS	Commodity manager
Farmers organization	Represents 15,000 Michigan farmers	Local representative
Farmers organization	Represents thousands of Michigan farmers	Regional representatives
Farmers organization	Represents Michigan corn growers	Director
Agricultural organization	Government org. with comprehensive information and databases	Several employees
Consultancy firm	Specialized maritime consultant	Executive consultant
Port authority	From a midsize port at Lake Michigan	Operations manager
Port authority	From a large Canadian east-coast port	Operations manager
Multinational grain trader	Operating in Milwaukee and Chicago area	Regional manager
Multinational grain trader	Operating in the Midwest and able to provide shipping rates	International operations manager
Transportation firm	Tug operator in the Great Lakes area	Director
Transportation firm	Large shipping firm in the GLSLS area	Director of sales
Transportation firm	Train and truck firm in the West Michigan area	Director
Transportation firm	Specialized in trans loading of goods and commodities in the Midwest	General manager
Transportation firm	International operating firm with overseas shipments from and to the GLSLS	GLSLS region manager
Transportation organization	Representing all sorts of transportation firms in Michigan	Director
Business organization	Representing West Michigan firms	Director

Appendix 5: Michigan exports

For the assessment of combining agricultural commodities with other goods an overview of the export flows of Michigan produced goods is provided. The data is obtained from the Freight Analysis Framework and applies to the year 2015. The data provides the origin of the goods, Michigan, the US export state, the foreign destination region, both domestic and foreign transportation mode and the weight plus value of the export flow. For reasons identified in chapter 8, only flows with a domestic waterborne flow are chosen. Moreover, exports of Motorized vehicles are excluded as well as goods with Canada as destination. Appendix figure 3 provides an overview of the top 40 exported goods who meet the conditions mentioned above.

Appendix figure 3: Export flows out of Michigan, top-40 ranked by value (year:2015)



FR_DEST	FR_OUTMODE	DMS_ORIG	DMS_DEST	SCTG2	DMS_MODE	Total KTons in 2015	Total M$ in 2015
Eastern Asia	Water	Michigan	California	Basic chemicals	Truck	14.35	332.97
Eastern Asia	Water	Michigan	California	Machinery	Truck	13.47	250.76
Eastern Asia	Water	Michigan	California	Transport equip.	Multiple modes & mail	2.75	232.22
Eastern Asia	Water	Michigan	California	Basic chemicals	Rail	8.73	187.05
Eastern Asia	Water	Michigan	California	Chemical prods.	Truck	35.29	182.21
Eastern Asia	Water	Michigan	California	Plastics/rubber	Truck	34.28	138.78
SE Asia & Oceania	Water	Michigan	California	Machinery	Truck	7.58	110.72
SE Asia & Oceania	Water	Michigan	New York	Mixed freight	Rail	0.20	91.88
SW & Central Asia	Water	Michigan	Virginia	Machinery	Multiple modes & mail	16.17	90.32
Eastern Asia	Water	Michigan	Ohio	Machinery	Water	0.48	87.14
Europe	Water	Michigan	New York	Machinery	Rail	5.26	86.69
SE Asia & Oceania	Water	Michigan	California	Mixed freight	Rail	0.16	86.57
Eastern Asia	Water	Michigan	California	Plastics/rubber	Multiple modes & mail	15.71	84.44
Eastern Asia	Water	Michigan	California	Articles-base metal	Truck	11.17	77.16
Eastern Asia	Water	Michigan	California	Other foodstuffs	Truck	9.32	72.38
Eastern Asia	Water	Michigan	California	Precision instruments	Truck	3.40	71.30
Europe	Water	Michigan	New York	Plastics/rubber	Rail	8.36	64.50
Europe	Water	Michigan	Virginia	Chemical prods.	Truck	14.45	64.49
Eastern Asia	Water	Michigan	California	Electronics	Truck	4.85	62.44
Eastern Asia	Water	Michigan	Washington	Machinery	Truck	2.23	60.84
Africa	Water	Michigan	Virginia	Transport equip.	Truck	3.64	60.47
Rest of Americas	Water	Michigan	Florida	Machinery	Truck	5.27	60.12
Africa	Water	Michigan	Virginia	Other foodstuffs	Multiple modes & mail	8.23	57.29
Eastern Asia	Water	Michigan	California	Animal feed	Truck	36.81	53.29
Europe	Water	Michigan	New York	Electronics	Rail	1.68	50.43
Europe	Water	Michigan	Virginia	Machinery	Multiple modes & mail	5.35	49.17
Europe	Water	Michigan	Michigan	Machinery	Water	2.88	48.78
Eastern Asia	Water	Michigan	Illinois	Machinery	Water	0.14	47.87
Rest of Americas	Water	Michigan	Florida	Electronics	Multiple modes & mail	3.40	47.47
Eastern Asia	Water	Michigan	California	Nonmetal min. prods.	Rail	1.66	46.84
Eastern Asia	Water	Michigan	California	Waste/scrap	Truck	65.67	45.94
Eastern Asia	Water	Michigan	California	Machinery	Multiple modes & mail	2.62	45.53
Europe	Water	Michigan	Virginia	Transport equip.	Truck	3.71	44.94
SW & Central Asia	Water	Michigan	New York	Machinery	Rail	3.93	44.37
Eastern Asia	Water	Michigan	Virginia	Machinery	Multiple modes & mail	1.71	43.62
Europe	Water	Michigan	Virginia	Plastics/rubber	Multiple modes & mail	9.69	42.91
Eastern Asia	Water	Michigan	California	Furniture	Truck	4.80	42.82
Eastern Asia	Water	Michigan	Washington	Chemical prods.	Truck	7.33	41.62
Rest of Americas	Water	Michigan	Florida	Chemical prods.	Truck	9.53	41.47
Eastern Asia	Water	Michigan	California	Chemical prods.	Multiple modes & mail	7.27	41.42

Source: Freight Analysis Framework (2015)

The second corridor under investigation in chapter 8 is the Muskegon – Chicago route. An overview of the 40 most exported products from Michigan to Chicago are depicted in appendix figure 4. As is the case with the general exports used for the assessment in chapter 8, motorized vehicles and related goods are excluded. However, all modes of transportation are now included since there is no foreign outbound flow.

Appendix figure 4: Export flows Michigan – Chicago area, top-40 ranked by value (year:2015)

DMS ORIG	DMS_DEST	SCTG2	DMS_MODE	Total KTons in 2015	Total M$ in 2015
Michigan	Chicago IL-IN-WI (IL Part)	Base metals	Truck	499.13	760.73
Michigan	Chicago IL-IN-WI (IL Part)	Other foodstuffs	Truck	380.00	620.41
Michigan	Chicago IL-IN-WI (IL Part)	Machinery	Truck	53.78	561.95
Michigan	Chicago IL-IN-WI (IL Part)	Milled grain prods.	Truck	229.01	433.32
Michigan	Chicago IL-IN-WI (IL Part)	Plastics/rubber	Truck	150.82	348.01
Michigan	Chicago IL-IN-WI (IL Part)	Meat/seafood	Truck	82.84	302.63
Michigan	Chicago IL-IN-WI (IL Part)	Chemical prods.	Truck	85.07	279.37
Michigan	Chicago IL-IN-WI (IL Part)	Machinery	Multiple modes & mail	2.20	233.71
Michigan	Chicago IL-IN-WI (IL Part)	Articles-base metal	Truck	190.13	221.95
Michigan	Chicago IL-IN-WI (IL Part)	Wood prods.	Truck	502.02	201.87
Michigan	Chicago IL-IN-WI (IL Part)	Misc. mfg. prods.	Truck	55.59	195.48
Michigan	Chicago IL-IN-WI (IL Part)	Other ag prods.	Truck	94.39	188.31
Michigan	Chicago IL-IN-WI (IL Part)	Furniture	Truck	25.60	171.54
Michigan	Chicago IL-IN-WI (IL Part)	Electronics	Multiple modes & mail	1.00	146.40
Michigan	Chicago IL-IN-WI (IL Part)	Waste/scrap	Truck	126.84	137.00
Michigan	Chicago IL-IN-WI (IL Part)	Electronics	Truck	11.81	135.98
Michigan	Chicago IL-IN-WI (IL Part)	Newsprint/paper	Truck	159.44	121.41
Michigan	Chicago IL-IN-WI (IL Part)	Tobacco prods.	Truck	3.23	119.23
Michigan	Chicago IL-IN-WI (IL Part)	Basic chemicals	Rail	129.46	117.59
Michigan	Chicago IL-IN-WI (IL Part)	Misc. mfg. prods.	Multiple modes & mail	2.19	113.10
Michigan	Chicago IL-IN-WI (IL Part)	Precision instruments	Multiple modes & mail	1.52	101.71
Michigan	Chicago IL-IN-WI (IL Part)	Coal-n.e.c.	Truck	179.89	85.81
Michigan	Chicago IL-IN-WI (IL Part)	Textiles/leather	Multiple modes & mail	1.64	75.77
Michigan	Chicago IL-IN-WI (IL Part)	Pharmaceuticals	Truck	3.70	70.62
Michigan	Chicago IL-IN-WI (IL Part)	Printed prods.	Truck	30.55	65.73
Michigan	Chicago IL-IN-WI (IL Part)	Articles-base metal	Multiple modes & mail	1.11	60.29
Michigan	Chicago IL-IN-WI (IL Part)	Nonmetal min. prods.	Water	632.18	58.38
Michigan	Chicago IL-IN-WI (IL Part)	Precision instruments	Truck	7.23	57.67
Michigan	Chicago IL-IN-WI (IL Part)	Newsprint/paper	Rail	63.24	53.81
Michigan	Chicago IL-IN-WI (IL Part)	Nonmetal min. prods.	Truck	51.00	47.59
Michigan	Chicago IL-IN-WI (IL Part)	Animal feed	Truck	43.68	46.48
Michigan	Chicago IL-IN-WI (IL Part)	Basic chemicals	Truck	27.10	44.45
Michigan	Chicago IL-IN-WI (IL Part)	Printed prods.	Multiple modes & mail	2.08	42.96
Michigan	Chicago IL-IN-WI (IL Part)	Nonmetallic minerals	Truck	216.66	36.31
Michigan	Chicago IL-IN-WI (IL Part)	Coal-n.e.c.	Rail	71.89	36.10
Michigan	Chicago IL-IN-WI (IL Part)	Plastics/rubber	Multiple modes & mail	0.71	34.29
Michigan	Chicago IL-IN-WI (IL Part)	Paper articles	Truck	29.91	33.80
Michigan	Chicago IL-IN-WI (IL Part)	Chemical prods.	Multiple modes & mail	0.95	22.92
Michigan	Chicago IL-IN-WI (IL Part)	Transport equip.	Multiple modes & mail	0.23	21.62
Michigan	Chicago IL-IN-WI (IL Part)	Transport equip.	Truck	1.09	19.31

Source: Freight Analysis Framework (2015)