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Economic competitiveness of rail transport to the port of Bahía Blanca

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Summary

Due to a global increase in food consumption and shipping, and regional developments like exploitation of the Vaca Muerta oil field, the port of Bahía Blanca in Argentina sees an opportunity to increase its activities. Therefore, a new container terminal will be constructed in the port of Bahía Blanca that can handle 500,000 TEU per year. This terminal is expected to be competitive to the container terminals in the port of Buenos Aires, which currently are Argentina's market leaders in container handling. In addition, a shorter entry channel and deeper draft makes the port of Bahía Blanca more attractive than the port of Buenos Aires.

Currently, it is unknown whether an increase in container throughput can be attracted from industries in the province of Buenos Aires. This province extends from Buenos Aires to Bahía Blanca, 650 km south of Buenos Aires. Next to that, it followed from qualitative interview sessions that all freight transport in the province is done by truck. As a result, roads are heavily congested during harvest season and for this reason container transport by train is preferred. Other reasons for choosing train as transport modality are the competitive location within the rail network of the port of Bahía Blanca and sustainable character of rail transport.

Because of the uncertainties and preferences mentioned above, this report aims to determine how container transport over rail can become economically competitive to the port of Bahía Blanca. The scope of research is limited to the logistic corridor between the port of Bahía Blanca and the port of Buenos Aires, which includes the container terminals, transshipment centers, railways and roads. In the system definition it became clear that neither the quality nor the capacity of the rail network is a problem, but access to the rail network is. Therefore, a hypothetical transshipment center with a yearly throughput of 20,000 and 100,000 containers was considered to be constructed in the province of Buenos Aires or near the city of Buenos Aires, respectively. A cost optimization model was created to determine how much demand is needed to make container transport by train to the port of Bahía Blanca economically most favourable, in relation to the location of the port of Buenos Aires and the transport modality of truck. Key factor of this model is the location of placing a transshipment center that allows for handling containers between truck and train.

The results show that the optimum location to place a transshipment center is 380 km from Bahía Blanca, with a minimum container export demand of 7200 TEU per year. This transshipment center has a yearly throughput capacity of 20,000 TEU and can be placed as far as 430 km from Bahía Blanca. In that case 10,000 TEU are exported from the province of Buenos Aires via the port of Bahía Blanca each year. Additionally, it is explained how this maximum distance can be extended by lowering the port costs of Bahía Blanca. This extension allowed for analyzing the placement of a transshipment center with a throughput of 100,000 containers per year close to the city of Buenos Aires. The results show that a minimum difference of port costs of 275 USD per TEU is needed to place this bigger transshipment center at 600 km distance from Bahía Blanca and thus close to Buenos Aires city. This will lead to an increase of containers that are imported via the port of Bahía Blanca and then transported via rail to the city of Buenos Aires.

Based on these findings it can be concluded that a transshipment center in the province of Buenos Aires is only feasible when there is concentrated container transport demand. Investigating the possibilities of concentrating industries around the transshipment center could be interesting. To balance the import/export ratio at the port of Bahía Blanca it should be investigated if lowering costs at the port could be cost-effective to attract container transport demand from the city of Buenos Aires.

It must be noted that this research contains several imperfections. The first is that the model does not take the time aspect of container transport into account. Another interesting direction for further research entails a more in-depth study into the design and operations of the transshipment center. Furthermore, it should be noted that in the future new limiting factors like insufficient capacity or network quality might arise while these are currently not an issue.

Contents

1 Introduction

The port of Bahía Blanca is located in the province of Buenos Aires in Argentina (see Figure 1.1). The distance to the biggest port of Argentina, the port of Buenos Aires, is approximately 650 km. The port of Buenos Aires currently handles around 85% of the containers entering or leaving Argentina [9]. This is mainly because the biggest share of the Argentine population lives in the Buenos Aires region, resulting in the largest demand of containers. Another reason is that most of Argentina's processing industries are located around Buenos Aires city. Being the largest port of the country, the port of Buenos Aires has the lowest port costs and the most frequent container vessel calls. The port of Bahía Blanca is much smaller and currently not competitive with the port of Buenos Aires. As a result, the port of Bahía Blanca attracts little to no demand from the province of Buenos Aires (Interview Pablo Arecco, September 2, 2019).

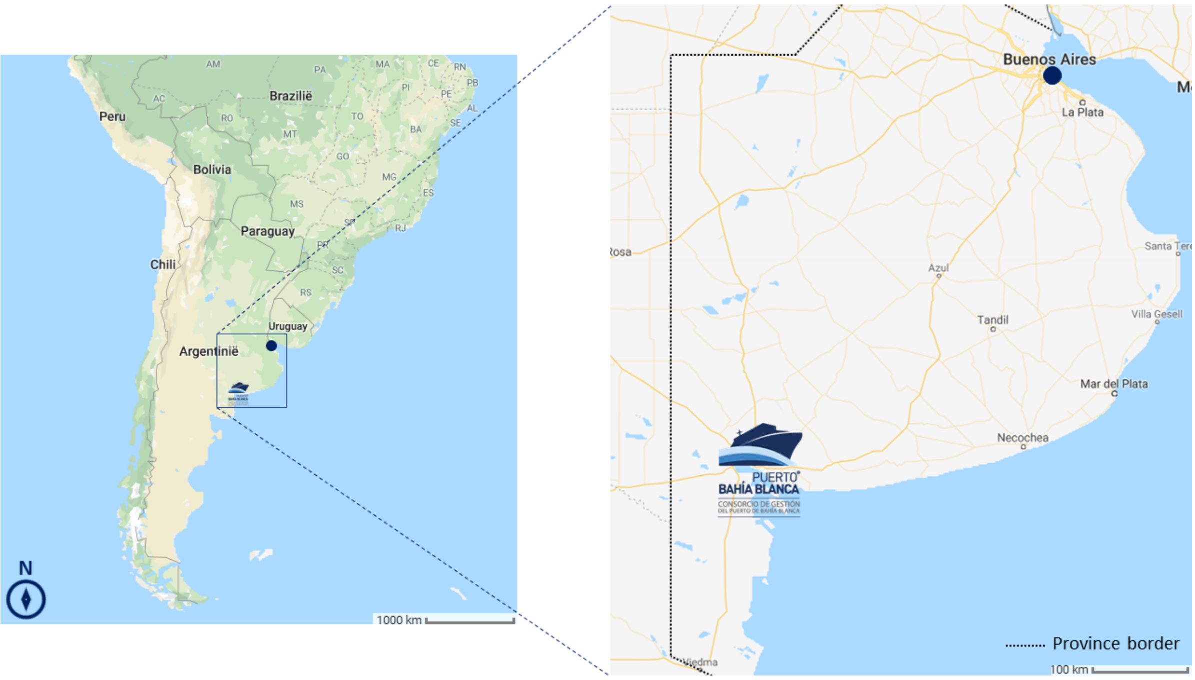

Figure 1.1: Location port of Bahía Blanca in Argentina and in the province of Buenos Aires

In its Port Vision for 2040 [13], the port of Bahía Blanca mentions global and regional developments that may influence the evolution of the port of Bahía Blanca itself. An increase in global food consumption and shipping are expected to lead to an increase in throughput at the port of Bahía Blanca. The reason for this is that Argentina is one of the largest food exporters in the world. Regionally, developments regarding the Vaca Muerta shale gas and oil formation are expected to affect the throughput of containers in Bahía Blanca to transport among others pipelines and equipment needed for fracking. Additionally, it is expected that a worldwide growth of the food industry in combination with an increase of supply of petrochemicals will attract companies in the plastic's industry. This is expected to lead to an increase in container throughput in the port of Bahía Blanca. Another development that will probably result in a growth of freight transport via Bahía Blanca is the fact that in the area around Bahía Blanca several wind farms are being constructed. To sum up, the port of Bahía Blanca expects that global and regional developments regarding energy and food production and consumption will lead to an increase in container transport via the port of Bahía Blanca.

For the reasons mentioned above, a new container terminal will be constructed in the port of Bahía Blanca that can handle 500,000 TEU per year. Due to the bigger terminal and its economies of scale, a decrease in handling and shipping costs can be expected. This will make the port of Bahía Blanca more competitive with the port of Buenos Aires, the biggest port in Argentina. Other factors that make the port of Bahía Blanca more attractive than the port of Buenos Aires are the shorter entry channel and the deeper draft (Interview Pablo Arecco, September 4, 2019). Because of the deeper draft the port of Bahía Blanca has the opportunity to accommodate bigger ships than the port of Buenos Aires. However, it is not known whether these benefits and the benefits that come with a larger container terminal will actually attract more containers from the province of Buenos Aires to the port of Bahía Blanca.

Currently, all freight transport in the province of Buenos Aires is done by truck. During the harvest season, the roads around the port of Bahía Blanca are heavily congested due to the huge amount of trucks and the handling times at the port of Bahía Blanca (Bolsa Cereales, interview, September 20th, 2019). This is one of the reasons why the port of Bahía Blanca has a preference for improving the accessibility by rail to attract more container demand from the province of Buenos Aires. Another reason is that the port of Bahía Blanca has a competitive location in Argentina's rail network. The third reason is that if transport via rail is well organized it is more sustainable than transport via road.

Combining the problem that it is currently unknown whether a larger container terminal in Bahía Blanca will attract container demand from the province of Buenos Aires and the fact that containers currently arrive in the port of Bahía Blanca by truck despite rail having several advantages, results in the following aim of the report. The aim of this report is to investigate how the accessibility of the port of Bahía Blanca by rail should be improved to attract more container transport demand from the province of Buenos Aires. Since transport by rail to the port of Bahía Blanca should be economically competitive with the other transport options to ship a container, the research question is formulated as follows:

"How can improving the accessibility of the port of Bahía Blanca by rail make container transport between the port of Bahía Blanca and the Buenos Aires province economically competitive with other transport options?"

This main research question will be answered through the following sub-research questions:

- *"Why is container transport by rail to the port of Bahía Blanca currently not competitive?"*
- *"How can rail infrastructure be improved to enhance the accessibility of the port of Bahía Blanca by rail?"*

Scope

The geographical scope defines the boundaries of this research. One of the boundaries is formed by the coast line of the Buenos Aires province. The western boundary is formed by the border of the province of Buenos Aires. Within the province, this research focuses on the connection between Buenos Aires and Bahía Blanca and thus the area of the province of Buenos Aires south of Bahía Blanca is out of scope. Although the city of Buenos Aires is not part of the province of Buenos Aires, it is part of the geographical scope of this research.

The infrastructural scope consists of the container terminals, transshipment centers, railways and roads in the province of Buenos Aires. The only ports that will be considered are the ports of Buenos Aires and Bahía Blanca, since the other ports are not focused on container transport and are substantially smaller. Regarding rail, the infrastructure in scope for this project are the tracks which connect Bahía Blanca and Buenos Aires. Regarding road, the national and provincial roads that lie in between the geographical boundaries defined above are also part of the infrastructural scope. As can be seen, short-sea shipping routes are not in the scope of this project. The reason for this is that short-sea shipping is not a competitive transport option to attract more container demand from the province of Buenos Aires to the port of Bahía Blanca. Additionally, the presence of strict cabotage laws restrict non-Argentine shipping companies in starting short-sea shipping routes while there currently are no Argentine shipping companies operating short-sea routes. (Interview Pablo Arecco, September 4, 2019)

Another important scoping criteria for this research is that only container transport is considered. The starting point is when a vessel calls at one of the ports in scope. The end is when it reaches its final destination in the province of Buenos Aires. Of course looking at export of containers the starting and ending point will turn around.

Lastly, in this project transport time is not considered to be of importance in the choice for a certain transport option. This choice has been made for simplicity reasons and as a result this report only focuses on transport costs.

Methodology and outline of the report

The methodology used for conducting the research will be a mathematical optimization model to estimate the economical competitiveness of rail transport compared to other modalities. Before the mathematical optimization model is explained and verified in chapter 3, the system is defined in chapter 2 by help of qualitative interview sessions and literature reviews. Chapter 4 states and evaluates the results which consists of a sensitivity analysis too. Finally, chapter 5 discusses and concludes on the research conducted. Included in this chapter is the final advice for the the Port authorities of Bahía Blanca and recommendations for further research. Figure 1.2 visualizes the outline of this report.

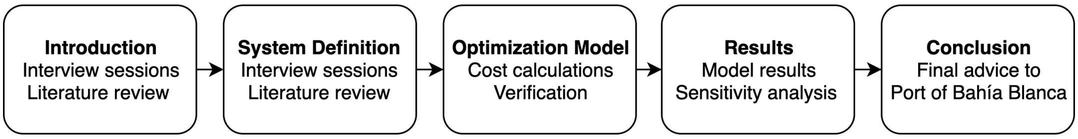

Figure 1.2: Outline of the report

2
System Definition

In this chapter the system within the research area will be defined. Firstly, the port of Bahía Blanca and the port of Buenos Aires will be presented in section 2.1. Thereafter, a closer look is taken at the state of road and train transport in section 2.3 and the developments of future container transport demand in the region (section 2.2). From analyzing these subjects, it is noticed that in order to make rail a more attractive modality, the addition of a transshipment center is needed. In section 2.4 considerations regarding the implementation of this transshipment center are discussed and the need for a model is introduced.

2.1. The port of Bahía Blanca compared to the port of Buenos Aires

The port of Buenos Aires is the biggest port of Argentina and handles about 1.4 million TEU's per year. Due to the port's location in the Rio de la Plata estuary, vessels have to navigate a 237 kilometer long access channel. The dredging of this channel is one of the biggest expenses of the port of Buenos Aires and brings a problem as well. The biggest ships cannot enter the port because of the limited draft of the access channel. To overcome this problem ships 'double-dip' at another port to unload cargo and pick it up later because this reduces weight and thus draft, but costs additional time and money. [9]

Besides that, the port does not have the possibility for expansion because of limited space in the busy city of Buenos Aires. Resulting from the location in this dense city, hinterland transport has a lot of problems with congestion. The port of Buenos Aires has two advantages: its location, which is really close to the container transport demand, and the possibilities to increase operations since the container terminals are not operating at full capacity. [9]

The port of Bahía Blanca is not located as close to the demand as the port of Buenos Aires. On the other hand it does not have to deal with limitations in draft and the access channel is significantly shorter with a total length of 100 kilometers (Interview Pablo Arecco, September 2, 2019). In Appendix A the advantages of Bahía Blanca regarding draft can be seen with the possibility of facilitating bigger vessels. The port of Bahía Blanca is planning to build a container terminal with a throughput capacity of 500,000 TEU per year in the near future because of high expected growth in different industries. This can be done because there is a lot of room for expansion in the port area in contrast to the port of Buenos Aires. All this together might make shipping via the port of Bahia Blanca very competitive compared to the port of Buenos Aires. (Appendix B and Appendix C)

In this research the large and efficient container terminal at the port of Bahía Blanca which is a result from the expected high growth as mentioned earlier will be used. With sufficient throughput for this terminal, handling costs can decrease due to economies of scale. Modern equipment means faster operations and the possibility to accommodate bigger vessels which both negatively affect the costs per TEU which will be positive for the port of Bahía Blanca (Appendix C).

It can be concluded that the port of Bahía Blanca could have a lot of advantages with the new container terminal in place. However, a drawback for the port of Bahía Blanca is that most of the demand is located near the port of Buenos Aires.

2.2. Developments in future container transport demand

Key information of this research is the amount of container transport demand and where it is located in the area of scope. This is needed to for research into changing the corridor to generate more container demand in Bahía Blanca. In the research area the most transported commodity is agri-bulk which is not transported in containers. However, after being processed in a factory, the final product can be transported in containers. These kind of factories can concentrate around strategic logistic hubs and thus generate demand. Thorough research and multiple interviews were carried out (see Appendix F) but it has not become clear how and where this container demand in the province of Buenos Aires would change in the future.

2.3. A closer look at the state of rail and road transport

Currently, rail-transshipment can only take place in the port of Buenos Aires and the port of Bahía Blanca. This also means that both ports are accessible for rail transport. Besides, the capacity on the railway is sufficient to accommodate more trains and the rail network is in sufficient state to handle container transport on rail (see Appendix E). However, due to the the lack of transshipment options alongside the railway, companies in the Buenos Aires province are not able to use rail as a possible transport option to either one of the ports. The container transport via rail can be cheaper over longer distances than transport by truck, but costs associated with transshipment from road to rail and pre-carriage by truck can also diminish cost benefits by rail.

When taking a look at the road network, it is not in perfect state and can be congested. Nevertheless, the road network is sufficient for container transport to both the port of Bahía Blanca and the port of Buenos Aires. Road transport is flexible, reliable and often the onlu transport option. Besides that, when using truck, there is only one company handling cargo of a client, which appears to be of value to customers in Argentina and makes it a popular transport mode in the country (Appendix D).

The discussed characteristics of the rail and road network result in different options of container transport in the region. These are are displayed in figure 2.1. In this figure, the road network covers the entire region and cargo can be transported from every company in the hinterland to either one of the ports and the other way around. Meanwhile, when a company wants to make use of the rail network, it is only possible to enter the network by transporting containers to and from one of the ports first. This would only be logical when importing or exporting costs of one of these ports is financially very advantageous in comparison with the other.

Figure 2.1: Current transport option choices

Since road-rail transshipment possibilities can only be found at the port of Buenos Aires and the port of Bahía Blanca, container transport by rail is currently not advantageous compared to container trucks. Therefore, it is researched whether improving the accessibility of the rail network makes container transport by rail a more economically competitive modality. Next to that, it will be researched in what situation this improvement would also make container transport via the port of Bahía Blanca more attractive than via the port of Buenos Aires. This research is not possible without the implementation of an extra transshipment center alongside the rail network in the province of Buenos Aires. In subsection 2.4 considerations regarding the implementation of a transshipment center are discussed in further detail.

2.4. Implementation of a transshipment center

The implementation of a transshipment center within the rail network, would account for creating four transport options for container flows in the region. The four schematic images in figure 2.2 are considered as an overview of the choice possibilities. These possibilities consist of choosing a modality and a port via which the container is shipped. A choice has to be made between shipping either via the port of Buenos Aires or the port of Bahía Blanca. At the same time it has to be chosen to either transport a container by truck to the corresponding port or by using truck for short distance, a transshipment center and a container train to move a container to and from the port. In this research it is investigated under which circumstances the desired transport option 3 in figure 2.2, which uses rail to get to Bahía Blanca, is the most attractive transport option.

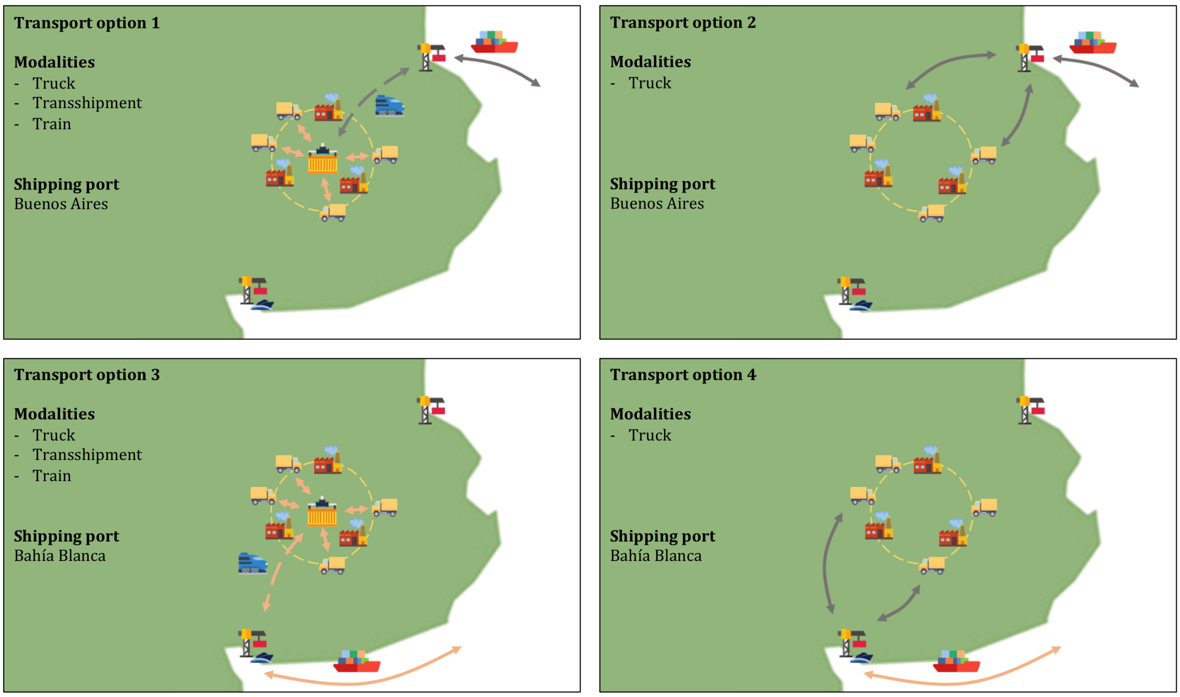

Figure 2.2: Transport option choices

As mentioned in section 2.2, little to nothing is known about future developments of container transport demand in the province. Therefore, the well educated assumption is made that a terminal of 20,000 TEU per year suffices in the province of Buenos Aires. In appendix G a possible layout of a transshipment center of this size and corresponding specifications and costs are discussed in more detail.

In and around the city of Buenos Aires the container transport demand is substantially larger than in the province caused by the higher population density. For that reason it would also be interesting to locate a transshipment center closer to the city of Buenos Aires. Therefore, it is chosen to make calculations for an enlarged transshipment center of 100,000 TEU per year into account that can be used in this research. The specifications and costs for a transshipment center of this size are explained in more detail in Appendix G.

It is not yet clear at what exact location a transshipment center must be placed in order to make the port of Bahía Blanca more attractive via rail. This decision is dependent on multiple factors like for example the distance to the port of Bahía Blanca, transport costs of both modalities, port costs, but also the container transport demand from different zones in the scope region. These zones can either be located near the city of Buenos Aires, resulting in very high demand, or in the province of Buenos Aires, where no demand can be pinpointed. These uncertain figures of demand make it more difficult to create a reliable estimation of the optimum location of the designed transshipment center. The main goal of this research is to find the circumstances under which transport option 3 is the most cost effective. Therefore, a model needs to be created that both seeks for the optimum location of the transshipment center and gives a corresponding necessary container transport demand of the surrounding area. In section 3 a further elaboration on the formalization of this model can be found.

3 Optimization Model

Based on the cost referred to in chapter 2 and explained in Appendix G, an optimization model is designed in this chapter to find out at what location and for which demand a transshipment center is feasible. This optimization model determines the minimum container transport demand needed to make the use of train, truck and transshipment center financially the most attractive option, at a certain location. To determine this demand, the methodology of designing a cost and demand optimization model for the logistic corridor between Bahía Blanca and the province of Buenos Aires is elaborated. The model is regarded to as an optimization since it results in the minimum or maximum costs and/or a minimum demand. The approach of the model is discussed in section 3.1. Second, an explanation and overview of all the model parameters is given in section 3.2. Section 3.3 provides the optimization of the model and the implementation of the parameters into the model. Lastly, in section 3.4 the model will be verified by testing the influence of changing the parameters.

3.1. Modelling Approach

Many different parameters have influence on the costs of container transport from and to the province of Buenos Aires. In order to map the different costs and the relationships between the different parameters, a model is made using Microsoft Excel. This model takes into account the transport of loaded containers from local producers to or from the container ship at Buenos Aires or Bahía Blanca, named container import- and export demand. The taken point of view is from the customer, which is an arbitrary number of local producers that produces container transport demand. These local producers can choose between different combinations of modalities for import or export via one of the ports. For instance, the container could be transported from local producer over a short distance to a transshipment center by truck, transshipped to train and transported over rail for a longer distance. An overview of the possible (multi)modalities is given by table 3.1. Those options have different costs depending on parameters such as distance and container load.

Table 3.1: Overview of different transport modalities

Destination/Origin	Modality	Transshipment
Bahía Blanca	Truck, train	Yes
Buenos Aires	Truck, train	Yes
Bahía Blanca	Truck	No
Buenos Aires	Truck	No

The outcome of the model is the container transport demand that is needed per year to make transport through truck, transshipment center and train to or from the port of Bahía Blanca financially the most attractive transport modality. In other words, it finds the minimum container transport demand needed for which the other transport modalities are more expensive (in USD/TEU) than the preferred modality. A parameter with large influence on the transport price is the transshipment cost. When container demand grows, transshipment cost goes down. Therefore, a higher container demand will result in a lower total cost for modality with transshipment included. Furthermore, the model can be used to check whether specific parameters (e.g. location of the transshipment center) should be changed to create an even better cost-based solution.

3.2. Explanation and overview of model parameters

The optimization model depends on various parameters, all having some influence on the required container transport demand to make transport through truck, transshipment center and train to or from the port of Bahía Blanca the financially most attractive modality. The data for the parameters are retrieved from literature and personal interviews with experts. The first part of this section explains the parameters in detail and shows how they were retrieved. The second part of this section will give an overview of all the parameters.

Distance transshipment center to Bahía Blanca or Buenos Aires

The total distance between Bahía Blanca (BB) and Buenos Aires (BA) is roughly 650 km for both rail and road transport (H. Torresi, interview, September 20, 2019). Due to the fact that small changes in distance will have no significant influence on the results, this distance is used in the model. The distance to Bahía Blanca is defined as the distance from the transshipment center to the port of Bahía Blanca. The distance to Buenos Aires is defined as the distance from the transshipment center to the port of Buenos Aires. The model will test different locations for the transshipment center, which means the distance to the ports will vary.

Radius industry area and distance to transshipment center

During an interview with the railway company Ferrosur Roca, it was mentioned that containers transshipped in a transshipment center operated by Ferrosur Roca were mostly coming from or distributed to locations within 50 km of the transshipment center. Therefore, this distance will be assumed as the demand radius of the industry area (R. Ceballos and O. Gauna, interview, September 19, 2019). The mean distance from anywhere in the area to the transshipment center is halfway the area of a circle with a radius of 50 km, thus calculated by $50 * \sqrt{0.5} = 35$ km. This mean distance is used to calculate the transportation cost to the transshipment center.

Container load

TEU's that are transported on the corridor are assumed to carry cargo with a weight of 13 tons. This is the number as used by the Port Vision for the port of Bahía Blanca [13].

Import/export ratio

Possible locations for the construction of a transshipment center are assumed to be regions with a high export and low import. This assumption is made due to the relatively low population density in the province outside of the city of Buenos Aires, compared to the high production of agricultural goods. The ratio between the amount of imported containers and exported containers is assumed to be 0.4, meaning that for every 10 containers exported, 4 are imported full and 6 are imported empty. However, if a transshipment center is built close to the city of Buenos Aires, the amount of imported containers is expected to exceed the amount of exported containers because of the high population density. In that case, the ratio in the model should be used as an export over import ratio. In addition, the outcome of the model will then be the amount of imported containers needed to make a transshipment center feasible instead of the amount of exported containers.

Transport cost rail

Rail transport companies often work with spot contracts for container transport, which means prices can differ. On average the costs for container transport by train costs 0.038 USD per tonkm, as was told in an interview with Ferrosur Roca (R. Ceballos and O. Gauna, interview, September 19, 2019). Currently, an empty container is also delivered back to the customer, which means that the train takes empty containers on the return and that the customer pays for a round-trip of the container. Every full container that is imported (due to import demand) influences the cost of transport for the exporter in a positive way. If import and export would be in perfect balance, trains would never have to return empty containers and the exporters would not have to pay for any empty container to be imported. The cost of transport including the initial import/export ratio becomes: $TC_{rail-inc} = TC_{rail-exc} \cdot (1 - \frac{Ratio}{2}) = 0.304$ USD/tonkm

Transport cost road

To obtain a price for container transport by truck, data from CATAC (Appendix D) is inserted in Microsoft Excel and a trend line is fitted. This trend line composes a formula for the transport costs in USD per tonkm, where $Dist$ is the distance in kilometers to any place: $-0.000017 \cdot Dist^2 + 0.061 \cdot Dist + 4.17$.

Port and handling cost Bahía Blanca and Buenos Aires

In an interview with Agro Primus, a popcorn producer, it was told that the port cost and container handling cost together in the port of Bahía Blanca is approximately 470 USD per TEU. In the same interview, information was obtained for the port cost and handling cost of one TEU in the port of Buenos Aires, being approximately 550 USD per TEU (G. Braseras and M. Amonte, interview, September 18, 2019).

Shipping cost Bahía Blanca and Buenos Aires

It is uncertain what the shipping costs will be with the new container terminal being in place. According to Agro Primus, it costs 1800 USD to ship a container from the port of Bahía Blanca to Turkey. Shipping from Buenos Aires to Turkey however, costs 900 USD per TEU. For the model, it is assumed the shipping cost for the port of Bahía Blanca is comparable to the cost for the port of Buenos Aires, given the new container terminal. Thus, the shipping cost is assumed to be 900 USD for both Bahía Blanca and Buenos Aires. This assumption is based on the larger future container terminal in Bahía Blanca, operating more efficient and attracting more shipping calls. (G. Braseras and M. Amonte, interview, September 18, 2019)

Transshipment costs per TEU

As referred to in chapter 2, the costs for transshipment centers with a 20,000 or 100,000 TEU/year throughput, to be built in the province or the city of Buenos Aires, were determined. The costs in USD/TEU are mentioned in Table G.1 and Table G.2 and will be used in the optimization model.

Overview of model parameters

Table 3.2: Model parameters (H. Torresi, interview, September 20, 2019), (R. Ceballos and O. Gauna, interview, September 19, 2019), (G. Braseras and M. Amonte, interview, September 18, 2019), [1] [15]

Input parameters	Abbreviation	Formula	(Initial) value	Unit
Distance BB-BA	$Dist_{total}$	-	650	km
Distance transship to BB	$Dist_{BB}$	-	-	km
Distance transship to BA	$Dist_{BA}$	-	-	km
Radius industry area	$Radius$	-	50	km
Distance from area to transship	$Dist_{Area}$	$Radius \cdot \sqrt{0.5}$	35	km
Container load (net)	$Load_{net}$	-	13	ton
Import/Export ratio	$Ratio$	-	0.4	-
Transport cost rail	TC_{rail}	-	0.038	USD/tonkm
Transport cost rail incl ratio	$TC_{rail-incl}$	$TC_{rail} \cdot (1 - \frac{Ratio}{2})$	0.0304	USD/tonkm
Transport cost road	TC_{road}	$-0.000017 \cdot Dist^2 + 0.061 \cdot Dist + 4.17$	-	USD/ton
Port and handling costs BB	HC_{BB}	-	470	USD/TEU
Port and handling costs BA	HC_{BA}	-	550	USD/TEU
Shipping cost BB	SC_{BB}	-	900	USD/TEU
Shipping cost BA	SC_{BA}	-	900	USD/TEU
Transshipment costs per TEU	$Transship_{TEU}$	-	-	USD/TEU

3.3. Implementation of parameters and optimization of model

All input parameters are provided in the previous section. The output parameters, costs and demand, can now be determined. This section explains the optimization modelling steps in detail which are necessary to come to these values. A visualization of these steps can be seen in figure 3.1.

An important characteristic of this model is that it provides an output of container demand X. For an export model, this X is the amount of exported containers needed to make the transshipment center feasible. In that case, an import/export ratio should be used to determine the amount of imported full and empty containers. If the model is used to determine the amount of imported containers, an export/import ratio should be used. This means that X is the amount of imported containers needed to make a transshipment center feasible.

The unknown demand X of containers from or to the chosen area of industry can be transported via the port of Buenos Aires or Bahía Blanca. Besides, the choice is made between the modalities of only truck or train (including transshipment and a short distance by truck). An important factor to the outcome of this decision will be the costs of transshipment from truck to train. This operational transshipment cost is dependent on the value of X, as the transshipment cost per container is calculated by dividing the total yearly transshipment cost including the ratio by X. Therefore, optimization modelling is needed to achieve a minimum value of X based on the parameters that are elaborated on in the previous section.

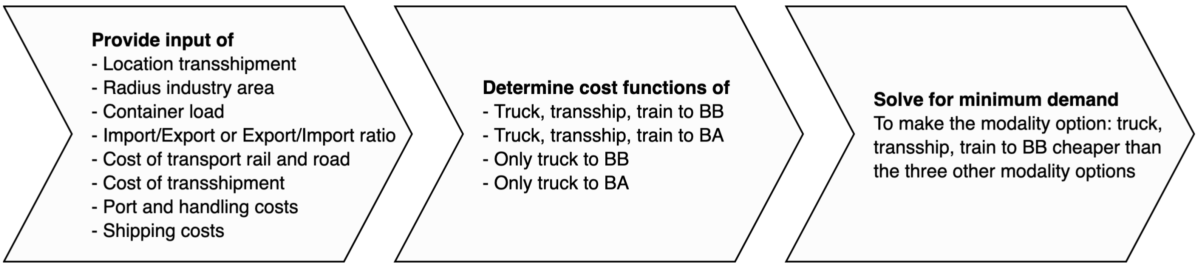

Figure 3.1: Optimization modeling steps

To find the minimum value of X, the total cost of transport using the modality of interest is calculated. Transport using a truck to the transshipment center and then using a train to ship from the port of Bahía Blanca is preferred. The formula for the cost of this transport choice is provided by the following formula:

$$Load \cdot (Distance_{ToTransship} \cdot TC_{road} + TC_{rail}(Distance_{BB})) + Transship_{TEU} + HC_{BB} + SC_{BB} \tag{3.1}$$

Furthermore, the total cost of transport for the other modality choices should be found, for which the formulas are provided below. Starting with the choice of transport using a truck to the transshipment center and a train to ship from the port of Buenos Aires, the cost formula gives:

$$Load \cdot (Distance_{ToTransship} \cdot TC_{road} + TC_{rail}(Distance_{BA})) + Transship_{TEU} + HC_{BA} + SC_{BA} \tag{3.2}$$

Besides choosing between Bahía Blanca and Buenos Aires, using only truck as transport modality is considered too. The formula for the cost of transportation by truck directly to ship from the port of Bahía Blanca (equation 3.3) and Buenos Aires (equation 3.4) are provided below:

$$Load \cdot Distance_{BB} \cdot TC_{road} + HC_{BB} + SC_{BB} \tag{3.3}$$

$$Load \cdot Distance_{BA} \cdot TC_{road} + HC_{BA} + SC_{BA} \tag{3.4}$$

Now all cost functions have been created, the objective function can be formulated that subtracts the minimum cost of alternative modality options from the cost of the preferred modality. The objective function is set equal to zero, such that the cost of using the preferred modality will never be higher than the cheapest option of the alternatives costs. This formula is provided below:

$$\begin{aligned}&Load \cdot (Distance_{ToTransship} \cdot TC_{road} + TC_{rail}(Distance_{BB})) + Transship_{TEU} + HC_{BB} + SC_{BB}\\&- min(Load \cdot (Distance_{ToTransship} \cdot TC_{road} + TC_{rail}(Distance_{BA})) + Transship_{TEU} + HC_{BA} + SC_{BA};\\&\quad Load \cdot Distance_{BB} \cdot TC_{road} + HC_{BB} + SC_{BB}; Load \cdot Distance_{BA} \cdot TC_{road} + HC_{BA} + SC_{BA}) = 0 \qquad (3.5)\end{aligned}$$

By using the Solver GRG Nonlinear option in Excel, the minimum value of X needed demand will be determined to reach the turning point of equal costs (see Appendix H. The objective function 3.5 shows that the objective cost function does not directly solve for X, in fact it provides the values of the variables that are based on X. The value X itself is constrained by the maximum throughput of the transshipment center, considering the throughput to be two times X. Furthermore, several variables are added to the solver model (see section 3.2) with constraints that can be altered for the sensitivity analysis. Based on these variables and corresponding constraints, the solver changes the variables to achieve the desired cost value. If no feasible solution can be found, the solver model shows what the cost gap is that needs to be closed.

3.4. Verification

In this final section of chapter 3, a check is performed to see if the optimization model is implemented correctly. Special tests are performed to check the model's outcomes with expectations. For the verification, 5% changes will be the standard to determine the result. The model is tested using the change in export demand needed to make the development of a transshipment center feasible. The parameters which influence the feasibility are the transshipment costs, the import/export ratio, the transport costs of rail and road, the cargo per container and the radius. The impact on the demand is measured in TEU, and the results are visible below in table Table 3.3.

Table 3.3: Model verification

Method	Expectation	Result	Verified
Increase transshipment costs	Higher export demand needed	+359	TRUE
Increase import/export ratio	Lower export demand needed	-235	TRUE
Increase transport cost rail	Higher export demand needed	+659	TRUE
Increase transport cost road	Lower export demand needed	-849	TRUE
Increase cargo per container	Lower export demand needed	-342	TRUE
Increase radius	Higher export demand needed	+142	TRUE
Decrease transshipment costs	Lower export demand needed	-359	TRUE
Decrease import/export ratio	Higher export demand needed	+246	TRUE
Decrease transport cost rail	Lower export demand needed	-557	TRUE
Decrease transport cost road	Higher export demand needed	+1112	TRUE
Decrease cargo per container	Higher export demand needed	+378	TRUE
Decrease radius	Lower export demand needed	-136	TRUE

The results show that the model works as it is expected to work with all tests being positive. Therefore, the model can be positively verified.

4

Results

In this chapter, the model outcomes are discussed. First in section 4.1 the feasible range of placing a transshipment center is discussed. This is followed by showing how the feasible range can be expanded in section 4.2. Section 4.3 and section 4.4 provide results on the placement of a transshipment center in the province of Buenos Aries and close to the city of Buenos Aires, respectively. Finally, the results of the sensitivity analysis are provided.

4.1. Feasibility range for a transshipment center on the logistic corridor

Figure 4.1 shows that the location of the transshipment center influences the needed export demand to make the transshipment center feasible. The graph gives the minimum export (or import) demand that is needed for placing the transshipment center at a certain distance from Bahía Blanca, on the corridor between Bahía Blanca and Buenos Aires. Placing the transshipment center at a distance less than 230 kilometers from Bahía Blanca or further than 430 kilometers will lead to infeasible solutions, which can be contributed to the fact that a transshipment point would need too much export demand to make the transshipment costs low enough to compete. Since the export (or import) capacity is capped at 10,000 TEU, this results in infeasible solutions. An additional explanation would be that transshipment at a distance which is close to large ports such as the port of Bahía Blanca or Buenos Aires would not be financially attractive. The reason for this is that the costs of pre-carriage by truck, transshipment and transport by rail exceeds the costs of direct transport by truck.

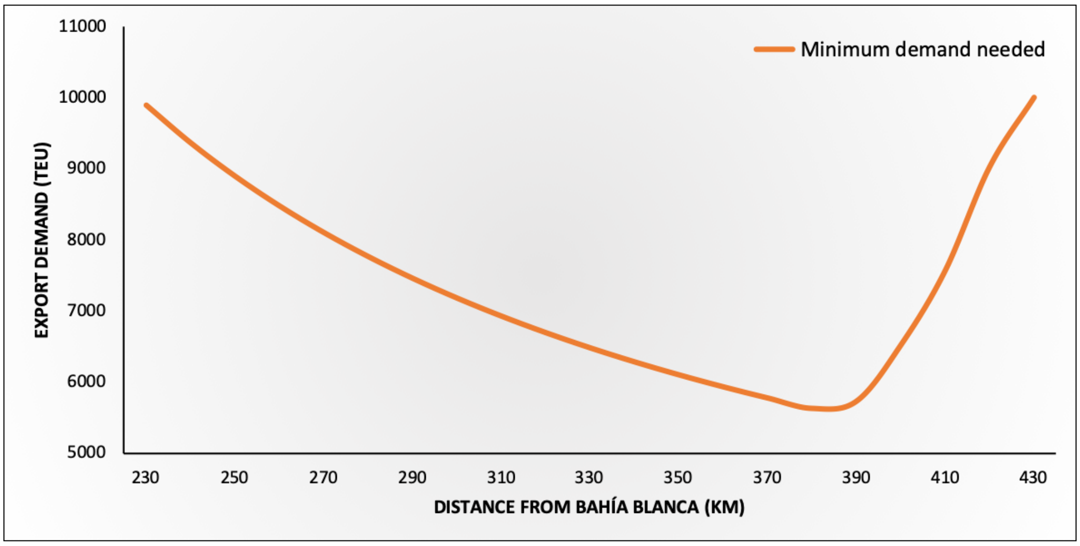

Figure 4.1: Demand versus distance from Bahía Blanca

The graph also shows that a distance further from Bahía Blanca leads to less export (or import) demand needed, until a point 380 kilometers from Bahía Blanca. This location is closer to the port of Buenos Aires than to the port of Bahía Blanca due to the lower port and handling costs in Bahía Blanca. Taking in consideration that the least demand needed is desirable, the best location to place a transshipment center would be at 380 km from Bahía Blanca. In reality, the presence of a suitable city with sufficient industry in that region also determines the best location. The range in which a transshipment center with a maximum yearly throughput of 20,000 TEU could be located is shown by figure 4.2.

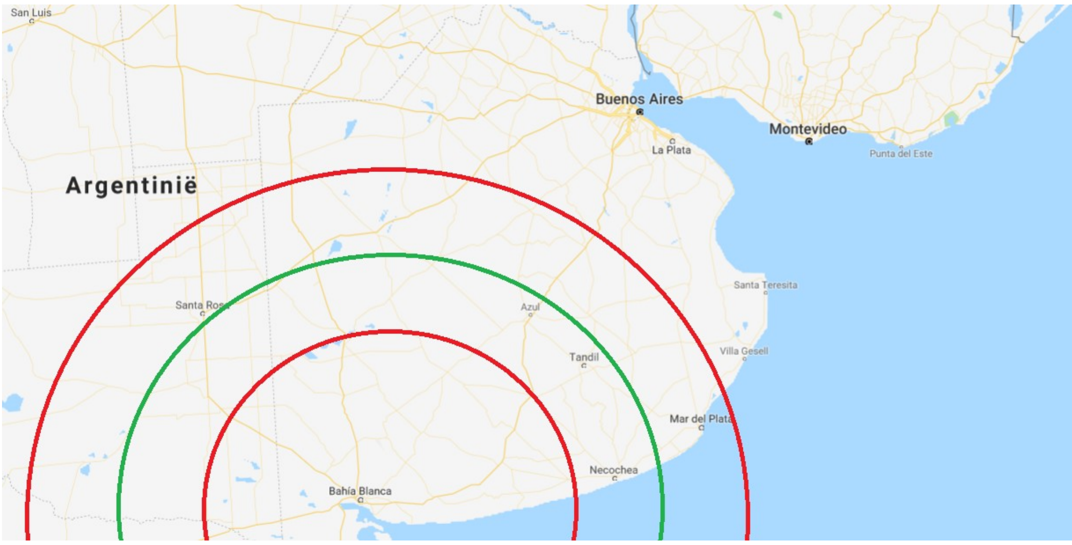

Figure 4.2: Distance range for transshipment center

4.2. Expansion of the feasibility range for a transshipment center

As mentioned in chapter 3, the shipping and port costs do not influence the demand needed to make a transshipment center feasible. However, they do have an effect on the transshipment location and to which port the containers are transported. Therefore, the effect of difference in these costs on the location of the transshipment center has been investigated. The difference in shipping and port costs is calculated by subtracting those costs in Buenos Aires from those in Bahía Blanca. It is important to mention that the port authorities of Bahía Blanca and Buenos Aires have a bigger influence on the port costs than on the shipping costs.

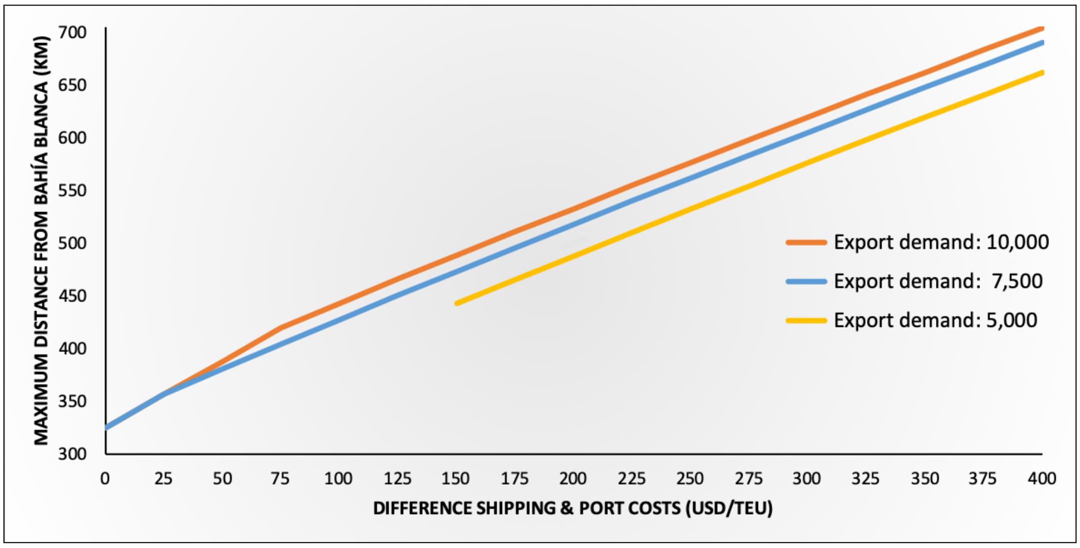

Figure 4.3: Difference in port costs versus distance transshipment center for a given demand

Figure 4.3 shows that the location at which the transshipment center can be located depends on difference in costs at the port and for the vessel. Besides, it depends on the demand that is taken as a constant. For this result, derived from the initial model with 20,000 throughput, three different values for export demand were selected: 5,000, 7,500 and 10,000 TEU/year. Furthermore, a maximum difference of shipping and port costs is chosen to be 400 USD/TEU and it is assumed that the port and shipping costs in the port of Bahía Blanca will not be lower than the costs in the port of Buenos Aires. The outcome of these results is a maximum distance from Bahía Blanca at which the transshipment center can be placed, for a given demand and difference in shipping and port costs.

In addition, the results show that the higher the demand, the bigger the range in which the terminal can be located. The reason for this is that transshipment is less expensive if more containers are exported. Another result provided by the figure is that too little export demand creates an infeasible solution if the difference of shipping, port and handling cost is small (e.g. lower than 150 USD/TEU for 5,000 TEU/year).

Finally, it can be seen that if the costs in the port of Bahía Blanca are much lower than in the port of Buenos Aires, the transshipment center could be located near Buenos Aires. In that case the lower costs in Bahía Blanca weigh up to the extra costs of transshipment and transport to the port of Bahía Blanca. This situation is looked further into in section 4.4.

4.3. Results of a transshipment center in the province of Buenos Aires

Using input parameters mentioned in section 3.2, and the results of section 4.1, the optimization model for a transshipment center in the province of Buenos Aires is run. Due to the fact that export is expected to exceed import, the model is considered to be an export model with an import/export ratio of 0.4. The outcome of the model is an export demand of at least 7200 TEU/year that is needed to make a new transshipment center feasible. This result is for the situation of a transshipment center with a throughput of 20,000 TEU/year and located in Olavarría at a distance of 300 kilometers from Bahía Blanca. The transshipment center should capture at least 7200 TEU yearly from an area with a radius of 50 kilometers from the transshipment center. The different costs of modality options (each line represents a modality option) to Buenos Aires or Bahía Blanca for a given demand are shown by figure 4.4 with the arrow pointing at the turning point of 7200 TEU/year. It should be mentioned that the shipping costs are not included in this figure, since these are equal for both Buenos Aires and Bahía Blanca in the considered situation. Additionally, on average two extra trains per week will have to make use of the corridor, which will cause no problems. Figure 4.5 shows the turning point in detail with the same arrow as in figure 4.4.

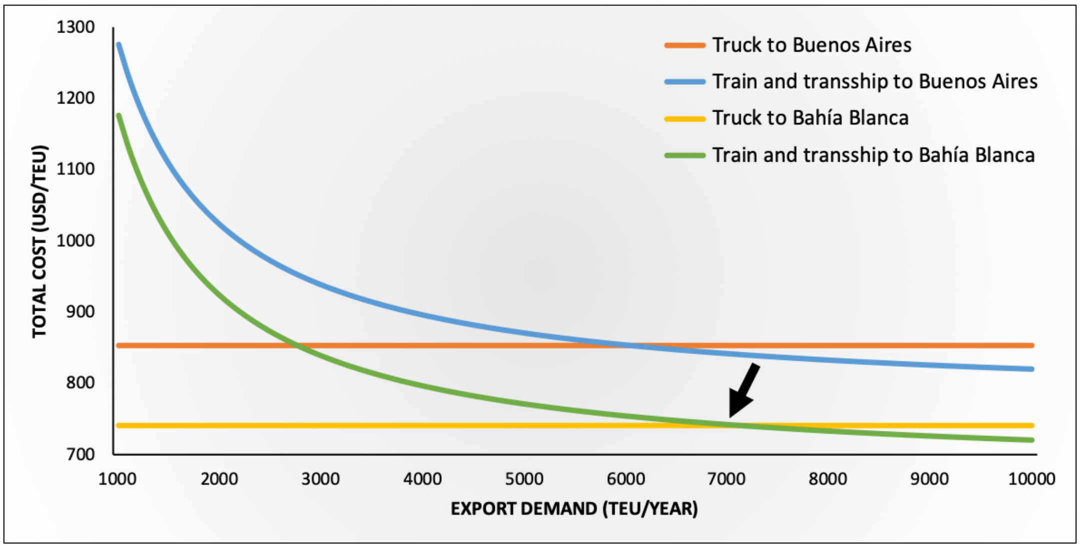

Figure 4.4: Results initial model

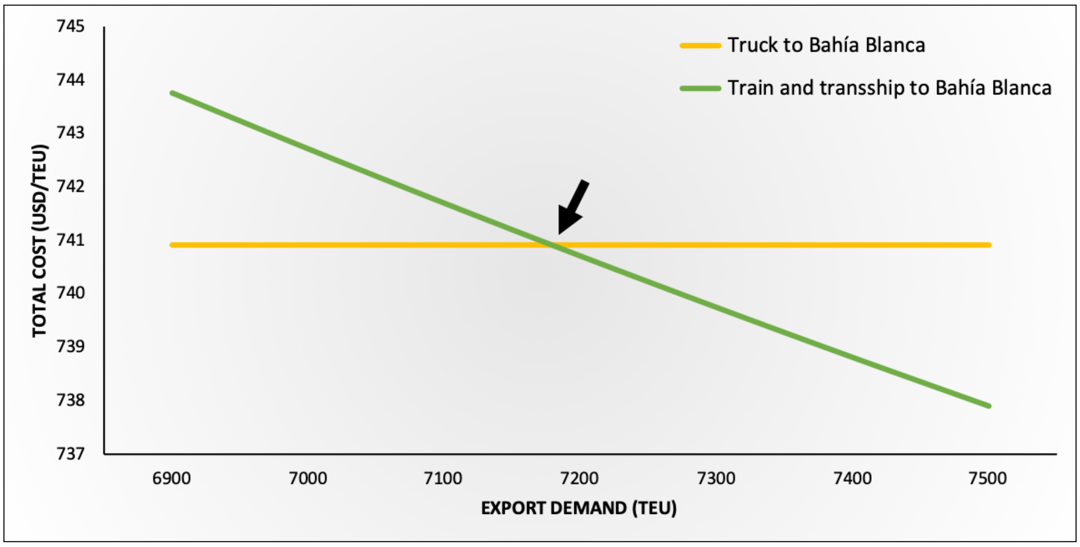

Figure 4.5: Results initial model zoomed in

4.4. Results of a transshipment center close to the city of Buenos Aires

For the following results the bigger transshipment center is used, as explained in chapter 2. Due to the increase in size and possible throughput of 100,000 TEU/year, the total transshipment center cost per year that are used as input parameter increase compared to the smaller terminal. However per TEU the transshipment cost decrease because the total yearly transshipment cost is divided by a larger number. The transshipment center is placed 600 km from Bahía Blanca, thus 50 km from Buenos Aires. Due to the big industries located and many people living around the city of Buenos Aires, the import demand is assumed to be higher than the export demand. Therefore, the optimization model used for this results is considered to be an import model.

Considering all other parameters the same as in the previous section, this transshipment center provides no economically feasible solution: for any import demand, there will be another modality option that is cheaper. Tot total gap that needs to be filled before containers are imported by train from or to Bahía Blanca is 179 USD/TEU.

However, when the port and shipping costs of Bahía Blanca decrease compared to Buenos Aires, a feasible solution can be derived. For example, if the total difference between costs in Bahía Blanca and Buenos Aires is 300 USD (a decrease of 220 USD compared to initial model), the minimum import demand should be 14,200 TEU/year. Table 4.1 shows how far away the transshipment center can be placed from Bahía Blanca for a specific demand and difference in shipping and port costs.

It can be seen that at least a difference in shipping and port costs of 275 USD/TEU is needed to place an economically feasible transshipment center near Buenos Aires. In that case the distance to Bahía Blanca is more than 600 km. However, when import demand is only around 30,000 TEU/year, the difference should be at least USD 300/TEU.

Table 4.1: Maximum distance from Bahía Blanca for an economically feasible transshipment center

Difference shipping and port cost (USD/TEU)	Import: 30000 TEU/year	Import: 40000 TEU/year	Import: 50000 TEU/year
200	530	542	549
225	552	564	571
250	574	586	593
275	595	607	614
300	617	629	635

4.5. Results sensitivity analysis

In order to determine the sensitivity of the outcome of the model, two sensitivity analyses have been performed. One using lower and upper case values for the parameters and one using a 5% decrease and increase for the parameters. Using the latter, the influence of each separate parameter can be compared. The parameters that have been changed are:

- Import/export ratio (-)
- Transport cost rail (USD/ton/km)
- Transport cost road (USD/ton/km)
- Transshipment cost(USD/year)
- Cargo per container (ton)
- Radius (km)

The numbers used in the sensitivity analysis are listed in table 4.2. This table is a summary of the sensitivity analysis in Appendix I. The table shows the lower and upper case values. The results of this analysis are discussed first.

Table 4.2: Lower and upper cases sensitivity analysis

	Import/export ratio	**Transport cost rail (USD /ton/km)**	**Transport cost road (USD /ton/km)**	**Transshipment cost (USD/year)**	**Cargo per container (ton)**	**Radius (km)**
Lower	0.25	0.01	0.8*TC_{road}	585,000	10	30
Base case	0.40	0.038	TC_{road}	632,500	13	50
Upper	0.55	0.057	1.2*TC_{road}	680,000	16	70

Table 4.3 shows the numbers used for the 5% increase and decrease of the base case. The results of this analysis are discussed after the lower and upper cases.

Table 4.3: Parameter range of 5% sensitivity analysis

	Import/export ratio	**Transport cost rail (USD/ton/km)**	**Transport cost road (USD/ton/km)**	**Transshipment cost (USD/year)**	**Container load (ton)**	**Radius (km)**
Lower	0.38	0.0361	0.95*TC_{road}	600,875	12,35	47,5
Base case	0.40	0.0380	TC_{road}	632,500	13	50
Upper	0.42	0.0399	1.05*TC_{road}	664,125	13,65	52,5

Sensitivity analysis - Lower and upper case

The sensitivity of the demand needed in a transshipment center is determined by changing the value of parameters. Each parameter is changed individually, using the lower and upper values, explained above. The results of the relative changes to the demand needed, are shown in figure 4.6. The changes to the demand are individual, which means the strength of parameter influences cannot be compared.

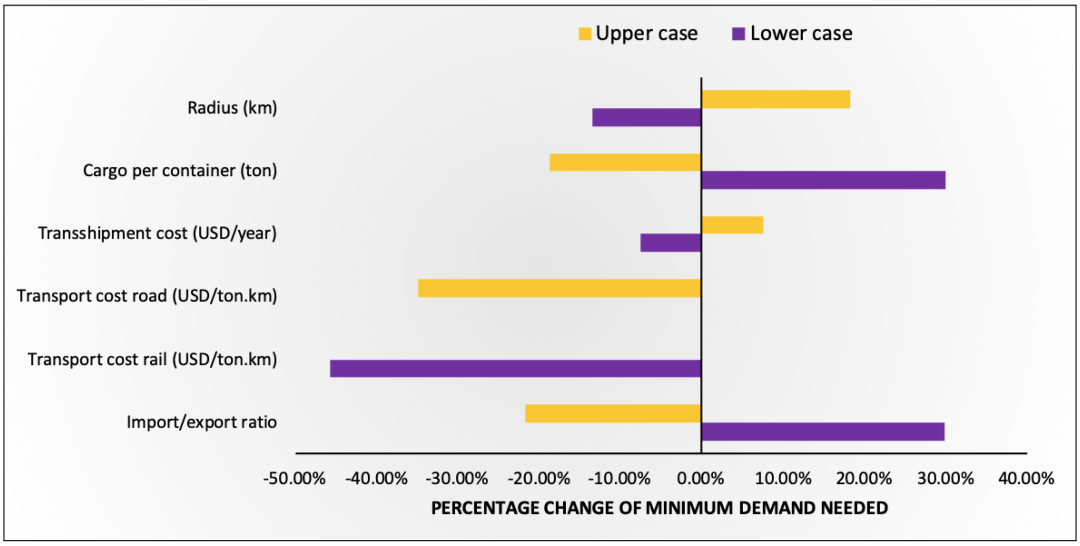

Figure 4.6: Sensitivity analysis lower and upper bound

The results of the lower and upper bound changes show that the lower bound case of road transport cost and upper bound case of rail transport cost lead to a non-feasible solution. This means the demand needed in the transshipment center is more than the capacity it was designed for. When looking at large possible changes, lower rail costs have the most impact when the absolute lower bound situation is met. The demand needed would decrease with more than 45%. A large increase in road transport costs would also significantly change the demand needed, with 35%. The transshipment cost and cargo weight per container can change the situation also, but less significantly, cause a maximum increase or decrease of 8%. The import/export ratio also influences the demand needed. With a lower ratio, the demand needed increases almost with 30%, while a higher ratio would decrease the demand need with 20%. The results also show that a larger radius leads to more demand needed, while a lower ratio leads to less demand needed. When only looking at results being positive or negative, the results are in line with expectation.

Sensitivity analysis - Increase and decrease of 5%

The sensitivity analysis using a 5% increase and decrease determines the relative influence each parameter has on the outcome of the model. The results of this analysis are shown in figure 4.7.

It can be seen that an increase in import/export ratio, road transport costs or the amount of tonnes in a container lead to a lower amount of container demand needed to realize a transshipment center. Regarding the import/export ratio this is logical because if the import/export ratio gets closer to one the transshipment center can be earned back by a higher amount of full containers. An increase in the transport cost via road leads to a decrease in demand needed because in that case the transshipment costs and transport costs via rail can be higher. Therefore, the costs of transshipping can increase. If the container load increases, less containers are needed to transport the same amount of goods. Since the load per container does affect the transport costs, but doesn't affect the transshipment costs an increase in load per container results in a lower amount of containers needed to make the transshipment center feasible.

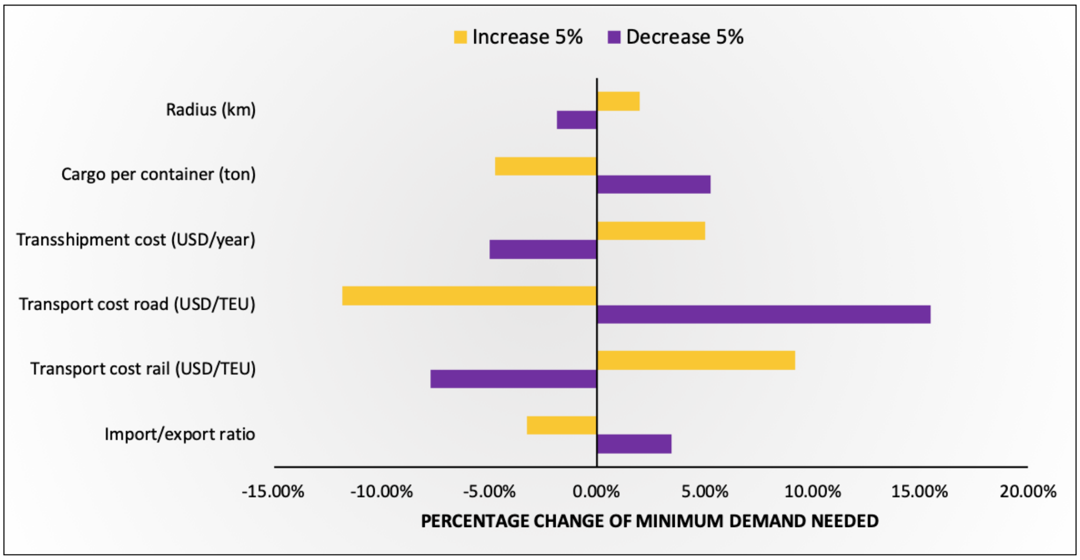

Figure 4.7: Sensitivity analysis percentage changes

As expected, a decrease in the transport costs via rail and in the transshipment costs leads to a lower amount of containers needed to make a new transshipment center feasible as these both positively affect the costs of the combination of transshipment and rail transport compared to the costs of transport via road. A decrease in radius has a positive influence because then the extra costs of transporting the container via road between the origin or destination and the transshipment center decrease.

Regarding the ratios of the effect of changing parameters, figure 4.7 shows that changes in costs have the biggest effect on the outcome of the model. Of these cost, the road transport costs have most influence, followed by rail transport costs and the transshipment costs have the least effect of the cost parameters. After the cost parameters, the cargo per container, the import/export ratio and the radius have a smaller, but not negligible effect on the outcome of the model.

Sensitivity analysis - Best and worst case scenario

For this analysis all the parameters from table Table 4.2 that have a positive influence will be put in the model simultaneously. This means the lower bound for rail transport costs, transshipment costs and the radius and the upper bound for import/export ratio, road transport costs and cargo per container. This gives as a result for the model that only 1850 TEU per year have to be exported via the transshipment center. In that case, the costs of transporting a container from the province to the port of Bahía Blanca are 870 USD/TEU. This value is without shipping costs.

The same analysis was done using the parameters from table Table 4.2 that have a negative effect on the outcome of the model. This means the upper bound for rail transport costs, transshipment costs and the radius and the lower bound for import/export ratio, road transport costs and cargo per container. As expected, this leads to a non-feasible outcome because the export demand exceeds 10,000 TEU/year. In this case, the costs of exporting from the province via the port of Bahía Blanca are 736 USD/TEU excluding shipping. This is almost 100 USD more expensive than the cheapest option which is transporting to Bahía Blanca by truck.

5
Conclusion

This closing chapter will conclude the findings of the research by answering the research question. Next to that, an advice for the Port of Bahía Blanca will be given. Lastly, interesting areas for further research regarding this topic will be discussed.

Conclusion
Following the studies in this report, in this conclusion an answer will be provided to the research question stated in the introduction. The question: *How can improving the accessibility of the port of Bahía Blanca by rail make container transport between the port of Bahía Blanca and the Buenos Aires province economically competitive with other transport options?* was divided into sub-questions, which are used to answer the main research question.

The first sub research question: *Why is container transport by rail to the port of Bahía Blanca currently not competitive?*, can be answered. The research has shown that the capacity and quality of the rail network is not the issue at the moment. The issue is the connection to the network. For this, a transshipment center is necessary, which needs to be built at a certain location near the network.

When looking at the second sub research question: *How can rail infrastructure be improved to enhance the accessibility of the port of Bahía Blanca by rail?*, the following can be concluded. In the case of building a transshipment center, it becomes clear that a minimum demand is needed to reduce the transshipment costs and thus make the option of rail transport to Bahía Blanca competitive. It can be concluded that different scenarios lead to different possible locations, with the the feasibility range assessment leading to the conclusion of a transshipment center between 230 and 430 kilometers from Bahía Blanca.

From the results it can also be concluded that the range has an optimum location at 380 kilometers. An expansion of the feasibility range is possible in the case of a larger terminal. More container export demand leads to a larger feasibility range. A transshipment center in the province of Buenos Aires has also been investigated using the scenario of similar shipping costs for Bahía Blanca and Buenos Aires. It can be concluded that at least 7200 TEU must be attracted from a radius of 50 kilometers. When researching a transshipment center close to Buenos Aires city, it can be concluded that a difference of 300 USD/TEU is needed to make a feasible solution. In that case, the distance to Bahía Blanca is over 600 km, which leads to a minimum import demand of 30,000 TEU/year. Analysing the sensitivity of parameters in the model leads to the conclusion that the transportation costs of road and rail are the most influential.

Advice

For the Port of Bahía Blanca, which is considered the main stakeholder for this research, an advice can be given. This advice can be concluded from the results of this research, and are subject to interpretation. The different topics on which the port of Bahía Blanca is advised, are summed up below.

- *Only support construction of transshipment center if concentrated container demand is available*

This advice is given using the conclusions from the model. From this it can be concluded that container transport demand should be concentrated in the catchment area of the transshipment terminal. Only if that is the case, the port should consider into the construction of a transshipment center.

- *Investigate possibilities of concentrating industries with container demand in the region*

Using the first advice, it should also be investigated whether concentrating industries with container demand in the region is possible. A steady and large flow of containers is the best way to make the center feasible. It should be investigated if there are possibilities of moving processing industries from around the city of Buenos Aires to the location of the transshipment center.

- *Investigate the effect of a more balanced import/export ratio obtained through a transshipment center near Buenos Aires, on lowering shipping and port costs.*

A final advice is to investigate how an increase in imported containers through Bahía Blanca due to construction of a transshipment center near Buenos Aires can cover the difference in port and shipping costs that is needed to make this transshipment center feasible. It is advised to look at the effect of a more balanced import/export ratio obtained through a transshipment center near Buenos Aires, on the shipping and port costs.

Recommendations for further research

The research conducted is subject to imperfections as several assumptions have been made. These imperfections are discussed and it is stated on what topics further research could help improve the conducted research. Three imperfections are discussed in the following section.

The first imperfection is the fact that time aspects are left out of the optimization model. This can be split up into two different aspects. The first being that the time a container travels is not in the model. At the moment there is little to indicate a slight change in time will make a user choose for another option. This has mainly to do with the already long travel times of the containers. In the future, transport time could play a role for the user, a dilemma could be influenced with the time aspect. Second, the time of building a terminal and the time that it takes for a shift in container transport, are left out of the research. This means that when it is decided the transshipment center should be built, the model takes it as if it is ready and attracts demand directly after it is operative. Further research could be looking into these aspects.

A second recommendation is the detail of the transshipment center. In this research, a rough indication of area and requirements is used. Would a terminal be built, it should be looked into what this will look like. Further research can indicate what connections a terminal would have, how many employees would be needed, how long equipment would be used. These are some examples of assumptions which could be interesting for more research.

A final recommendation has to do with the shift of limiting criteria regarding container transport in the future. At the moment, the limiting criteria has to do with the connections. It is also estimated that the capacities of the rail or road network are not the issue. In the future, this could shift, the roads could become the bottleneck or the trains could be fully used. Further research could look into what different limiting criteria could affect operations in the new state.

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Appendices

A

Expected vessel sizes and required draft

The route in figure A.1 is the only container shipping line that is operating via the port of Bahía Blanca. This is the Hamburg-Süd line which covers the East and West coast of South America and calls at the port only once a week since it is a weekly service line. The time from Bahía Blanca to Itapoá, where transatlantic overhaul takes place, is four days. The different vessels have a capacity between 1580 and 3600 TEU, in combination with 200 to 800 reefer plugs.

Figure A.1: Hamburg Süd ABAC – CONOSUR [16]

The current shipping line has eight vessels in use with a capacity of 1580-3600 TEU. Each ship takes 56 days for a total round voyage. An example of a ship using this route is the Cap Palmas of Hamburg-Süd that is displayed in figure A.2. This ship, with a draught of 6,5 meters, has a gross tonnage of 25,7 thousand tons.

Figure A.2: Cap Palmas [2]

When working with the expected numbers for the new container terminal with a throughput of 500,000 TEU and a 60% import share, assumptions on call sizes can be made for ships. When three ships call every week, it means that there will be a total of 1923 TEU of import movements and 1282 TEU of export movements per call. On lines between Europe and the Far East, call sizes vary around 20% on the European side and 10% on the side of the Far East [8]. On this line there is mainly import from Europe and export to the Far East. Since the import/export share in Bahía Blanca are much closer together it is assumed that an average call size could be 15%. Besides that the current call sizes also have shares of around 20% based on the provided annual throughput, import/export ratio and call frequencies. All these numbers are depicted in the table below.

Table A.1: Ship size calculation

Throughput per year	500,000	TEU
Shipping services per week	3	#
Import share	60%	%
Call size %	15%	%
Results in:		
Throughput per service	3205	TEU
Import per service	1923	TEU
Export per service	1282	TEU
Min capacity vessel	1923	TEU
Vessel size needed	12821	TEU

When all these number are taken into account and a calculation for the size of ships is made, it will exceed the 10.000 TEU border fast. Bigger vessels have impact on the draft needed in the port. The size of the vessel has impact but also the load percentage makes a big difference. In table A.2 the different drafts are shown as result of the mentioned variables.

Table A.2: Draft depending on vessel size and load percentage [9]

	Load %			
TEU	100%	75%	50%	25%
>20.000	18.0	16.2	14.4	12.6
<20.000	16.5	14.9	13.2	11.6
<15.000	16.0	14.4	12.8	11.2
<10.000	15.5	14.0	12.4	10.9
<5.000	14.0	12.6	11.2	9.8
<3.000	13.9	12.5	11.1	9.7

Since the port of Buenos Aires can accommodate a maximum draft of 13 meter after extensive dredging it runs into limitations quite fast. The port of Bahia Blanca is able to accommodate those bigger vessels that are required in a future situation with a container terminal designed for a throughput of 500.000 TEU per year.

B

Port costs

Using information from different sources, an indication of the port cost can be made. Using previous research papers, experiences from companies and insights from the port authority it became clear that it is difficult to find matching figures.

Using this, a more detailed approach to finding costs is possible. When looking at tariffs from the port authority and container terminal, it is noticeable that total costs are complex, as different ship sizes, container sizes, overhaul times and weight all influence the cost. Currently the port of Bahia Blanca is not charging a cargo rate for containerized transport to support this kind of transport. However, the port is planning to charge a cargo rate in the future when the throughput gets bigger. Next to the port costs there are also handling costs. The tariffs used by Patagonia Norte for container handling in the Bahía Blanca container terminal are not public, making it necessary to make estimations. With help from CREEBBA, an economic research agency, the Bahía Blanca port costs can be estimated.

To make the overview more clear, the costs can be divided in three parts, namely the shipping costs, the container terminal costs and the port authority costs. Based on a previous research conducted by CREEBBA, an estimation can be done for transporting a container via the port of Bahía Blanca. Transporting a 40 ft. reefer container from Bahía Blanca to Rotterdam (via Brasil) is considered as a base point for the estimated costs. The corresponding handling costs at Bahía Blanca are estimated to be USD 380. The costs for the port authority are as follows (Gonzalo Semilla, interview, September 20, 2019);

- Bill of load: USD 90
- Gate out: USD 50
- Handling: USD 50
- Adminstration fee: USD 99 + iva
- Documentation USD 90 + iva

Agroprimus S.A., a popcorn producer who exports the corn out of Argentina to sell on the international market, gave some costs insights as well. The handling and port costs are estimated around 470 USD per TEU in the Port of Bahia Blanca (Gonzalo Braceras, interview, September 18, 2019).

Understanding the current costs per TEU at the port of Bahia Blanca can be quite hard but in this research the starting point is a large and efficient container terminal at the port of Bahia Blanca which is a result from the high growth scenario as mentioned earlier. With sufficient throughput for this terminal handling costs can decrease due to economies of scale. Modern equipment means faster operations and bigger ships can mean a bigger call size which both negatively effect the costs per TEU which will be positive for the port of Bahia Blanca. This research will also focus on the sensitivity of the relation between handling costs and container demand.

C

Costs of shipping

Economies of scale is a very important factor for shipping costs as shown in figure C.2. When looking at the current costs of exporting via the port of Bahia Blanca it immediately becomes clear that shipping costs play a big role. From both CREEBBA as Agroprimus S.A. comparable values for transporting via Bahia Blanca were obtained. These values are depicted in figure C.1 where the impact to the total costs becomes clear of the different stages in shipping. When speaking to producers in the region a recurring notion is that the shipping cost from Bahía Blanca is often the defining factor to not choose for shipping via Bahia Blanca.

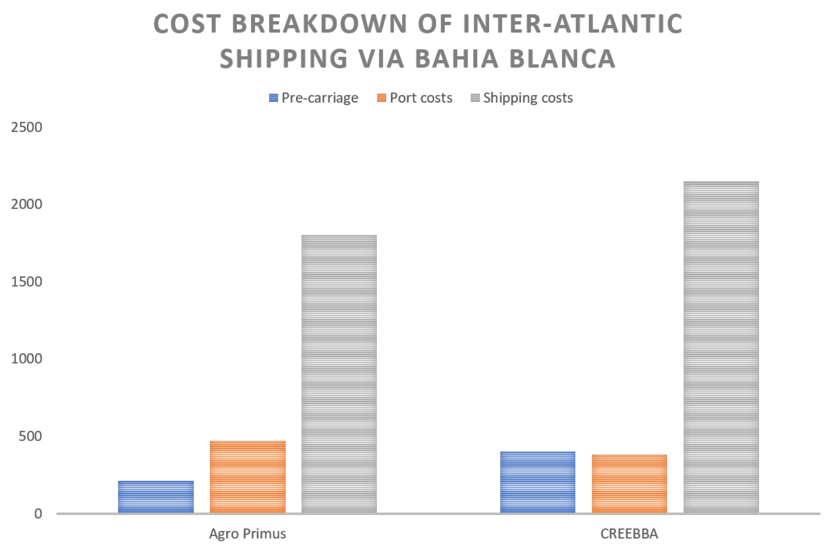


Figure C.1: Cost breakdown of inter-Atlantic shipping via Bahia Blanca in euro/TEU

As can be seen in figure C.1 shipping costs are the most important part of the total costs. This shows the importance of the right shipping lines calling at the port of Bahia Blanca. By building a new terminal port costs could well be lowered due to efficiency and economies of scale but it is way more import to first lower the shipping costs. Evidently these two go hand-in-hand while a bigger terminal is needed to attract the shipping lines.

The economies of scale that are inherent to increasing ship sizes can be a huge advantage for the port of Bahía Blanca. This will lower shipping costs which is needed to successfully operate a large sized container terminal. Bigger vessel sizes reduces costs per TEU when their capacity is utilized to a certain extent. Merk (2015) [8] shows how much this cost reduction is for increasing vessel sizes. This is visualized in figure C.2.

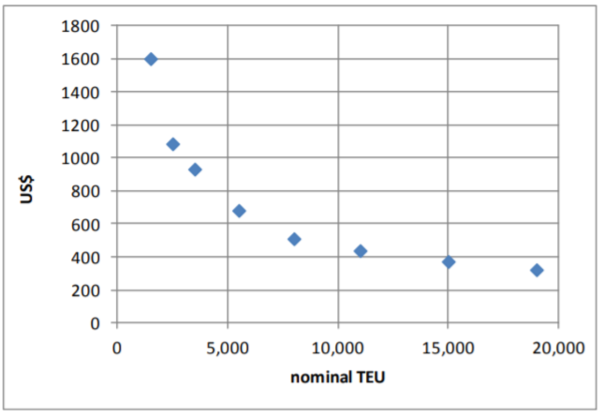


Figure C.2: Cost reduction per TEU due to vessel growth (85% utilization) [8]

D

Road transport

This appendix gives insight in road transport in the province of Buenos Aires. Firstly, it shows the situation of the road infrastructure and use in the entire province of Buenos Aires, the area of scope. The section after that focuses on the road infrastructure around the port of Bahia Blanca. In the end the costs of road transport are assessed.

Characteristics of road network in area of scope

The road network of the province of Buenos Aires consists of more than 120,000 km, of which 4,675 km are national routes that cross the province, 36,052 km correspond to provincial roads and the remaining part belongs to the municipalities. All national roads are paved and from the provincial roads 10,272 roads, thus approximately 30% has pavement, the other part is either ground or enhanced ground. The roads and rail lines connecting the port of Bahia Blanca with the port of Buenos Aires are shown in figure D.1.

Due to environmental factors and excessive loads, the road network has deteriorated over time. Arterial roads are subject to traffic loads above capacity, which results in lower service levels and an increased level of road accidents. Currently all containers in the region are transported by truck using the road infrastructure except for a daily container train travelling from Bahía Blanca to Buenos Aires and vice versa.

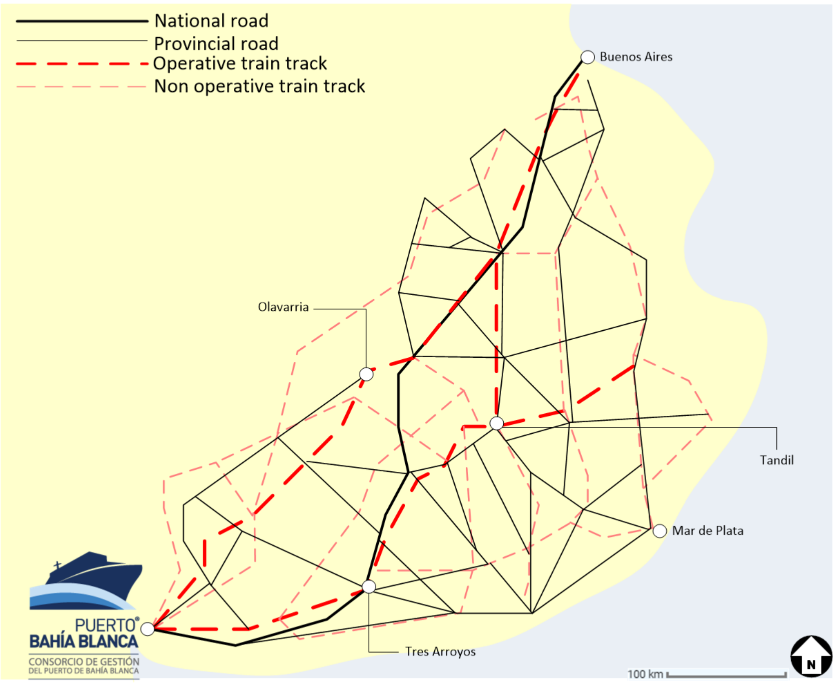


Figure D.1: Infrastructure network between Bahía Blanca and Buenos Aires

Road infrastructure around the port of Bahia Blanca

The city of Bahía Blanca has multiple road connections to the province of Buenos Aires, namely the RN33, RN35 and the RP51 (see figure D.2). However the only access route to the port of Bahía Blanca is the Ruta Nacional 3 (RN3), which crosses Bahía Blanca from the Buenos Aires province, across the port towards the south of Argentina. The roads, 18 de Julio and the Ruta Nacional 252 (RN252), form the only connection between the RN3 and the port of Bahía Blanca (see figure D.2). The red area in between these two access roads has weight restrictions of 6 tons per truck axle resulting in no trucks trespassing the municipality routes to reach the port. This also causes the fact that the container terminal, located at the black pin of figure D.2, can only be reached via 18 de Julio[10]. In 2016 an average of 700 trucks per day driving over these roads was estimated, with relatively high fluctuations due to the harvest season of grains three or four months a year. According to BOLSA Cereales truck transport gets very congested during the harvest season, resulting in high waiting times for container trucks as well. This has to do with the infrastructure but also with the handling capacity of the port of Bahia Blanca.

Costs of road transport

In literature not much information can be found of the current container transportation costs by truck. The Confederación Argentina del Transporte Automotor de Cargas (CATAC) does provide yearly reference tariff documents about truck transport in Argentina. At the end of this appendix the reference tariffs in the province of Buenos Aires dated from August 2019 are provided. It shows that transport from Bahía Blanca to Buenos Aires (or the other way around) will be approximately 35 US $/ton with the current rate of exchange.

Figure D.2: Access roads to port of Bahía Blanca [10]

CONFEDERACIÓN ARGENTINA DEL
TRANSPORTE AUTOMOTOR DE CARGAS

TARIFA DE REFERENCIA DE LA PROVINCIA DE BUENOS AIRES

Tarifa de Referencia de Cereales y Oleaginosas - AGOSTO 2019

1	225,00	51	428,44	101	619,03	151	779,82	201	944,59
2	225,00	52	432,05	102	622,21	152	783,07	202	947,87
3	225,00	53	435,68	103	625,39	153	786,33	203	951,15
4	225,00	54	439,31	104	628,57	154	789,59	204	954,44
5	225,00	55	442,95	105	631,76	155	792,85	205	957,73
6	225,00	56	446,60	106	634,94	156	796,11	206	961,03
7	225,00	57	450,26	107	638,13	157	799,37	207	964,33
8	225,00	58	453,92	108	641,32	158	802,64	208	967,63
9	225,00	59	457,59	109	644,51	159	805,90	209	970,94
10	225,00	60	461,27	110	647,70	160	809,17	210	974,25
11	229,04	61	464,96	111	650,89	161	812,44	211	977,56
12	233,12	62	468,65	112	654,08	162	815,71	212	980,88
13	237,22	63	472,36	113	657,28	163	818,99	213	984,20
14	241,36	64	476,07	114	660,47	164	822,26	214	987,53
15	245,53	65	479,79	115	663,67	165	825,54	215	990,85
16	249,74	66	483,52	116	666,87	166	828,82	216	994,19
17	253,98	67	487,26	117	670,07	167	832,10	217	997,52
18	258,27	68	491,00	118	673,28	168	835,38	218	1.000,86
19	262,59	69	494,75	119	676,48	169	838,66	219	1.004,21
20	266,95	70	498,52	120	679,68	170	841,95	220	1.007,55
21	271,35	71	502,29	121	682,89	171	845,23	221	1.010,90
22	275,80	72	506,07	122	686,10	172	848,52	222	1.014,26
23	280,28	73	509,86	123	689,31	173	851,81	223	1.017,62
24	284,82	74	513,66	124	692,52	174	855,10	224	1.020,98
25	289,40	75	517,46	125	695,73	175	858,40	225	1.024,35
26	294,02	76	521,28	126	698,95	176	861,69	226	1.027,72
27	298,70	77	525,11	127	702,17	177	864,99	227	1.031,10
28	303,43	78	528,94	128	705,38	178	868,29	228	1.034,47
29	308,21	79	532,78	129	708,60	179	871,59	229	1.037,86
30	313,05	80	536,64	130	711,82	180	874,89	230	1.041,24
31	317,94	81	540,50	131	715,04	181	878,19	231	1.044,64
32	322,89	82	544,37	132	718,27	182	881,50	232	1.048,03
33	327,90	83	548,26	133	721,49	183	884,81	233	1.051,43
34	332,97	84	552,15	134	724,72	184	888,12	234	1.054,83
35	338,11	85	556,05	135	727,95	185	891,43	235	1.058,24
36	343,32	86	559,97	136	731,18	186	894,74	236	1.061,65
37	348,59	87	563,89	137	734,41	187	898,06	237	1.065,07
38	353,94	88	567,82	138	737,64	188	901,37	238	1.068,49
39	359,36	89	571,76	139	740,88	189	904,69	239	1.071,92
40	364,86	90	575,72	140	744,11	190	908,01	240	1.075,34
41	370,44	91	579,68	141	747,35	191	911,33	241	1.078,78
42	376,10	92	583,66	142	750,59	192	914,66	242	1.082,22
43	381,85	93	587,64	143	753,83	193	917,98	243	1.085,66
44	387,68	94	591,64	144	757,07	194	921,31	244	1.089,11
45	393,62	95	595,65	145	760,32	195	924,64	245	1.092,56
46	399,65	96	599,67	146	763,56	196	927,97	246	1.096,01
47	405,78	97	603,70	147	766,81	197	931,30	247	1.099,47
48	412,02	98	607,74	148	770,06	198	934,64	248	1.102,94
49	418,36	99	611,79	149	773,31	199	937,97	249	1.106,41
50	424,82	100	615,85	150	776,56	200	941,31	250	1.109,88

Tarifa Estadía: **$5.400**

CONFEDERACIÓN ARGENTINA DEL TRANSPORTE AUTOMOTOR DE CARGAS

TARIFA DE REFERENCIA DE LA PROVINCIA DE BUENOS AIRES

Tarifa de Referencia de Cereales y Oleaginosas - AGOSTO 2019

251	1.113,36	301	1.292,65	351	1.421,63	401	1.550,60	451	1.679,57
252	1.116,84	302	1.295,23	352	1.424,20	402	1.553,18	452	1.682,15
253	1.120,33	303	1.297,81	353	1.426,78	403	1.555,76	453	1.684,73
254	1.123,82	304	1.300,39	354	1.429,36	404	1.558,34	454	1.687,31
255	1.127,32	305	1.302,97	355	1.431,94	405	1.560,92	455	1.689,89
256	1.130,82	306	1.305,55	356	1.434,52	406	1.563,50	456	1.692,47
257	1.134,33	307	1.308,13	357	1.437,10	407	1.566,08	457	1.695,05
258	1.137,84	308	1.310,71	358	1.439,68	408	1.568,66	458	1.697,63
259	1.141,35	309	1.313,29	359	1.442,26	409	1.571,23	459	1.700,21
260	1.144,87	310	1.315,87	360	1.444,84	410	1.573,81	460	1.702,79
261	1.148,40	311	1.318,45	361	1.447,42	411	1.576,39	461	1.705,37
262	1.151,93	312	1.321,03	362	1.450,00	412	1.578,97	462	1.707,95
263	1.155,47	313	1.323,61	363	1.452,58	413	1.581,55	463	1.710,53
264	1.159,01	314	1.326,18	364	1.455,16	414	1.584,13	464	1.713,11
265	1.162,55	315	1.328,76	365	1.457,74	415	1.586,71	465	1.715,69
266	1.166,10	316	1.331,34	366	1.460,32	416	1.589,29	466	1.718,26
267	1.169,66	317	1.333,92	367	1.462,90	417	1.591,87	467	1.720,84
268	1.173,22	318	1.336,50	368	1.465,48	418	1.594,45	468	1.723,42
269	1.176,79	319	1.339,08	369	1.468,06	419	1.597,03	469	1.726,00
270	1.180,36	320	1.341,66	370	1.470,64	420	1.599,61	470	1.728,58
271	1.183,93	321	1.344,24	371	1.473,21	421	1.602,19	471	1.731,16
272	1.187,52	322	1.346,82	372	1.475,79	422	1.604,77	472	1.733,74
273	1.191,10	323	1.349,40	373	1.478,37	423	1.607,35	473	1.736,32
274	1.194,70	324	1.351,98	374	1.480,95	424	1.609,93	474	1.738,90
275	1.198,29	325	1.354,56	375	1.483,53	425	1.612,51	475	1.741,48
276	1.201,90	326	1.357,14	376	1.486,11	426	1.615,09	476	1.744,06
277	1.205,50	327	1.359,72	377	1.488,69	427	1.617,67	477	1.746,64
278	1.209,12	328	1.362,30	378	1.491,27	428	1.620,24	478	1.749,22
279	1.212,74	329	1.364,88	379	1.493,85	429	1.622,82	479	1.751,80
280	1.216,36	330	1.367,46	380	1.496,43	430	1.625,40	480	1.754,38
281	1.219,99	331	1.370,04	381	1.499,01	431	1.627,98	481	1.756,96
282	1.223,63	332	1.372,62	382	1.501,59	432	1.630,56	482	1.759,54
283	1.227,27	333	1.375,19	383	1.504,17	433	1.633,14	483	1.762,12
284	1.230,92	334	1.377,77	384	1.506,75	434	1.635,72	484	1.764,70
285	1.234,57	335	1.380,35	385	1.509,33	435	1.638,30	485	1.767,27
286	1.238,23	336	1.382,93	386	1.511,91	436	1.640,88	486	1.769,85
287	1.241,89	337	1.385,51	387	1.514,49	437	1.643,46	487	1.772,43
288	1.245,56	338	1.388,09	388	1.517,07	438	1.646,04	488	1.775,01
289	1.249,24	339	1.390,67	389	1.519,65	439	1.648,62	489	1.777,59
290	1.252,92	340	1.393,25	390	1.522,22	440	1.651,20	490	1.780,17
291	1.256,61	341	1.395,83	391	1.524,80	441	1.653,78	491	1.782,75
292	1.260,30	342	1.398,41	392	1.527,38	442	1.656,36	492	1.785,33
293	1.264,00	343	1.400,99	393	1.529,96	443	1.658,94	493	1.787,91
294	1.267,71	344	1.403,57	394	1.532,54	444	1.661,52	494	1.790,49
295	1.271,42	345	1.406,15	395	1.535,12	445	1.664,10	495	1.793,07
296	1.275,14	346	1.408,73	396	1.537,70	446	1.666,68	496	1.795,65
297	1.278,86	347	1.411,31	397	1.540,28	447	1.669,25	497	1.798,23
298	1.282,59	348	1.413,89	398	1.542,86	448	1.671,83	498	1.800,81
299	1.286,33	349	1.416,47	399	1.545,44	449	1.674,41	499	1.803,39
300	1.290,07	350	1.419,05	400	1.548,02	450	1.676,99	500	1.805,97

Tarifa Estadía: **$5.400**

CONFEDERACIÓN ARGENTINA DEL
TRANSPORTE AUTOMOTOR DE CARGAS

TARIFA DE REFERENCIA DE LA PROVINCIA DE BUENOS AIRES

Tarifa de Referencia de Cereales y Oleaginosas - AGOSTO 2019

501	1.808,67	551	1.944,75	601	2.082,22	651	2.180,43	701	2.276,77
502	1.811,38	552	1.947,49	602	2.084,21	652	2.182,37	702	2.278,68
503	1.814,08	553	1.950,23	603	2.086,19	653	2.184,32	703	2.280,59
504	1.816,79	554	1.952,98	604	2.088,17	654	2.186,26	704	2.282,49
505	1.819,49	555	1.955,72	605	2.090,15	655	2.188,20	705	2.284,40
506	1.822,20	556	1.958,47	606	2.092,13	656	2.190,15	706	2.286,30
507	1.824,91	557	1.961,21	607	2.094,11	657	2.192,09	707	2.288,21
508	1.827,62	558	1.963,96	608	2.096,09	658	2.194,03	708	2.290,11
509	1.830,33	559	1.966,71	609	2.098,06	659	2.195,97	709	2.292,02
510	1.833,04	560	1.969,45	610	2.100,04	660	2.197,91	710	2.293,92
511	1.835,75	561	1.972,20	611	2.102,02	661	2.199,85	711	2.295,82
512	1.838,46	562	1.974,95	612	2.103,99	662	2.201,78	712	2.297,72
513	1.841,17	563	1.977,71	613	2.105,97	663	2.203,72	713	2.299,62
514	1.843,88	564	1.980,46	614	2.107,94	664	2.205,66	714	2.301,52
515	1.846,60	565	1.983,21	615	2.109,91	665	2.207,59	715	2.303,42
516	1.849,31	566	1.985,97	616	2.111,88	666	2.209,53	716	2.305,32
517	1.852,02	567	1.988,72	617	2.113,86	667	2.211,46	717	2.307,22
518	1.854,74	568	1.991,48	618	2.115,83	668	2.213,39	718	2.309,11
519	1.857,46	569	1.994,23	619	2.117,80	669	2.215,32	719	2.311,01
520	1.860,17	570	1.996,99	620	2.119,77	670	2.217,26	720	2.312,90
521	1.862,89	571	1.999,75	621	2.121,73	671	2.219,19	721	2.314,80
522	1.865,61	572	2.002,51	622	2.123,70	672	2.221,12	722	2.316,69
523	1.868,32	573	2.005,27	623	2.125,67	673	2.223,05	723	2.318,58
524	1.871,04	574	2.008,04	624	2.127,63	674	2.224,97	724	2.320,48
525	1.873,76	575	2.010,80	625	2.129,60	675	2.226,90	725	2.322,37
526	1.876,48	576	2.013,56	626	2.131,56	676	2.228,83	726	2.324,26
527	1.879,21	577	2.016,33	627	2.133,53	677	2.230,76	727	2.326,15
528	1.881,93	578	2.019,10	628	2.135,49	678	2.232,68	728	2.328,04
529	1.884,65	579	2.021,86	629	2.137,45	679	2.234,61	729	2.329,93
530	1.887,37	580	2.024,63	630	2.139,41	680	2.236,53	730	2.331,82
531	1.890,10	581	2.027,40	631	2.141,37	681	2.238,45	731	2.333,70
532	1.892,82	582	2.030,17	632	2.143,33	682	2.240,38	732	2.335,59
533	1.895,55	583	2.032,94	633	2.145,29	683	2.242,30	733	2.337,48
534	1.898,28	584	2.035,72	634	2.147,25	684	2.244,22	734	2.339,36
535	1.901,00	585	2.038,49	635	2.149,21	685	2.246,14	735	2.341,25
536	1.903,73	586	2.041,27	636	2.151,17	686	2.248,06	736	2.343,13
537	1.906,46	587	2.044,04	637	2.153,12	687	2.249,98	737	2.345,01
538	1.909,19	588	2.046,82	638	2.155,08	688	2.251,90	738	2.346,89
539	1.911,92	589	2.049,60	639	2.157,03	689	2.253,82	739	2.348,78
540	1.914,65	590	2.052,38	640	2.158,99	690	2.255,73	740	2.350,66
541	1.917,38	591	2.055,16	641	2.160,94	691	2.257,65	741	2.352,54
542	1.920,12	592	2.057,94	642	2.162,89	692	2.259,56	742	2.354,42
543	1.922,85	593	2.060,72	643	2.164,84	693	2.261,48	743	2.356,30
544	1.925,58	594	2.063,51	644	2.166,79	694	2.263,39	744	2.358,17
545	1.928,32	595	2.066,29	645	2.168,74	695	2.265,31	745	2.360,05
546	1.931,06	596	2.069,08	646	2.170,69	696	2.267,22	746	2.361,93
547	1.933,79	597	2.071,87	647	2.172,64	697	2.269,13	747	2.363,80
548	1.936,53	598	2.074,66	648	2.174,59	698	2.271,04	748	2.365,68
549	1.939,27	599	2.077,45	649	2.176,54	699	2.272,95	749	2.367,55
550	1.942,01	600	2.080,24	650	2.178,48	700	2.274,86	750	2.369,43

Tarifa Estadía: **$5.400**

CONFEDERACIÓN ARGENTINA DEL TRANSPORTE AUTOMOTOR DE CARGAS

TARIFA DE REFERENCIA DE LA PROVINCIA DE BUENOS AIRES

Tarifa de Referencia de Cereales y Oleaginosas - AGOSTO 2019

751	2.371,30	801	2.464,75	851	2.592,28	901	2.722,54	951	2.809,15
752	2.373,17	802	2.467,27	852	2.594,87	902	2.724,29	952	2.810,87
753	2.375,05	803	2.469,80	853	2.597,45	903	2.726,04	953	2.812,58
754	2.376,92	804	2.472,32	854	2.600,04	904	2.727,78	954	2.814,30
755	2.378,79	805	2.474,85	855	2.602,63	905	2.729,53	955	2.816,01
756	2.380,66	806	2.477,37	856	2.605,22	906	2.731,28	956	2.817,73
757	2.382,53	807	2.479,90	857	2.607,81	907	2.733,02	957	2.819,44
758	2.384,39	808	2.482,43	858	2.610,40	908	2.734,76	958	2.821,15
759	2.386,26	809	2.484,96	859	2.613,00	909	2.736,51	959	2.822,86
760	2.388,13	810	2.487,49	860	2.615,59	910	2.738,25	960	2.824,57
761	2.389,99	811	2.490,02	861	2.618,19	911	2.739,99	961	2.826,29
762	2.391,86	812	2.492,55	862	2.620,79	912	2.741,73	962	2.827,99
763	2.393,72	813	2.495,08	863	2.623,39	913	2.743,47	963	2.829,70
764	2.395,59	814	2.497,62	864	2.625,99	914	2.745,21	964	2.831,41
765	2.397,45	815	2.500,15	865	2.628,59	915	2.746,95	965	2.833,12
766	2.399,31	816	2.502,69	866	2.631,20	916	2.748,69	966	2.834,83
767	2.401,18	817	2.505,23	867	2.633,81	917	2.750,43	967	2.836,53
768	2.403,04	818	2.507,77	868	2.636,42	918	2.752,17	968	2.838,24
769	2.404,90	819	2.510,31	869	2.639,03	919	2.753,91	969	2.839,95
770	2.406,76	820	2.512,85	870	2.641,64	920	2.755,64	970	2.841,65
771	2.408,62	821	2.515,40	871	2.644,25	921	2.757,38	971	2.843,36
772	2.410,48	822	2.517,94	872	2.646,87	922	2.759,11	972	2.845,06
773	2.412,33	823	2.520,48	873	2.649,48	923	2.760,85	973	2.846,76
774	2.414,19	824	2.523,03	874	2.652,10	924	2.762,58	974	2.848,46
775	2.416,05	825	2.525,58	875	2.654,72	925	2.764,31	975	2.850,17
776	2.417,90	826	2.528,13	876	2.657,34	926	2.766,05	976	2.851,87
777	2.419,76	827	2.530,68	877	2.659,97	927	2.767,78	977	2.853,57
778	2.421,61	828	2.533,23	878	2.662,59	928	2.769,51	978	2.855,27
779	2.423,47	829	2.535,78	879	2.665,22	929	2.771,24	979	2.856,97
780	2.425,32	830	2.538,34	880	2.667,85	930	2.772,97	980	2.858,67
781	2.427,17	831	2.540,89	881	2.670,48	931	2.774,70	981	2.860,36
782	2.429,02	832	2.543,45	882	2.673,11	932	2.776,43	982	2.862,06
783	2.430,87	833	2.546,01	883	2.675,74	933	2.778,16	983	2.863,76
784	2.432,72	834	2.548,57	884	2.678,38	934	2.779,88	984	2.865,45
785	2.434,57	835	2.551,13	885	2.681,02	935	2.781,61	985	2.867,15
786	2.436,42	836	2.553,69	886	2.683,65	936	2.783,34	986	2.868,84
787	2.438,27	837	2.556,25	887	2.686,30	937	2.785,06	987	2.870,54
788	2.440,12	838	2.558,82	888	2.688,94	938	2.786,79	988	2.872,23
789	2.441,96	839	2.561,38	889	2.691,58	939	2.788,51	989	2.873,93
790	2.443,81	840	2.563,95	890	2.694,23	940	2.790,23	990	2.875,62
791	2.445,66	841	2.566,52	891	2.696,88	941	2.791,96	991	2.877,31
792	2.447,50	842	2.569,09	892	2.699,53	942	2.793,68	992	2.879,00
793	2.449,34	843	2.571,66	893	2.702,18	943	2.795,40	993	2.880,69
794	2.451,19	844	2.574,23	894	2.704,83	944	2.797,12	994	2.882,38
795	2.453,03	845	2.576,81	895	2.707,49	945	2.798,84	995	2.884,07
796	2.454,87	846	2.579,38	896	2.710,15	946	2.800,56	996	2.885,76
797	2.456,71	847	2.581,96	897	2.712,81	947	2.802,28	997	2.887,45
798	2.458,55	848	2.584,54	898	2.715,47	948	2.804,00	998	2.889,14
799	2.460,39	849	2.587,12	899	2.718,13	949	2.805,72	999	2.890,82
800	2.462,23	850	2.589,70	900	2.720,79	950	2.807,44	1000	2.892,51

Tarifa Estadía: **$5.400**

E

Rail transport

In this appendix the assessment of rail transport in the area of scope can be found. The first section is about the characteristics of rail network in area of scope. The second part focuses on the infrastructure around the port of Bahia Blanca. After that the operations, technical characteristics and the costs of rail transport are illustrated. The section in the end informs about current transshipment options on the network since this is of particular interest to the research paper.

Characteristics of rail network in area of scope

Considering freight transport, two private railway companies are currently operating in the area of scope, Ferrosur Roca S.A. (Ferrosur) and Ferroexpreso Pampeano S.A. (FEPSA). A large share of the area is operated and maintained by Ferrosur, and FEPSA is only responsible for the rails around the port and city of Bahía Blanca. In this appendix their network, operations and characteristics are described.

Figure E.1: Total Ferrosur network

Ferrosur operates and maintains most of the considered network. Their concession area, which was acquired in December 1992 and ends in March 2023, entails a network with a total length of 3.377 km. The main artery, an artery with a total of 650 km, runs from Buenos Aires, where it has access to the ports Dock Sud and Puerto Nuevo, via Olavarría to Bahía Blanca. In fact, the line does not stop at Bahía Blanca, but runs for another 741 km to Zapala in the west of Argentina. However, this part of the line is not in scope of this project. Next to the main line through the area there is a secondary rail line from the port of Bahía Blanca via Tres Arroyos and Tandil to Las Flores where it connects to the main artery again. In addition to these two lines, there are multiple lines that are only operative if there is demand (e.g. during harvest season) and lastly, 18% of the lines is not operative at all [3]. The overview of the total network of Ferrosur Roca can be found in figure E.1.

Next to Ferrosur, FEPSA is operating and transporting cargo in the studied region too. FEPSA's concession started in 1991 and will end in November 2021. That concession entails a network of 5,094 km which is located in the western part of the Buenos Aires province and in the province of La Pampa. For that reason most of their network is out of scope for this project. Although only 55% of FEPSA's network is operative, the part that is operative is nearly saturated. [10].

Rail infrastructure around the port of Bahia Blanca

Railway company FEPSA has a principal line to the port of Bahía Blanca and maintains and operates the tracks in the port itself. Direct access means that there are no permits needed which results in less waiting time and faster rotation of their material compared to going to another port. At the container terminal a well-functioning rail infrastructure is present as well, but the access and egress to and from this terminal is currently only performed by trucks. This can be explained by the fact that the entrance is blocked when more than ten train wagons are coupled. Furthermore, railway operators indicated that the urge of handling on terminal ground is limited [10].

Due to the fact it has direct access to the port of Bahía Blanca, FEPSA transports more than 70% of its cargo via the port of Bahía Blanca. To gain better insights in the current operations on the network, it is important to know the commodity and the amount of transported cargo. In 2016, 9.97 million tonnes of cargo were transported via the port of Bahía Blanca. Of this amount 30%, 2.98 million tonnes, was cargo from FEPSA. 0.22 million tonnes came from the direction of Coronel Pringles to Bahía Blanca and thus used part of the Ferrosur network. In total FEPSA transported 4.24 million tonnes of cargo, mostly grains and food [14].

In order to reach the port of Bahía Blanca, Ferrosur has to make use of the rail network of FEPSA, which is a disadvantage for this company. FEPSA on the other hand, can only reach the eastern part of the Buenos Aires province by the network of Ferrosur. Through mutual agreements both railway companies are able to use each others networks (D. San Juan, interview, September 19, 2019).

Current operations

Ferrosurs most important operations on the network are concentrated around Olavarría, since it is an important place for cement production in Argentina. For that reason, 8 to 12 trains leave from Olavarría to Buenos Airs each day. Combined with other traffic, this part of the network can be considered saturated. The part of the network from Bahía Blanca to Olavarría is less congested as only 4 to 6 trains take this route each day (H. Torresi, interview, September 20, 2019).

At this moment container transport by rail is not commonly used. Only a single train with 45 loaded containers runs daily from Bahía Blanca to Buenos Aires from Monday up until Saturday, thus six times per week. These containers are only filled with polyethylene grains produced by Dow chemicals located in the port. These grains are transported to Buenos Aires, from which a part is for domestic use in that region and the other part is exported via the port of Buenos Aires. Each train returns with empty containers to Bahía Blanca. The total round trip to Buenos Aires and back to Bahía Blanca takes three days. Using the fact that the fleet of Ferrosur consists of 350 container wagons, it can be assumed that around half of these are used for their daily service to Buenos Aires [11].

Characteristics network

Trains on the Ferrosur network drive with an operational speed of between 40 and 50 km/h. The maximum speed that could be reached on the network is 60 km/h. (H. Torresi, interview, September 20, 2019) One of the reasons that the maximum speed is not reached is that the line consists of only one track. Therefore, trains have to wait for a passing train at a station where more tracks are available. Next to that, the railway crosses a lot of small villages in which a velocity of around 15 km/h is expected. As a result, the average speed is only 35 km/h which explains the three days duration of a round trip to Buenos Aires and back.

Another characteristic of the operations on the network is that regular and irregular train operations are mixed. Therefore, the offered services have no clear timetable which makes the operations less optimized and gives opportunity for improvement (J.P. Martinez, interview, September 14, 2019).

The main railway from Bahía Blanca via Olavarría to Buenos Aires can facilitate a maximum load on the track of 20 tons per axle of the wagons. Since a wagon has a load of approximately 25 tons, the load of the container(s) and its content on one wagon may not exceed 55 tons. The train between Bahía Blanca and Buenos Aires also crosses 'Sierra de las Ventanas', a hilly area with an uphill gradient of 7%. This region is constraining the maximum load and velocity of the trains. A train going from Bahía Blanca to Buenos Aires cannot have a gross weight over 3200 tons. In the opposite direction the steep slope is in the downhill direction and therefore the maximum gross weight is 4000 tonnes. The secondary line of Ferrosurs network, which connects Bahía Blanca and Buenos Aires via Tres Arroyos and Tandil, is in worse shape. Because of the worse condition, the velocity on this longer route is lower and the maximum weight of the container and its content on these track is 43 tonnes. On the remaining tracks in the region the maximum axle load is 17 tonnes also due to poorly maintained rails. (H. Torresi, interview, September 20, 2019) Another issue regarding capacity of container transport by train is that double stacking of containers is not possible (J. Kohon, interview, September 24, 2019).

Costs of rail transport

Transport per train normally costs around 0,05 $/tonkm. However, due to the current economic position of Argentina the costs for transporting one ton of cargo over one kilometer are currently 0,035 $. Transshipping a container from truck to train or vice versa costs around 1$ per ton. (D. San Juan, interview, September 19, 2019; J. Kohon, interview, September 24, 2019)

Transshipment center

Alongside the studied corridor, the railway companies do not facilitate transshipment areas for containers. Ferrosur has two locations in their network where containers are transshipped, namely in the ports Dock Sud and Puerto Nuevo. On the FEPSA network, only one transshipment center is located at Dow chemicals in Bahía Blanca, operated by Celsur Logística. Furthermore, as already mentioned, transshipment of containers via rail directly to a vessel can take place in the port of Bahía Blanca. However, these tracks are currently not in use by FEPSA. Due to the few transshipment options alongside the railway, companies in the Buenos Aires province are not able to use rail as a possible transport option to the ports.

F

Container transport demand in the province of Buenos Aires

Information that is key in this research is the amount of container demand and where it is located in the area of scope. To come up with ideas about changing the corridor to generate more container demand in Bahía Blanca it is necessary to know where to get this container demand from.

Literature research was done to get insight in the commodities produced in the region. This also gave insight in the type of product that was mainly transported. It became clear that this is agri-bulk. Containers can be used to transport agri-bulk but it is not very common, especially not in Argentina. However, there are some companies that actually produce products that are shipped in containers in the region. Companies like Farm Frites import potatoes from local suppliers as bulk to their facilities but export the final product in containers.

In order to find out more about these types of companies, field research was done by visiting multiple companies and experts in the province of Buenos Aires. Some of the companies that where visited were mainly focused on agri-bulk and did not use containers for transporting their products. An exception on this was a pop-corn producer called Agroprimus S.A. This producer uses containers to transport its products to countries like Turkey and Nigeria. Some very useful insights were gained about container demand and transport in the region, but also about transport costs. Every year Agroprimus S.A. exports around 400 TEU via the port of Buenos Aires to destinations on the other side of the Atlantic ocean. The port of Buenos Aires is chosen for shipping because of lower shipping costs. The companies that were interviewed did not know of other companies that transported their goods in containers.

To dig one step deeper experts from the region were interviewed as well. Those experts also confirmed that containerized transport was not widely used but that there are some more exceptions on this like Agroprimus S.A.. From interviews with Bolsa Cereales (Bolsa Cereales, interview, September 20, 2019) and Ivan Ulmann (Ivan Ulmann, interview, September 20, 2019) it became clear that there were producers of olive oil, honey, wine, durum wheats and organic cereals that also use containerized transport. Onions and garlic used to be transported in containers but this is not the case anymore, Bolsa Cereales was unclear about the reason why this changed. All these producers account for a small container demand and they are not located near to each other.

Getting back to the first paragraph, producers like Farm Frites that have bulk as import and containerized transport as an output could be really interesting for the region. Agri-products need to be processed and after processing those finished goods can not be transported in bulk anymore. This does not only account for potatoes, for example, there is a lot of meat production in the region but the slaughterhouses are located in the industrial area of Buenos Aires. Locating these processing factories more close to the origin of the product could increase container transport in the research area.

The main reason why those companies are located in Buenos Aires is because they prefer to be as close to the customer as possible. As can be seen in figure F.1 most of the population of Argentina lives in Buenos Aires.

This figure also immediately makes clear why container transport is currently preferably done via the port of Buenos Aires. Containerized transport in Buenos Aires is mostly used for manufactured goods [9] that find their highest demand on densely populated areas.

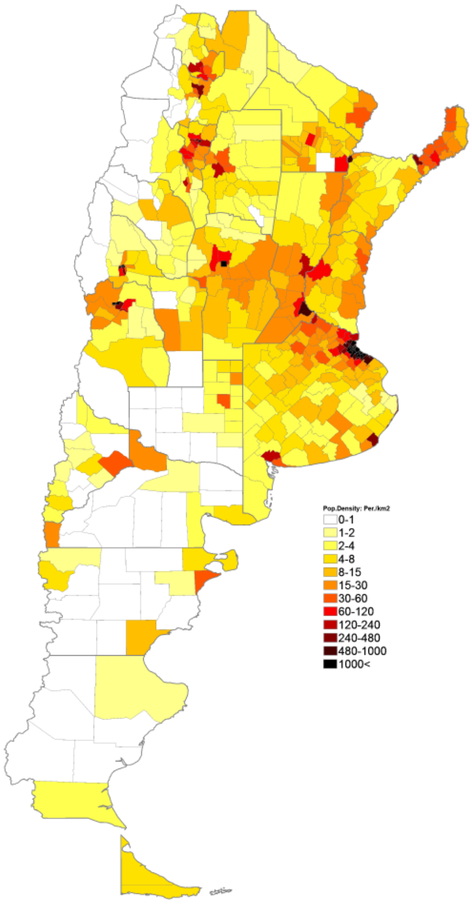


Figure F.1: Population density Argentina

Demand in the region for containerized transport is low and scattered. The main reasons for this are that the majority of the products is agri-bulk and that the area is not densely populated (figure F.1). There are chances for the containerized transport to grow in the region if the processing of agri bulk would happen closer to the source of those products. But it is only interesting for companies to do that when transport to the region with demand can be executed in an efficient way. Besides that smaller producers of products that are shipped in containers can bundle their forces to generate a larger container throughput together which can also benefit the efficiency of transporting their products. It can be concluded that there are chances for container transport demand to grow in the region but it is not sure by how much.

G
Specifications of transshipment center

Transshipment terminal in the province of Buenos Aires

Since the population density in the province of Buenos Aires is low, it is expected that the amount of exported containers is higher than the amount of imported containers. These exported containers come from companies in the region. Although the average population density in the province is low there are still some areas where population is quite dense. Depending on the placement of the transshipment terminal this will have effect on the import demand of the terminal. As a rule of thumb a container demand of 10,000 inhabitants account for a container demand of 1,000 TEU per year (P. Arecco, interview, October 24, 2019).

To accommodate the exported containers the terminal is designed in a flexible way. The design is based on findings by Wiegmans and Behdani and adjusted to Argentinian standards and prices [17]. The terminal has one hectare of stacking area. In that way, when only one reach stacker operates the terminal, the capacity of this stacking area is 500 TEU [6]. A reach stacker is relatively cheap, very versatile and able to load and unload trains and trucks. It is expected that one hectare of stacking area and one reach stacker is sufficient for a maximum yearly throughput of 10,000 TEU. If it turns out that a larger yearly throughput is needed to make realization of the transshipment terminal feasible, additional equipment is necessary to increase the storage capacity. Two possible pieces of equipment have been considered: a straddle carrier and a rubber tyred gantry crane. A straddle carrier only increases the practical storage capacity with 25% to 625 TEU per hectare. A rubber tyred gantry crane makes storing 1,000 TEU on one hectare possible [5]. For this reason adding a rubber tyred gantry crane will be chosen if a yearly throughput over 10,000 TEU is necessary to make the realization of the container terminal feasible.

In order to tranship from all possible train compositions the terminal needs to extent over a length of the longest possible train. In this case this adds up to around 700 meter (H. Torresi, interview, September 20, 2019). The assumption that a great share of the train load is transferred at the terminal makes a long platform a necessity. Since the train route mostly consists of only one track it is needed to construct an extra track at the terminal in order to make sure that the network does not get congested due to transshipment operations. Besides that transshipment operations can be easily secured into a confined space which is beneficial to safety.

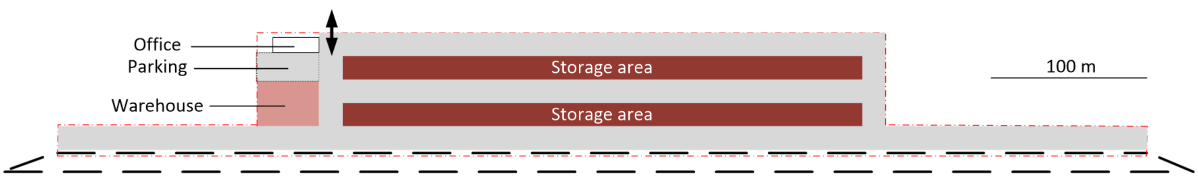


Figure G.1: Terminal design for a transshipment center in the province of Buenos Aires

In Figure G.1 a possible layout of the terminal can be found. As mentioned before, the terminal consists of 10,000 m2 storage area. To achieve more optimal operations this area is split up in two storage areas of 5,000 m2 surrounded by roads. In addition to this, there is a warehouse of 1,200 m2 for added services and an office area for customs, security and terminal operators of 150 m2. The road system contains of 15 meters wide roads along the rail track and the storage area. A 15 meter wide road is needed to manoeuvre a reach stacker carrying a FEU through the terminal. In addition to the road network there is space for around 10 trucks to park in the terminal.

If it turns out that a maximum yearly throughput of 10,000 TEU does not suffice (which proved to be the case in the research), the amount of storage area needed remains one hectare. However, minor adjustments to the terminal design might be necessary. For example the road crossing the storage area might not be needed anymore. In addition, the office area increases as more employees will be needed to operate a bigger terminal. Of course, a big change is that design needs to be adjusted to make rubber tyred gantry crane operations possible.

Table G.1: Costs for terminal in the province

	10,000 TEU/year terminal		**20,000 TEU/year terminal**		**Unit**
	Lower bound	*Upper bound*	*Lower bound*	*Upper bound*	
Investment costs	2,617,000	3,347,000	3,398,000	4,330,000	USD
Depreciation years	30	30	30	30	year
Investment costs	87,000	115,000	133,000	144,000	USD/year
Operational costs	223,000	286,000	319,000	359,000	USD/year
Total yearly costs	373,000	480,000	584,000	679,000	USD/year
Minimal costs per TEU	37	48	29	34	USD/TEU

In table G.1 the costs of a 10,000 and 20,000 TEU per year terminal can be found. The investment costs consist among others of new rail tracks, pavement and terminal equipment. Next to investment costs there are also operational costs. Examples of operational costs are salaries for employees, maintenance costs and costs for fuel and electricity. Maintenance costs account for around 60% of the operational costs. Another big part, 20%, is due to labour. The investment costs are spread out over 30 years. The operational costs in USD per year are added to this to get to the total yearly costs. Dividing this by the maximum amount of TEU the terminal can transship in one year leads to the minimal costs per TEU. In table G.1 it can be seen that if the terminal is used up to its maximum capacity, the minimal costs per TEU are lower for a bigger terminal. The calculation of the investment and operational costs can be found in *Terminal-design-costs.xlxs*.

Transshipment terminal in the city of Buenos Aires

As mentioned before, a transshipment terminal near the city of Buenos Aires that handles 20,000 containers a year seems small. Therefore, the terminal in the city of Buenos Aires is designed to handle 100,000 TEU a year. In addition to this, it should be noted that a transshipment terminal in the city of Buenos Aires will handle more import containers than export containers. The size of the terminal is based on a well educated guess and it is between 5-10 % of the total throughput in Buenos Aires [9]. This throughput is also needed to lower transshipment costs and make it more feasible to use Bahía Blanca as shipping port instead of Buenos Aires despite the longer transport distance over land.

Compared to the smaller terminal more concrete pavement is needed since the storage area should enable storage of much more containers. However, due to application of other equipment the storage area will be used more efficiently thus the relation between maximum throughput and concrete pavement is not linear. Investments in equipment consist of two additional gantry cranes and two extra reach stackers compared to the terminal that can handle 20,000 TEU per year. Another important investment that is needed to achieve smooth operations at a larger terminal is a second rail track of 700 meters long. One of the gantry cranes will enable loading and unloading on the trains.

Next to additional investment costs a bigger terminal will result in higher operational costs. A growth in operations will result to higher fuel and electricity costs. Next to that more employees and guards are needed to handle containers smoothly.

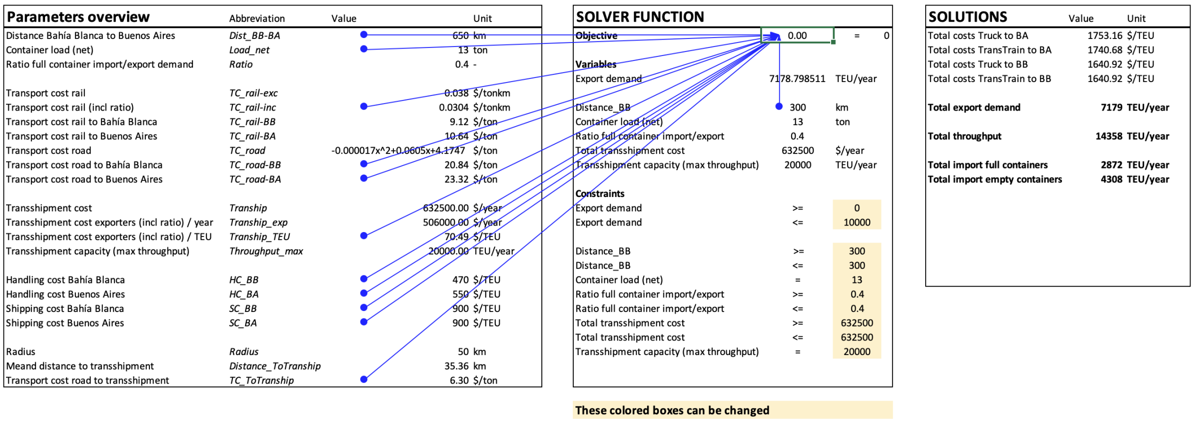
In Table G.2 the costs for building and operating a terminal that is designed for a yearly throughput of 100,000 TEU, is shown. If the costs of a terminal in the province are compared to the costs of a terminal in the city of Buenos Aires it can be seen that due to economies of scale the minimal costs per TEU decrease significantly. A more extensive breakdown of the investment and operational costs can be found in *Terminal-design-costs.xlxs.*

Table G.2: Costs of terminal in the city of Buenos Aires

	100,000 TEU/year terminal		**Unit**
	Lower bound	*Upper bound*	
Investment costs	11,585,000	14,223,000	USD
Depreciation years	30	30	year
Investment costs	386,000	474,000	USD/year
Operation costs	966,000	1,198,000	USD/year
Total yearly costs	1,825,000	2,257,000	USD/year
Minimal costs per TEU	18	23	USD/TEU

H

Model solver function



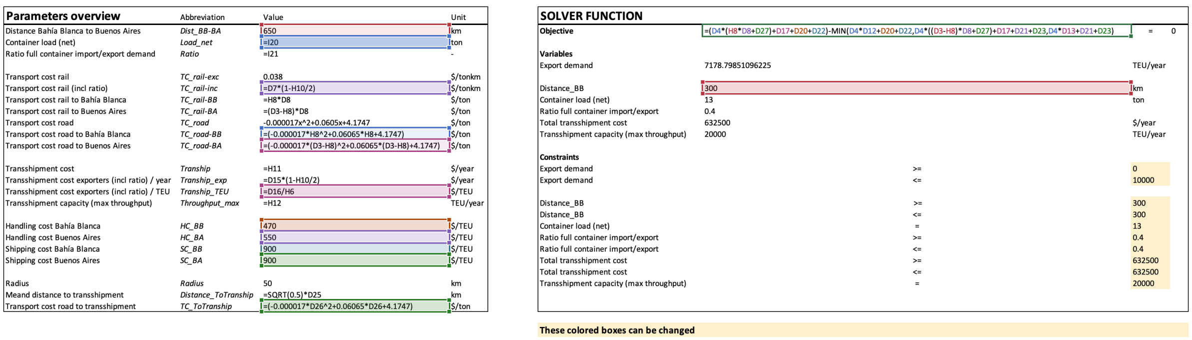
Parameters overview	Abbreviation	Value	Unit
Distance Bahía Blanca to Buenos Aires	*Dist_BB-BA*	650	km
Container load (net)	*Load_net*	13	ton
Ratio full container import/export demand	*Ratio*	0.4	-
Transport cost rail	*TC_rail-exc*	0.038	$/tonkm
Transport cost rail (incl ratio)	*TC_rail-inc*	0.0304	$/tonkm
Transport cost rail to Bahía Blanca	*TC_rail-BB*	9.12	$/ton
Transport cost rail to Buenos Aires	*TC_rail-BA*	10.64	$/ton
Transport cost road	*TC_road*	-0.000017x^2+0.0605x+4.1747	$/ton
Transport cost road to Bahía Blanca	*TC_road-BB*	20.84	$/ton
Transport cost road to Buenos Aires	*TC_road-BA*	23.32	$/ton
Transshipment cost	*Tranship*	632500.00	$/year
Transshipment cost exporters (incl ratio) / year	*Tranship_exp*	506000.00	$/year
Transshipment cost exporters (incl ratio) / TEU	*Tranship_TEU*	70.49	$/TEU
Transshipment capacity (max throughput)	*Throughput_max*	20000.00	TEU/year
Handling cost Bahía Blanca	*HC_BB*	470	$/TEU
Handling cost Buenos Aires	*HC_BA*	550	$/TEU
Shipping cost Bahía Blanca	*SC_BB*	900	$/TEU
Shipping cost Buenos Aires	*SC_BA*	900	$/TEU
Radius	*Radius*	50	km
Meand distance to transshipment	*Distance_ToTranship*	35.36	km
Transport cost road to transshipment	*TC_ToTranship*	6.30	$/ton

SOLVER FUNCTION			
Objective	0.00	=	0
Variables			
Export demand	7178.798511	TEU/year	
Distance_BB	300	km	
Container load (net)	13	ton	
Ratio full container import/export	0.4		
Total transshipment cost	632500	$/year	
Transshipment capacity (max throughput)	20000	TEU/year	
Constraints			
Export demand		>=	0
Export demand		<=	10000
Distance_BB		>=	300
Distance_BB		<=	300
Container load (net)		=	13
Ratio full container import/export		>=	0.4
Ratio full container import/export		<=	0.4
Total transshipment cost		>=	632500
Total transshipment cost		<=	632500
Transshipment capacity (max throughput)		=	20000

These colored boxes can be changed

SOLUTIONS	Value	Unit
Total costs Truck to BA	1753.16	$/TEU
Total costs TransTrain to BA	1740.68	$/TEU
Total costs Truck to BB	1640.92	$/TEU
Total costs TransTrain to BB	1640.92	$/TEU
Total export demand	**7179**	**TEU/year**
Total throughput	**14358**	**TEU/year**
Total import full containers	**2872**	**TEU/year**
Total import empty containers	**4308**	**TEU/year**

Figure H.1: Model solver function showing precedents of objective



Parameters overview	Abbreviation	Value	Unit
Distance Bahía Blanca to Buenos Aires	*Dist_BB-BA*	650	km
Container load (net)	*Load_net*	=I20	ton
Ratio full container import/export demand	*Ratio*	=I21	-
Transport cost rail	*TC_rail-exc*	0.038	$/tonkm
Transport cost rail (incl ratio)	*TC_rail-inc*	=D7*(1-H10/2)	$/tonkm
Transport cost rail to Bahía Blanca	*TC_rail-BB*	=H8*D8	$/ton
Transport cost rail to Buenos Aires	*TC_rail-BA*	=(D3-H8)*D8	$/ton
Transport cost road	*TC_road*	-0.000017x^2+0.0605x+4.1747	$/ton
Transport cost road to Bahía Blanca	*TC_road-BB*	=(-0.000017*H8^2+0.06065*H8+4.1747)	$/ton
Transport cost road to Buenos Aires	*TC_road-BA*	=(-0.000017*(D3-H8)^2+0.06065*(D3-H8)+4.1747)	$/ton
Transshipment cost	*Tranship*	=H11	$/year
Transshipment cost exporters (incl ratio) / year	*Tranship_exp*	=D15*(1-H10/2)	$/year
Transshipment cost exporters (incl ratio) / TEU	*Tranship_TEU*	=D16/H6	$/TEU
Transshipment capacity (max throughput)	*Throughput_max*	=H12	TEU/year
Handling cost Bahía Blanca	*HC_BB*	470	$/TEU
Handling cost Buenos Aires	*HC_BA*	550	$/TEU
Shipping cost Bahía Blanca	*SC_BB*	900	$/TEU
Shipping cost Buenos Aires	*SC_BA*	900	$/TEU
Radius	*Radius*	50	km
Meand distance to transshipment	*Distance_ToTranship*	=SQRT(0.5)*D25	km
Transport cost road to transshipment	*TC_ToTranship*	=(-0.000017*D26^2+0.06065*D26+4.1747)	$/ton

SOLVER FUNCTION				
Objective	=(D4*(H8*D8+D27)+D17+D20+D22)-MIN(D4*D12+D20+D22,D4*((D3-H8)*D8+D27)+D17+D21+D23,D4*D13+D21+D23)		=	0
Variables				
Export demand	7178.79851096225		TEU/year	
Distance_BB	300		km	
Container load (net)	13		ton	
Ratio full container import/export	0.4			
Total transshipment cost	632500		$/year	
Transshipment capacity (max throughput)	20000		TEU/year	
Constraints				
Export demand		>=	0	
Export demand		<=	10000	
Distance_BB		>=	300	
Distance_BB		<=	300	
Container load (net)		=	13	
Ratio full container import/export		>=	0.4	
Ratio full container import/export		<=	0.4	
Total transshipment cost		>=	632500	
Total transshipment cost		<=	632500	
Transshipment capacity (max throughput)		=	20000	

These colored boxes can be changed

Figure H.2: Model solver function showing formulas for parameters and objective

I

Sensitivity figures

Sensitivity analysis

A sensitivity analysis determines the influence of parameters on the outcome of the model and by that can help indicate which changes are promising or should be avoided or acted upon. In this appendix the parameters that are interesting to change are explained. The parameters are changed to analyse their sensitivity and thus realistic changes should be estimated. Below, the probability of these changes, including how they could change, are discussed. This will determine the range of the numbers used during the sensitivity analysis. In addition to using a lower and upper bound value, the sensitivity of a 5% increase and decrease of these parameters is put in the model as well. Each changed parameter will be separately put in the model while all other parameters keep their initial value. After this, all parameters that have a negative effect on the outcome of the model will be put in the model simultaneously. The same is done for the parameters that positively influence the outcome. The resulting outcomes of these sensitivity analyses will be presented in chapter 4.

Container load (net)

Changes in the container load can be changed with regard to the commodity which is transported. An average net load of 13 tons is used in the market study. When goods with a higher density are transported the container weight can increase. As the average load is determined by the commodities transported, a change in commodities can change the average. Both the transport costs for road and rail are calculated per ton but the costs of transshipping are calculated tariffs per TEU. This means that weight does not matter for transshipping. This results in a lower cost per ton for the good transported in a container, when they are heavier. The low and high value used to determine the sensitivity of the net container load are 10 ton and 16 ton, respectively.

Transport cost rail

The transport costs of rail can change due to ownership, investments and usage of the network. All of these rely on the economic setting present. Private ownership might handle with the aim of maximizing profits, while a governmental investment would be beneficial for its citizens in the form of sufficient supply of transport. In times of economic stability, the government could be more eager to invest in a rail network. The current costs are $0.038 per ton kilometer.

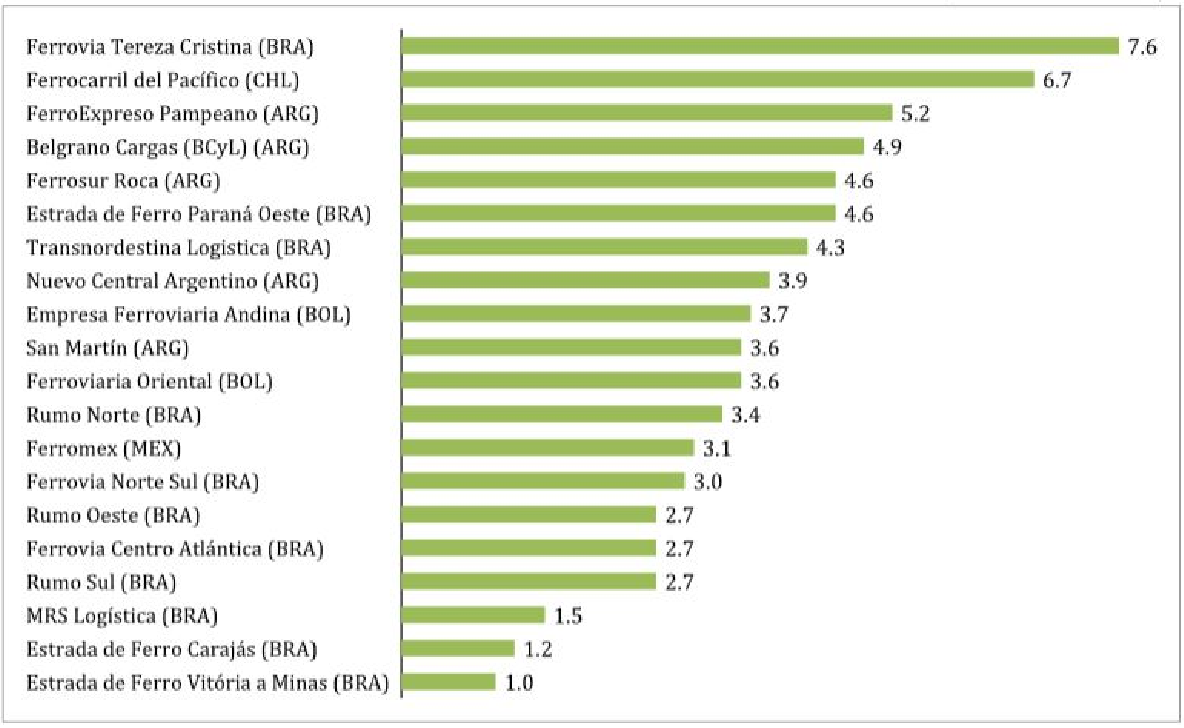


Figure I.1: Cargo tariffs in Latin America in 2016, in dollar cents per ton per km [7]

In a study by Jorge Kohon [7], the cost of transporting cargo in Latin America is investigated. From this study it can be concluded that the rail costs can be highly differential in different areas and situations. The initial model uses a 3.8 for the transport costs. Figure I.1 shows a high rail cost of 7.6 dollar cents, and a low cost of 1.0 dollar cents. Both of these rail operators are located in Brasil. For the sensitivity analysis a 50% increase would lead to \$0.057 per ton per kilometer, which is realistic looking at similar transporters. A more positive value of 50% decrease, would be \$0.019 per ton per kilometer.

Transport cost road

The current costs of trucking are measured per ton per km. The total costs are determined using a non-linear function, which is as mentioned in the previous chapter, where x is the distance in kilometers to the destination and the outcome is in \$ per ton: $-0.000017x^2 + 0.061x + 4.17$. To determine the impact of the cost of road transport, a decrease and increase of 20% is used. The total costs rely on the economic situation, the trucking unions and the oil price. Economic instability can lead to an unhealthy use of the trucks, as this might lead to an unbalanced demand for train and truck cargo transport. The truckers in Argentina are supported by trucking unions. They are influential in politics. Similar to other transport modes is the relation with the oil price. Increasing oil prices quickly lead to higher fuel prices and total transport costs. Governance in fuel usage of a country can influence this. Emissions are becoming a more important subject, which might affect the road transport costs.

Yearly cost transshipment terminal

It is also interesting to investigate what effects lower costs for transshipping (e.g. from truck to rail) have on the flow of needed container demand. A change in transshipment costs can be obtained by changes in the investment and operational costs of the rail terminal. To investigate the effect of the yearly costs to earn back the transshipment terminal a lower and a higher value is taken in the sensitivity analysis. The lower bound of the yearly costs is US \$632.5 thousand. This results in values of US \$585 thousand and US \$680 thousand for the sensitivity analysis.

Import and export Ratio

The ratio of import and export is expected to influence the model significantly. The ratio in the initial case is 0.4, which is the ratio of import containers divided by exported containers. This is highly unbalanced and in a perfect scenario would be 1. In order to test the sensitivity of this parameter, a reduction to 0.25 is used. A positive scenario will show a ratio of 0.55. This would mean a smaller number of transported empty containers.

Important for this ratio is the number of inhabitants in the region. The ratio is expected to decrease if there are less inhabitants in the area where the transshipment center is located. If the transshipment center is located near Buenos Aires, the ratio would increase.

When looking at innovative ideas to improve the ratio, the inclusion of spot demand can improve the ratio. At the moment there are 40 containers imported for every 100 which are exported. This means 60 empty containers are to be imported. This repositioning is not wanted for any party. Empty container movement is not only an issue in Argentina, and it has been studied before.

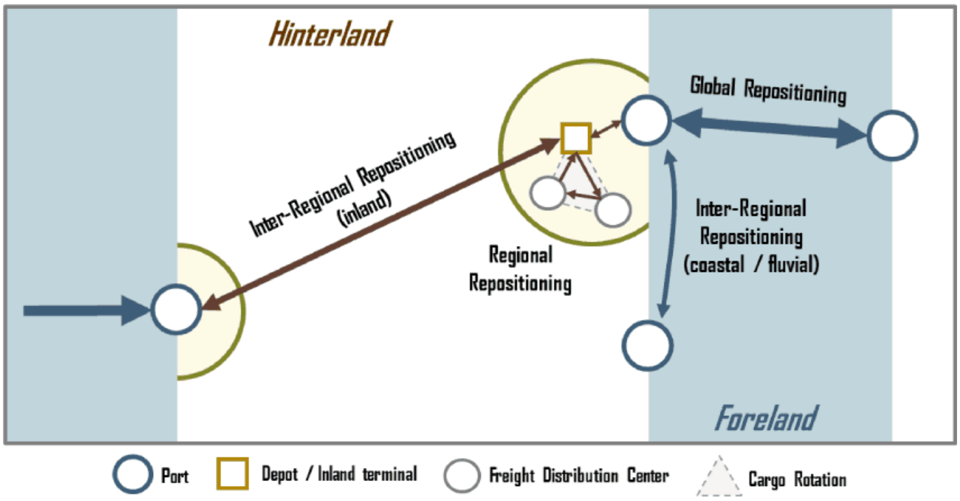


Figure I.2: Empty container re-positioning [12]

When looking at figure I.2, it becomes clear that this empty container flow does not only impact the transshipment center. For the situation in Buenos Aires, there is a need for more importing containers in the region where the transshipment center is located. When positioning the transshipment center, it should be clear what the expected demand for container import is, in order to create a healthy import/export ratio. What could help when developing the area is including companies which import containers. A lot of goods can be transported using containers and the more populated the city the more containers are to be imported. This would likely consist largely of retail, conglomerate and electronics. All are attracted by larger cities and determined by the population.

Radius

The radius parameter determines the area of industries that makes use of the transshipment center and transport their containers to it by truck. Enlarging the radius leads to a larger area from which more demand can be acquired. Additionally, a larger area produces more demand. To visualize the area which is described, figure I.3 shows the area which can be reached with a 50 km radius.

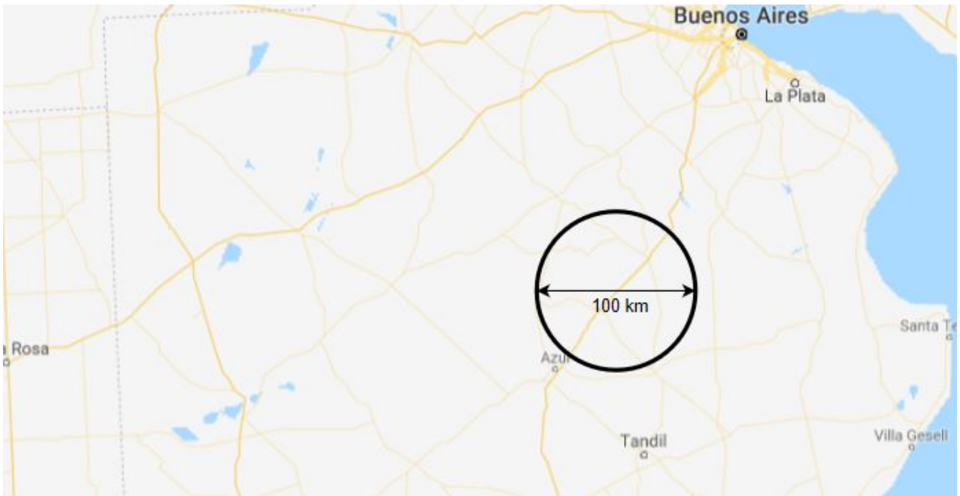


Figure I.3: Radius

On the negative side, a larger area would lead to a larger average distance to be covered by truck to the transshipment center. Thus increasing the average costs of using this modality choice. In order to analyse the sensitivity, a value of 70 km and 30 km is used. A smaller radius would be possible if a container demand producer increases its demand. It is interesting to look at these areas as the complexity of a larger area plays a role too, due to the fact that a larger area is not linear with the produced demand.

Port costs

In the model the shipping and handling costs do not influence the demand needed to make a transshipment center feasible. However, they do affect to which port containers will be transported and at which location the transshipment center should be built. For these reasons, the sensitivity of the port costs regarding with respect to the distance of the transshipment center from Bahia Blanca is investigated. The demand is set to a fixed value of 5,000 TEU or 10,000 TEU. The difference in total port costs which consists of the shipping and the handling costs, is the variable that determines how far the transshipment terminal could be realized. For that reason, it is necessary to understand that a change in handling cost in one port has the same effect as a similar change in shipping costs in the same port. Additionally, a change in handling or shipping cost in one port has the same effect as an opposite change in handling or shipping cost in the other port. Below several scenarios are described in which the shipping or handling costs in both ports can change.

Handling cost Bahia Blanca

Container handling costs make up a substantial part of the total costs in freight transportation. For that reason, it is interesting to investigate what effect an increase or decrease in handling costs has on the results of the model. Handling costs in Bahia Blanca could decrease once the new terminal is operative. The reason for this is that in the new terminal operations will be more optimal and efficient due to new technologies, more (continuous) container demand and economies of scale. Furthermore, the handling costs depend on the state of the Argentine economy. More inflation will lead to a further increase in prices while deflation triggers the opposite. Additionally, the type of containers affects the handling costs. For example, a reefer needs to be plugged into an electricity source and needs to be monitored more frequently than a regular container. This will lead to higher prices.

Shipping cost Bahia Blanca

A bigger terminal in Bahia Blanca will not only lead to lower costs regarding container handling in the terminal. It is expected that vessels will call at Bahia Blanca more frequently. Moreover, these vessels will be bigger than current vessels calling at Bahia Blanca. These economies of scale can lead to a decrease in shipping costs. Other factors that are important regarding shipping costs are the commodity, the load of the cargo and the state of the economy, including fuel prices.

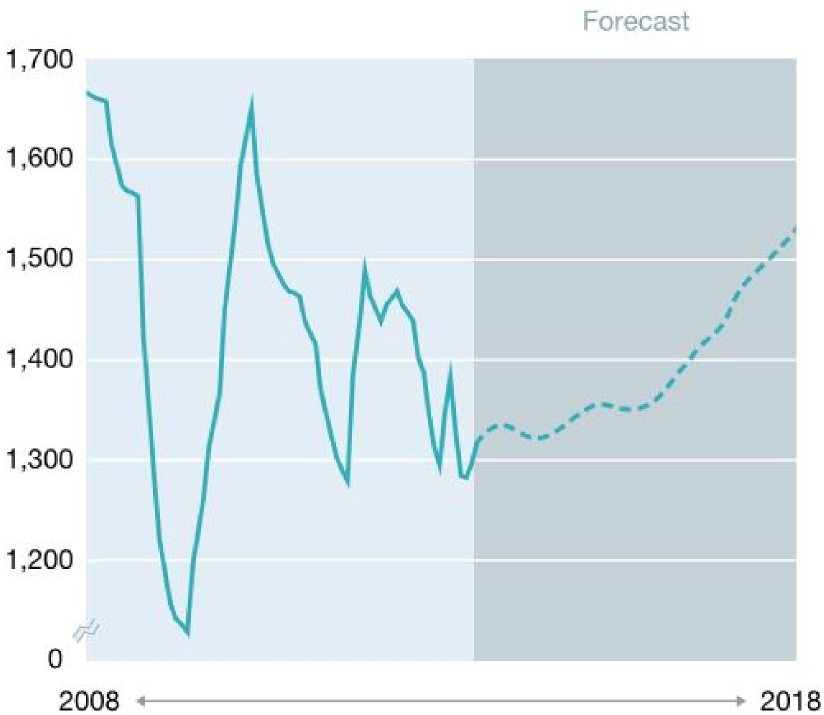


Figure I.4: Ocean freight rates in US$ per TEU [4]

As can be seen in figure I.4, the costs of shipping a container can change a lot throughout the years. This shows the global average costs, which are assumed to be similar to the costs in South America.

Handling cost Buenos Aires

Compared to Bahia Blanca the situation in Buenos Aires is different. There are multiple terminal operators in the port of Buenos Aires. This means more competition which naturally leads to lower prices. However, it is important to note that the concessions for the terminal operators in the port of Buenos Aires end in 2020.

Several scenarios are conceivable when the concession ends. One is that there is no new operator for a certain period of time. Another scenario is that the three terminals make room for one terminal operated by only one operator, resulting in a less competitive market. Lastly there might be a chance that the ending concession in Buenos Aires triggers one of the current terminal operators to find another port for their activities, for instance Bahía Blanca. These hypothetical scenarios will have different effects on the handling costs in Buenos Aires. Another factor that influences the handling costs in Buenos Aires is that there is little space left to expand the area to be used for container handling. This means that a further decrease of handling costs due to economies of scale is less likely.

Shipping cost Buenos Aires

Compared to the port of Bahía Blanca, the port of Buenos Aires has some limitations regarding vessel calls. The channel that enables access to the port is not wide enough for two vessels to pass each other which results in waiting times to enter this channel and a limitation of the frequency of vessels calling at the port of Buenos Aires (A. Zuidwijk & N. Boot, interview, September 19, 2019). The limited frequency and the waiting time in combination with the limited vessel size in the port of Buenos Aires makes it unlikely that the shipping prices at the port of Buenos Aires can lower significantly.