Container terminal development for the Port of Bahía Blanca

A research on the future container throughput in the Port of Bahía Blanca and the adaptation to the container terminal to these developments

Researchers:

Anniek Munters

Bas Stam

Thijs van der Wel

Robbin Wesstein

Supervisors:

Prof. T. Vellinga

Dr. B. W. Wiegmans

THIS PAGE WAS INTENTIONALLY LEFT BLANK

Sponsors and partners

THIS PAGE WAS INTENTIONALLY LEFT BLANK

Preface

This report contains the research on the future container throughput in the Port of Bahía Blanca and the adaptation of the container terminal to these developments. This research is performed as multidisciplinary project as part of the master Civil Engineering at the Delft University of Technology by Anniek Munters, Bas Stam, Thijs van der Wel and Robbin Wesstein. It was a great opportunity to contribute to the master planning of the Port of Bahía Blanca and to work in a unique environment in the capital of Argentina, Buenos Aires.

First, we want to thank everybody within Besna. They made it possible to execute this multidisciplinary project in Argentina. Besna arranged a place to work in their office and the colleagues made us feel part of the team. Special thanks to Pablo Arecco for all his support from the start to the end of the project. We contacted Pablo as he is an alumnus of our University, and from the first day he was willing to help us setting up the project. Pablo, your help and comments have been very valuable for the project. Additionally, we would like to thank you for making us feel at home in Buenos Aires city.

Secondly, we want to thank the many professionals who provided input during the project, and answering our questions related to the research. Your contributions to this research were very valuable and highly appreciated. Special thanks to Rául Escalante, Sebastián Garcia, Ricardo Schwarz, Pedja Zivojnovic and Niek Boot for the useful discussions.

Thirdly, we want to express our appreciation to the Consorcio de Gestión del Puerto de Bahía Blanca (CGPBB), which manages and operates the Port of Bahía Blanca. We have had such positive experiences with all employees recognizing the drive to grow in all of you. Special thanks to Natalia Urizza for perfectly arranging all our trips to Bahía Blanca.

Furthermore, we owe our thanks to the Dutch engineering company Arcadis for sponsoring part of our expenses during the trip.

Finally, our gratitude goes to our project supervisors of the Delft University of Technology, Tiedo Vellinga and Bart Wiegmans. Thank you Tiedo and Bart, for your inspiring lectures about ports, helping to define our project and bringing clarity during the project.

We are thankful for this opportunity to work in Argentina for two months.

Master students Civil Engineering – Delft University of Technology

Anniek Munters	*Transport Engineering*
Bas Stam	*Transport Engineering*
Thijs van der Wel	*Hydraulic Engineering*
Robbin Wesstein	*Hydraulic Engineering*

THIS PAGE WAS INTENTIONALLY LEFT BLANK

Summary

Bahía Blanca in Buenos Aires province is located 600 kilometres south of Buenos Aires city. The port complex of Bahía Blanca has the second largest throughput in Argentina considering tons, mainly attributed to the agro, - and the petrochemical industry. The port handles containers as well, however with an average of 30 thousand TEU/year this throughput is rather small.

The authority of the Port of Bahía Blanca sees opportunities to increase container throughput in the port due to recent developments in the region. In 2011, the shale gas basin Vaca Muerta was discovered which is located close to Bahía Blanca. It is assumed that the recent investments in the region will lead to an increase in the recovery of gas. The petrochemical companies located in the Port of Bahía Blanca will in turn increase their production of, among others, PVC, polyethene, and polypropylene. Due to the increase of container throughput, the costs per container is expected to decrease. It is therefore likely that more regional cargo will be attracted to the port. For example, fruits that are produced close to Bahía Blanca are currently exported to Brazil by truck because of the financial benefits of this option. The container throughput is estimated for 2040, considering the petrochemical cluster and fruits. Four different trends show a container throughput of respectively 30, 155, 250 and 360 thousand TEU/year.

The capacity of the container terminal is estimated at 50 thousand TEU/year, based on the equipment, the dwell time and the terminal area. The terminal should improve when throughput will increase. In three of the four proposed scenarios throughput exceeds 50 thousand TEU already in, or before 2023.

There are different possibilities to increase the capacity of the terminal. To start, number of calls and call size are assumed based on future throughput, decreasing the average dwell time for export containers from 8 days to 5 days in the final scenario. Additionally, a larger quantity and more advanced equipment is required to handle the increase in throughput. For example, adding a STS gantry crane to the current crane at the quay will increase the number of movements per hour from 10 to 30. In the final situation three STS gantry cranes handle the containers increasing movements per hour to 60 and capacity of the terminal to 200 thousand TEU/year. Lastly, the terminal area itself can be increased significantly from 8ha to 22ha in its maximum configuration. The increase in storage area allows the capacity to grow from 50 thousand TEU/year to 215 thousand TEU/year. Even though the land reclamation of some locations is rather simple and inexpensive, the largest expansions are costly and will have a negative impact on the social image of the port. The final capacity of the terminal is limited by the capacity of the berth being approximately 200 thousand TEU/year. Possible bottlenecks should be considered when increasing capacity of the terminal. They basically consist of the equipment at the terminal area itself and customs.

It is important to realize that further expansion of the terminal is not possible. The area around the terminal is restricted, increase of berths is not possible and the infrastructure going to and from the port is not suitable for larger container volumes. Because of these limitations in capacity, the possibility of constructing a new container terminal was considered as well. A multi criteria analysis in combination with a financial analysis on the possible location showed that two out of four possibilities are suitable for the development of a new container terminal. The suitable locations are located west and east of the current terminal.

The new container terminal should have the capacity to handle the expected container throughput generated locally. The possibility to attract additional cargo to the port was researched as well. The draught limitations in the Port of Buenos Aires could cause problems when the total container throughput of Argentina would increase significantly. As Bahía Blanca does not face these limitations its cost competitiveness is analysed. When comparing the cost for calling a vessel in Buenos Aires and in Bahía Blanca the differences seem rather small. Additionally, the current shipping lines were analysed which also indicate that the draught limitation in Buenos Aires will not cause problems.

To conclude, when container throughput in the region will increase, the capacity of the container terminal is required to increase as well. With the right adaptations and improvements, the terminal can increase significantly in capacity.

List of Symbols and Abbreviations

CBA	Cost Benefit Analysis
CGPBB	Consorcio de Gestión del Puerto de Bahía Blanca
DWT	Deadweight Tonnage
FEU	Forty Foot Equivalent Unit
GDP	Gross Domestic Product
GRT	Gross Register Tonnage
ISPS	International Ship and Port Facility Security
MCA	Multicriteria Analysis
MLWS	Mean Low Water Springs
MSL	Mean Sea Level
NRT	Net Register Tonnage
PoBA	Port of Buenos Aires
PoBB	Port of Bahía Blanca
PoSAE	Port of San Antonio Este
RMG	Rail Mounted Gantry
RTG	Rubber Tyred Gantry
SC	Straddle Carrier
SENASA	Servicio Nacional de Sandidad y Calidad Agroalimentaria
STS	Ship to Shore
TEU	Twenty Foot Equivalent Unit
YPF	Yacimientos Petrolíferos Fiscales

THIS PAGE WAS INTENTIONALLY LEFT BLANK

Table of Contents

1 Introduction

Due to globalization and a growing world economy, worldwide container throughput has been increasing steadily in the past. This led to increased efficiency in container handling and cost savings due to economies of scale, which in turn contributed to the overall growth of container throughput as well. In 2009, a decrease in global throughput was observed when the world was recovering from the economic crisis in 2008. This negative growth is exceptional in the normally growing trend. In Figure 1.1 the container throughput of the world (top) is compared to the worldwide Gross Domestic Product (GDP), as indicator of economic development (bottom). Economic development is commonly used as indicator for future estimations of container throughput. In Figure 1.1 indeed a similar trend between the two is observed. In addition to the increase in throughput, container vessels increased in size as well (Table 1.1). In 13 years, the capacity of the largest vessels has doubled. Ports are adapting to handle the increase in throughput and the larger vessels. Container throughput is expected to keep growing in the future, making it an interesting industry for ports (Schäfer, 2014).

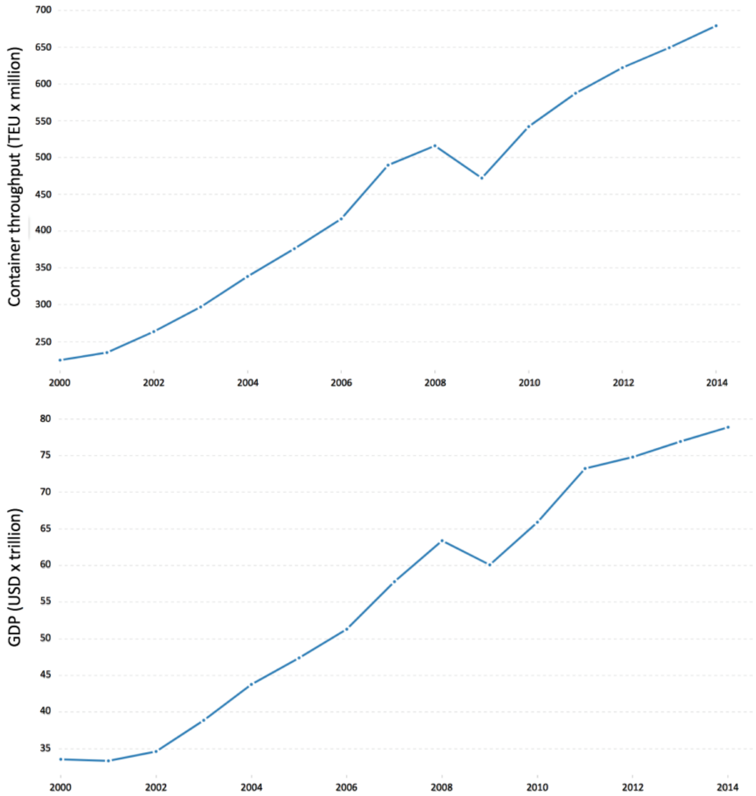


Figure 1.1 – Worldwide container throughput (top) and GDP (bottom) 2000-2014 (The World Bank Group, 2017b) (The World Bank Group, 2017a)

Table 1.1 - Largest container vessels over time (Container transportation, 2014)

Year	Owner	Capacity [TEU]
2006	Emma Maersk	11,000
2012	CMA CGM Marco Polo	16,000
2017	OOCL Hong Kong	21,413
2019	CMA CGM	22,000

When zooming into the container throughput of Argentina, it seems that the country did not recover from the crisis in 2008 as well as the global container throughput did (Figure 1.2, top). In contrast, the container throughput in Argentina showed peaks and falls since 2008. In 2016, the national throughput was 1.59 million Twenty Foot Equivalent Unit (TEU) which was the lowest throughput for over more than 10 years (TheStatisticsPortal, 2017). The stagnant growth can be explained by a similar trend of GDP in Argentina (Figure 1.2, bottom). Due to expected GDP growth in the country, container throughput is expected to grow in the coming years (International Monetary Fund, 2017).

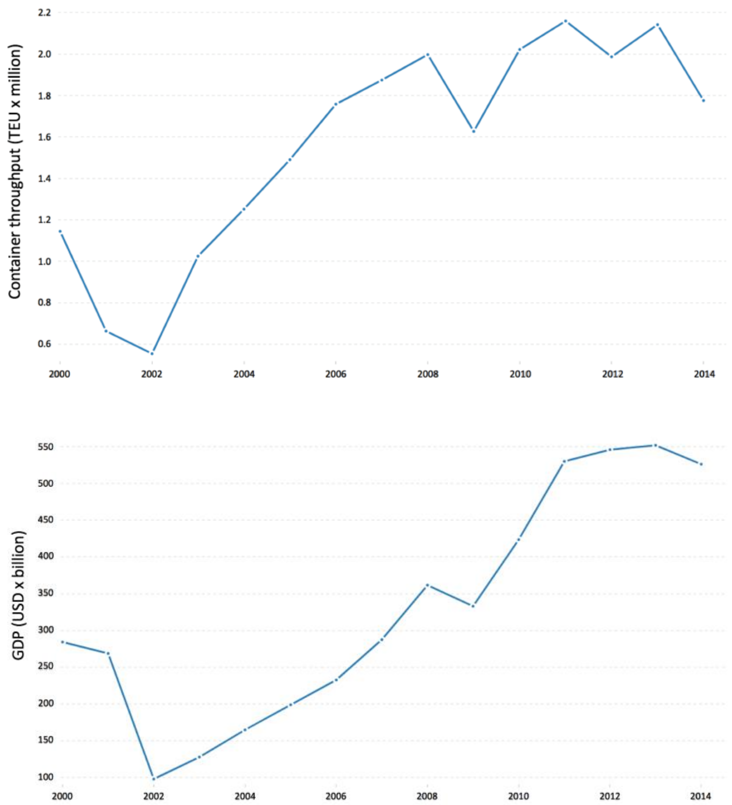
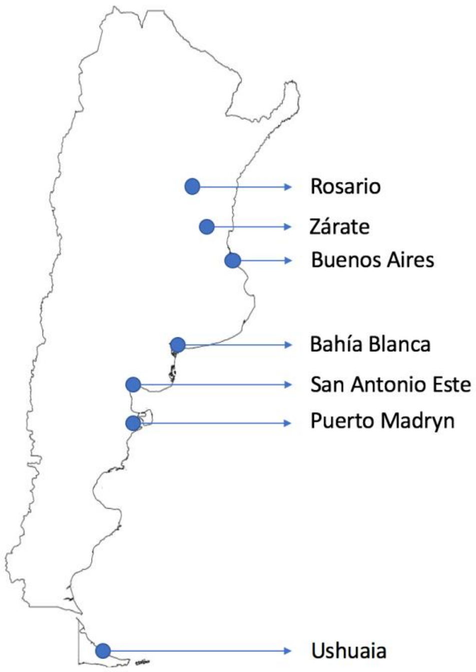


Figure 1.2 – Container throughput (top) and GDP (bottom) of Argentina 2000-2014 (The World Bank Group, 2017b) (The World Bank Group, 2017a)

The Argentine ports are located along the East coast of South America and the Paraná river (Figure 1.3). The ports located around Buenos Aires city handle significantly the largest share of container throughput, over 80% of the total container throughput of Argentina. The main consumption area of Argentina is in the region of Buenos Aires city, for which the location of the terminals is convenient. In contrast, parts of the production areas are located further into the hinterland. In these cases, the containers are first transported to Buenos Aires, most commonly via road. In addition to the ports location in Buenos Aires city, the Port of Zárate also handles a significant share of the total container throughput (Figure 1.3).



Port	Throughput [x1,000 TEU]	Percentage
Port of Buenos Aires	998	59.6%
Dock Sud (Buenos Aires)	403	24.1%
Zárate	129	7.7%
Ushuaia	64	3.8%
Bahía Blanca	31	1.8%
Rosario	27	1.6%
Puerto Madryn	24	1.4%
Total	**1676**	**100%**

Figure 1.3 - Locations of the ports that handle containers (left) and right the percentage of total container throughput per port in 2014 (CEPAL, 2015)

The Port of Bahía Blanca is an important port considering bulk transport in Argentina. However, as can be seen in Figure 1.3, the container throughput is relatively low in the port. Comparative to the general trend of Argentina, the container throughput in Bahía Blanca does not show a specific positive or negative trend going in the last few years (Arecco, Besson, van Drunen, & Sendra, 2017). Recent developments in the region of Bahía Blanca give reason to assume that container throughput in the port will increase. In addition, expected GDP growth in Argentina and Brazil possibly leads to an increase in local container throughput as well.

To handle the expected growth in container throughput, the capacity of the current container terminal should increase. It is a challenge for the Port Authority of Bahía Blanca to adapt to expected growth in container throughput and realize the capacity at the terminal.

1.1 Problem definition

The main driver of expected increase in container throughput is the exploitation of Vaca Muerta, a shale gas and shale oil basin close to Neuquén city. The basin is of interest for the Port of Bahía Blanca because of its advantageous geographical location, especially compared to the ports located around Buenos Aires city (Figure 1.4). Therefore, production originated from the Neuquén region is likely to be exported via the Port of Bahía Blanca. Vaca Muerta has a total surface area of 3ha and the total shale gas basin is estimated at 3 million m^3 gas (Arecco, Besson, van Drunen, & Sendra, 2017). The first shale gas well was completed in July 2010 by Yacimientos Petrolíferos Fiscales (YPF). Since 2013, projects are exploiting the shale gas by the method of hydraulic fracturing (fracking). Because of the drop in oil prices, developments in the area have been rather slow in the beginning. However, since 2014 oil prices have been raising and investments in the region increased. The gas winning itself will not cause an increase in container throughput. However, as some of the product is processed into containerized solid products before being exported, the container throughput is expected to increase due to the exploitation of the basin.

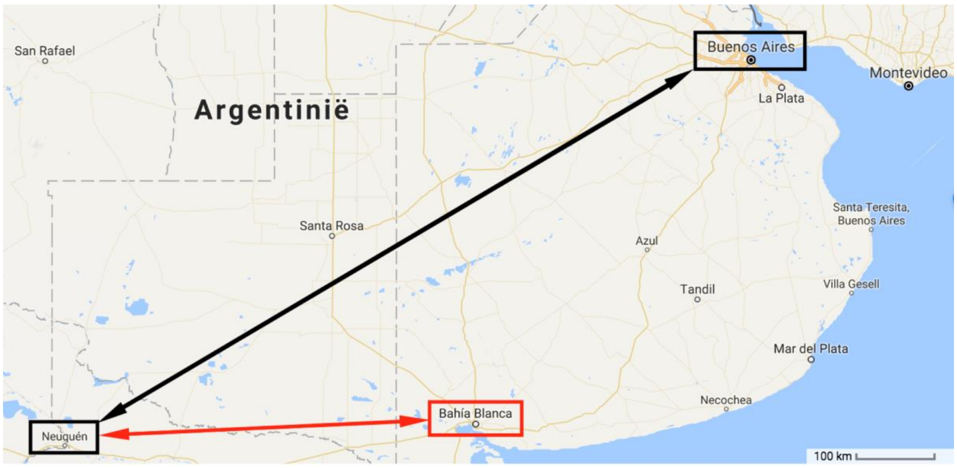


Figure 1.4 – Distance between Bahía Blanca and Neuquén relative to the distance between Buenos Aires and Neuquén (Adapted from Google, 2017).

As the Port of Bahía Blanca has naturally a large draft, it has the potential of handling large container vessels. Currently, the cost of container transport via the Port of Bahía Blanca is relatively high. This is mainly due to high sea rates charged by shipping lines caused by the low throughput. Especially compared to the ports located in the region of Buenos Aires city the rates are significantly more (Bosso, 2017a). When container throughput in the port would increase due to growth in local demand, prices per container are expected to decrease. The competitiveness of the Port of Bahía Blanca would benefit from this development. In theory, the port could attract more cargo due to an economically advantageous position considering other ports in Argentina. For terminal planning and design this possible development should be taken into consideration.

The container terminal can currently handle the throughput without facing serious problems. However, when container volumes increase significantly, adaptations and improvements to the terminal are required. The capacity of the terminal can be improved by upgrading the equipment, increasing efficiency by lowering dwell time and increasing the terminal area. The improvements will increase the capacity of the terminal, however, due to characteristics of the terminal, it is restricted in its expansion. Therefore, alternatives to the current terminal should be considered as well.

First, the port layout and its infrastructure are highlighted to understand the expansion limitations of the current container terminal and identify possible locations for a new terminal. Secondly, the research description and methodology are explained. After which the research questions will be answered subsequently. Finally, the research is concluded by answering the research question and providing recommendations for next steps.

1.2 Background; port analysis

The port complex of Bahía Blanca is located along the southern Atlantic coast in the south of the Province of Buenos Aires. The access channel to the port complex has a length of 97km and a minimum depth of 12.8m with respect to the Mean Low Water Springs (MLWS) (Arecco, Besson, van Drunen, & Sendra, 2017). The port complex of Bahía Blanca can be categorized into four different ports, spread over a coastline of 25km (Figure 1.5). Puerto Cuatreros is in the West of the complex at the end of the sea inlet. Puerto Belgrano, the most important Navy base in Argentina, and Puerto Rosales are in the East of the port complex in the city of Punta Alta. The Port of Bahía Blanca is in the middle of the complex.

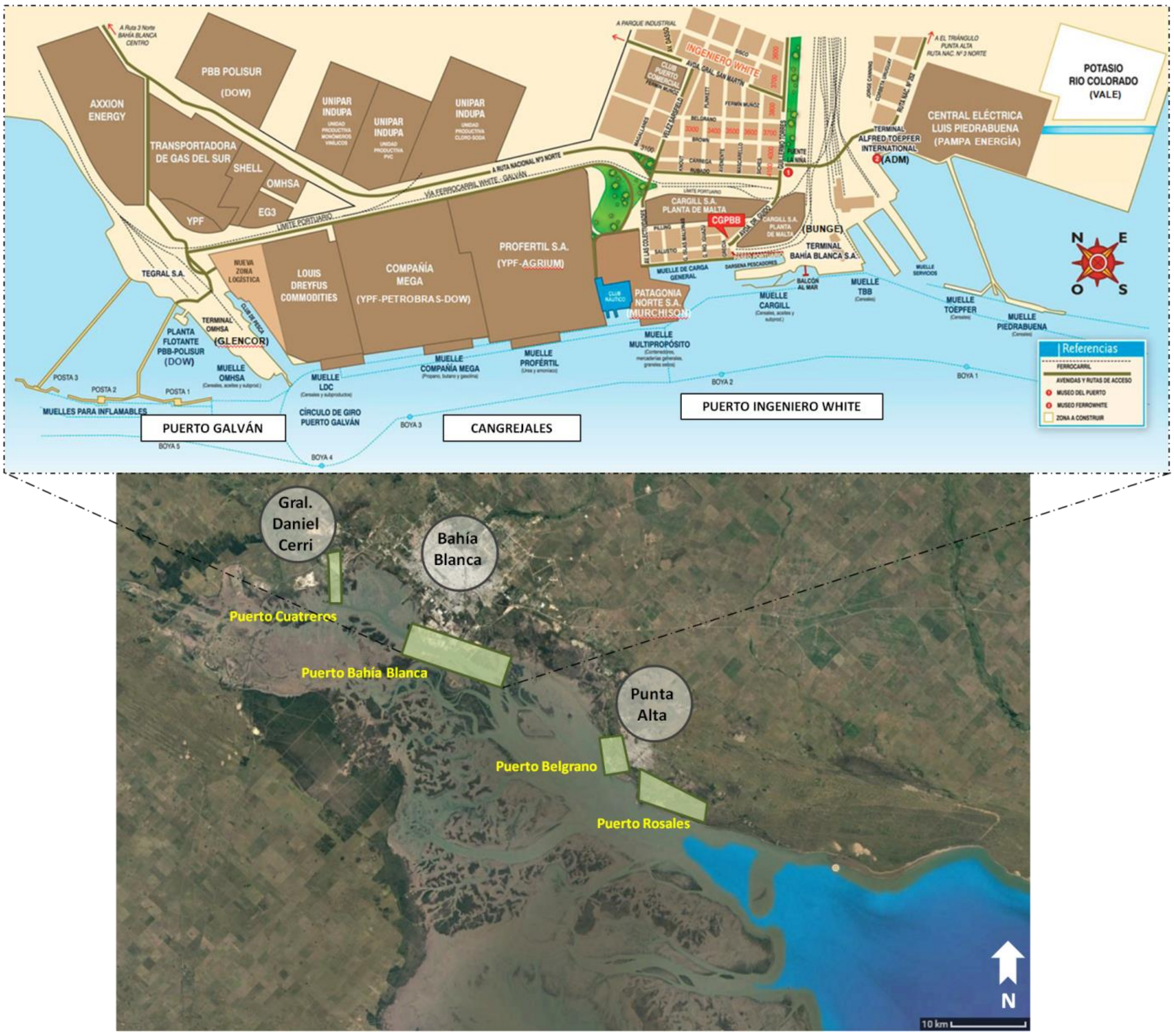


Figure 1.5 – Location and overview of the Port of Bahía Blanca (Adapted from Google, 2017) (CGPBB, 2017f)

The total throughput of the port complex was 27 million tons in 2016, making it the second biggest port complex of Argentina (CGPBB, 2017g). This amount can be attributed to two different ports; 60% to the Port of Bahía Blanca and 40% to Puerto Rosales, leaving Puerto Belgrano for military purposes and Puerto Cuatreros unused. In the remaining of this study, only the Port of Bahía Blanca is considered since the container terminal is located here. Since 1993, the Port of Bahía Blanca is managed and operated by the Consorcio de Gestión del Puerto de Bahía Blanca (CGPBB). In 2017 the CGPBB had a total of 64 employees working. The consortium is a non-state public entity, which made the Port of Bahía Blanca the first autonomous port of Argentina. The financing of the port originates of funds from its own management and not from the public state, shortening the duration of decisions and improving the efficiency.

A total of 13 terminals are located in the Port of Bahía Blanca. The existing terminals are rather diversified, ranging from ex- and importing cereals, to petrochemicals products, containers and the handling of general cargo. As can be seen in Figure 1.6, the agro- and petrochemical industry are responsible for most of the throughput of the port, while the transportation via containers currently has a negligible share in the total throughput. A more detailed analysis of the different terminals in the Port of Bahía Blanca and a description of the current state of the infrastructure can be found in Appendix A.

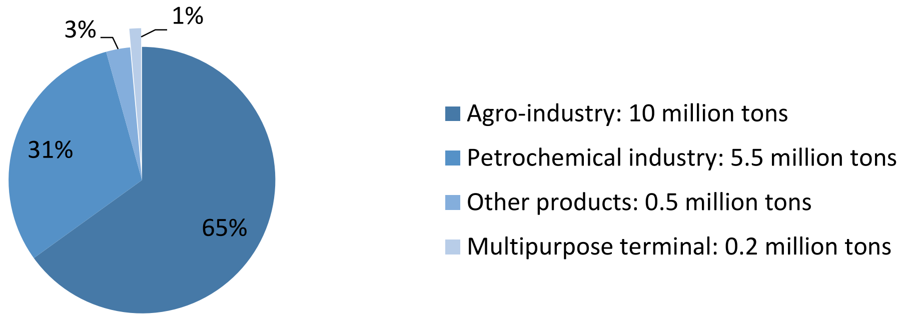


Figure 1.6 – Total throughput of the Port of Bahía Blanca in 2016. Three categories are distinguished, additionally the container terminal is highlighted (CGPBB, 2013/14)

1.3 Research description and methodology

To start, by means of interviews with companies around the Port of Bahía Blanca and with the members of the CGPBB, an estimation of the future container throughput is made. In addition, the input from meetings with container terminal operators and shipping lines in Buenos Aires are used to include local, regional and national (cargo/economic) trends in the estimations. Secondly, analysis on the current efficiency of the container terminal is executed. Additionally, different options for capacity improvements are researched and elaborated on in the report. By comparing the different trends of container throughput to the capacity of the container terminal, the CGPBB can be advised on the possible construction of a new container terminal. Thirdly, the most suitable location for a new container terminal is determined using the input of multiple experts on the topic, such as members of the CGPBB. Next, the competitiveness of the Port of Bahía Blanca compared to the Port of Buenos Aires is assessed by using existing data on calling costs of both ports. Lastly, conclusions and recommendations are drawn to finalize the research.

1.3.1 Research questions

The following research question is formulated to address the problem that is outlined in section 1.1.

How can the Port Authority of Bahía Blanca adapt to the future developments in container throughput?

The main research question is divided into four sub questions. By addressing those, the research question is logically answered.

SQ1: What is the expected increase in container throughput due to import and export until 2040?

- Which factors are expected to influence the container throughput in the future?
- How much do each of these factors contribute to the increase in container throughput and when will this occur?

SQ2: What is the potential capacity of the current container terminal?

- What is the capacity of the current container terminal?
- How can the capacity of the current container terminal be improved?

SQ3: Which location is most suitable for a potential new container terminal, when considering the costs in addition to the already executed MCA?

SQ4: How can the Port of Bahía Blanca be competitive with the current ports operating?

- Which cost factors are expected to influence the competitiveness of the Port of Bahía Blanca?
- What are the port calling costs for the Port of Bahía Blanca compared to the Port of Buenos Aires?

1.3.2 Structure and index

The report is organized as in Figure 1.7. SQ1 is required input for SQ2, as SQ2 is input for SQ3. All sub questions are input to answer the research question.

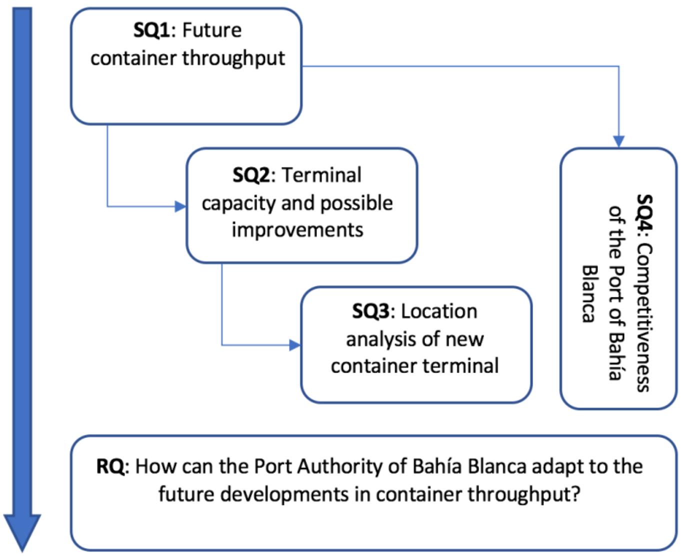


Figure 1.7 – Structure of the report (own work)

2 Future container throughput at the Port of Bahía Blanca

In this chapter, four future scenarios for container throughput are estimated. By providing these possible trends, SQ1 will be fully answered.

2.1 Methods for estimating future container throughput

Expected future container throughput is essential input data for terminal planning. Most commonly estimations of throughput are based on GDP growth of the country of interest, or of the world in general. Indeed, when container throughput of the terminal includes the most important products and no specific developments are expected, this method is rather suitable. In addition, it is simple to execute. In contrast, when the container throughput depends on several specific products or developments, using GDP forecasting will most likely predict a wrong trend. Several additional research methods exist to forecast future demand. Examples of methods are, among others: expert opinions, multiple scenarios, demand/hazard forecasting, comparative analysis, and back casting. For the Port of Bahía Blanca, using only expected GDP growth is not suitable due to the characteristics of the future throughput; including specific segments and planned investments. Therefore, expert opinions are used to forecast container throughput as well.

Two main notes are of importance when considering the analysis of the estimated final container throughput. First, only cargo segments that are well defined are included in the predictions. However, local cargo is expected to be attracted and transported via the port, as prices will become more competitive when throughput increases. Furthermore, predictions until 2040 are done for future throughput as it is beneficial for terminal planning. However, as the development are relatively abrupt predictions can be unreliable.

2.2 Petrochemical cluster: Vaca Muerta & YPF

YPF plays a significant role in the exploitation of Vaca Muerta, holding a concession of more than 1.2ha, almost half of the total area. Therefore, their estimations on future production is expected to be accurate for the increase in container throughput in the Port of Bahía Blanca.

Three segments are indicated that could influence container throughput in the Port of Bahía Blanca. To start, special sand for the process of retrieving the gas is currently imported via Buenos Aires. In the future, the import will be via the Port of Bahía Blanca (Marchionni, 2017). However, the transport will shift from containers to bulk when the quality of the rail connection between the basin and Bahía Blanca will improve. As this railway line is already under development, the potential throughput of this segment is not taken into consideration here. More information about the size of the import and general information on YPF can be found in Appendix B.

In addition, container throughput might increase due to the import of partial equipment. This depends on the need for maintenance of the machines that are used for, among others, fracking. As the site (and thus equipment) is rather new, this transport is currently not relevant and estimations for the future are difficult to make. As for the sand, importing via the Port of Bahía Blanca will be more convenient compared to transporting via the ports located in Buenos Aires city.

Lastly, export is expected to increase due to the exploration of Vaca Muerta. For example, companies as Dow Argentina and Unipar Indupa can increase their production due to the increase in supply of gas**.** More companies are expected to increase production due to the developments in

Vaca Muerta. As the product is not exported in gaseous form, but processed into solid products first, the container throughput is expected to increase due to the expansion. For the design of the container terminal, the expected export due to the exploitation of the basin is the most important one to consider. An overview of the discussed factors is shown in Figure 2.1.

To conclude, YPF itself will not be responsible for increased container throughput. However, it has an adequate overview of other companies increasing production due to the increase of recovery of shale gas. The companies of interested are listed in the following section.

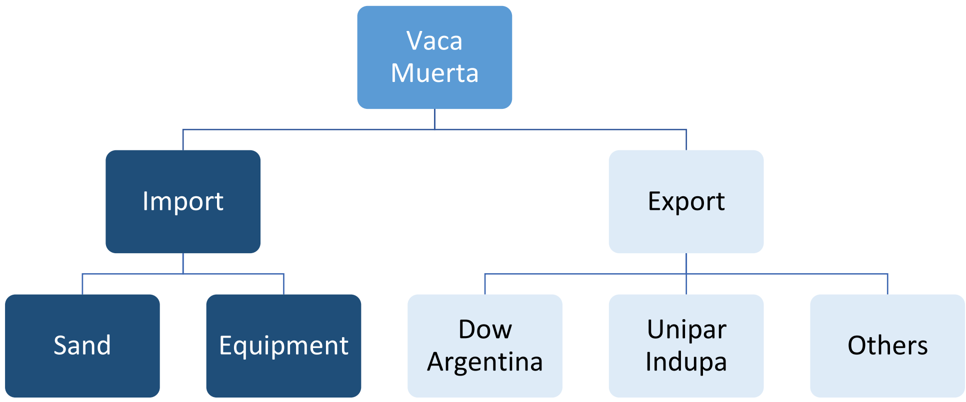


Figure 2.1 – Factors that influence future container throughput in the Port of Bahía Blanca due to the development of Vaca Muerta (own work)

Dow Argentina

Dow Argentina in Bahía Blanca has a production capacity of 660,000 tons polyethene per year. In 2016, Dow Argentina produced 603,000 tons polyethene (CGPBB, 2017). The polyethene is transported in Forty Foot Equivalent Unit (FEU) units with a load of 27 tons per container. An increase of polyethene production of 1-2% is planned in 2018. In the same year, Dow Chemicals is planning to invest in one of their three production locations worldwide. For Dow Argentina, this would imply a possible duplication of the current production of polyethene. In addition to this potential increase, the mode of transport for export might shift from train to vessel. These three developments all contribute to expected increase in container throughput.

Unipar Indupa

Unipar Indupa has a production capacity of 200,000 tons PVC per year. Currently, they produce at half their capacity mainly due to gas shortage in the winter period. Due to the exploitation of the basin it is expected that Unipar Indupa will produce at capacity in the future years.

Others

After discussing future container throughput in the Port of Bahía Blanca with YPF, it seems that in addition to Dow Argentina and Unipar Indupa, two other companies will increase their container throughput due to the developments in Vaca Muerta. Due to confidential reasons, the names of the companies are not mentioned. The expected production in 2022 is 45,000 tons of MCl and 450,000 tons of polypropylene (Marchionni, 2017).

Based on these expected developments four scenarios are defined that estimate future container throughput in the Port of Bahía Blanca. For all companies the guidelines as in Table 2.1 are used for the different scenarios.

Table 2.1 – General guidelines for the different scenarios describing future container throughput.

Scenario	Actions
Current situation	Most negative scenario. The container throughput in the Port of Bahía Blanca does not change compared to the current situation.
Scenario 2	Production grows at the same rate of the GDP of the importing country until current capacity. Model split is being reconsidered.
Scenario 3	Production grows at a higher rate than the GDP of the importing country. Investments ensure that this rate is achievable. Model split is being reconsidered.
Scenario 4	Most positive scenario. The increased capacity due to investments is used for production in a fast pace.

The four scenarios of the petrochemical cluster show the expected container export due to the developments in this area (Figure 2.2). The estimations are based on the input of YPF and Dow Argentina. The assumptions and calculations for the different scenarios are in Appendix C.

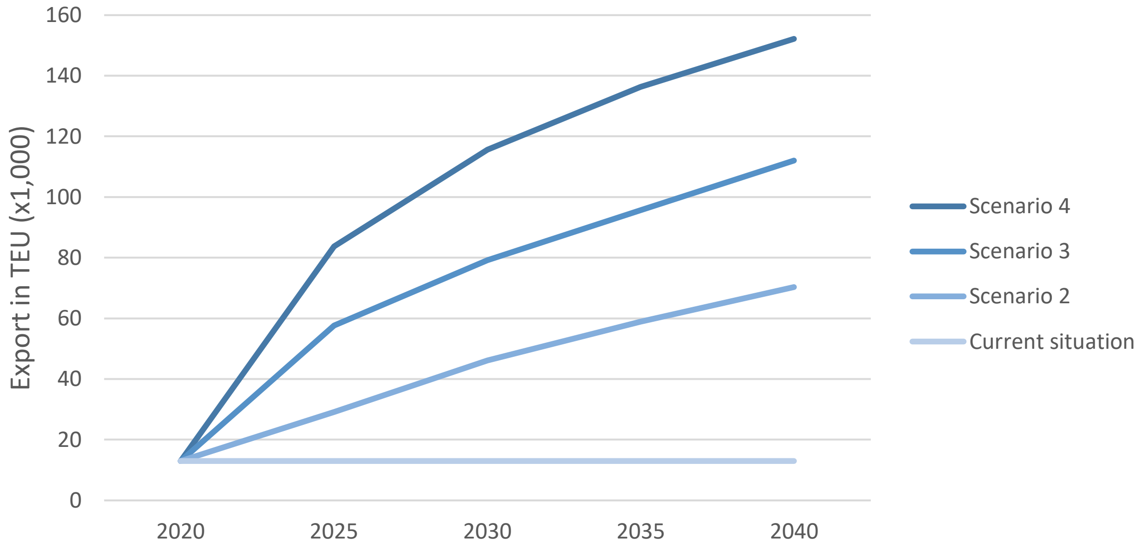


Figure 2.2 – Estimation of future export for the petrochemical industry based on four different scenarios.

2.3 Food industry

Food production in Argentina is not expected to increase more than the average growth of GDP. However, port split for export might change in the future. Currently, the agricultural export in the container terminal is almost zero (CGPBB, 2017a). Nevertheless, the CGPBB is researching the possibilities of attracting cargo to their port. Especially fruit and wine export are of interest for the port due to their location of production.

Fruits that are produced around Rio Negro in Argentina are exported in reefer containers to Brazil, either by vessel or by truck. When transported by vessel the containers go via the Port of San Antonio Este. Figure 2.3 shows the relative distance of the production area and both the Port of Bahía Blanca and the Port of San Antonio Este. There is a distinction between seasonal fruits and products that are produced throughout the year. In Figure 2.4 an overview of potential throughput is provided, including the magnitude of the current export, distance from the production area to the Port of Bahía Blanca and the mode and cost of transport. The operators that export the products to Brazil by truck are likely to switch to transporting by vessel when prices become competitive. In contrast, changing the port for the 8,000 TEU that are transported via the Port of San Antonio Este will not solely depend on cost. The main throughput at the container terminal of Port of San Antonio Este is generated by these fruits. As both the Port of Bahía Blanca and the Port of San Antonio Este have the same terminal operator it is unlikely that this cargo will shift to Bahía Blanca. This is mainly due to the cost associated to changing the location of the export port. However, when costs of operations decrease in the Port of Bahía Blanca this portion of fruit production is a potential market.

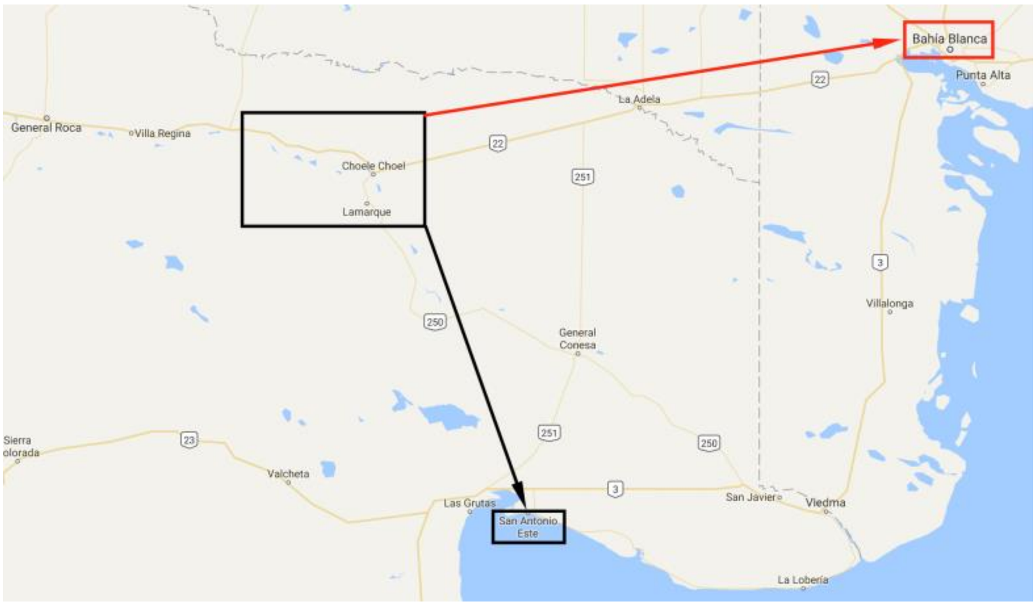


Figure 2.3 – Distance between Bahía Blanca and fruit production area relative to the distance between San Antonio Este and fruit production (Adapted from Google, 2017)

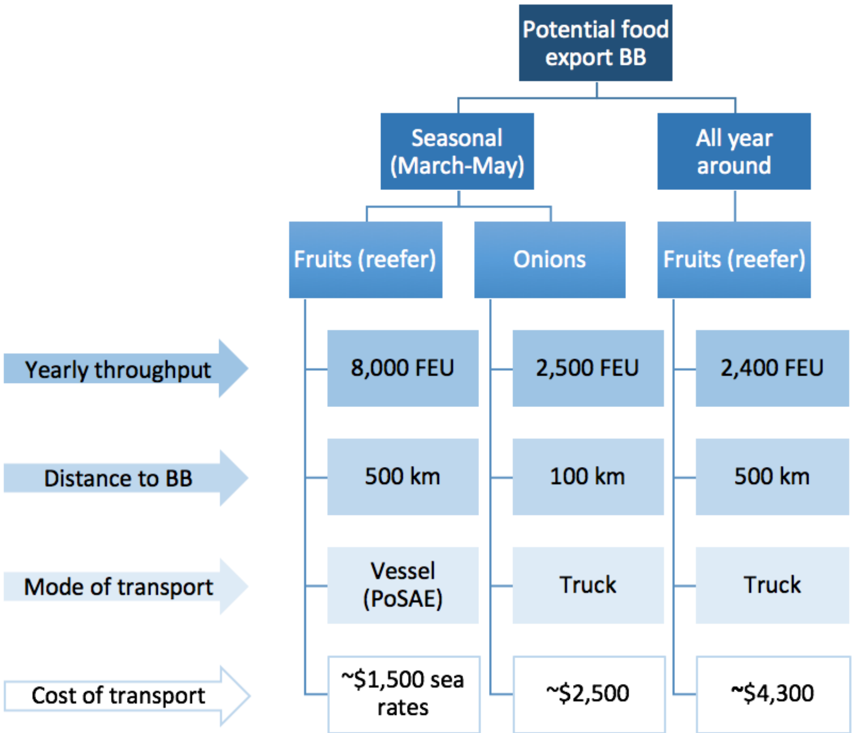


Figure 2.4 – Differentiation of fruit and onion production close around the Port of Bahía Blanca (Bosso, 2017b).

The four scenarios of the food cluster show the expected container throughput due to the expected shift in transport mode. The estimations are based on the input of D. Bosso solely (2017b). The assumptions and export estimation for the different scenarios are in Appendix D.

2.4 Total throughput

Using the input of the sections before, four scenarios for container throughput are estimated. The results are shown Figure 2.5. The final scenarios are established by adding scenario 1 of both fruits and the petrochemical, and equal for scenario 2, 3 and 4. It is also possible that the petrochemical cluster develops, whereas the fruits does not. However, it is expected that the increase of volume due to the cluster will lead to decreasing prices for the Port of Bahía Blanca which in turn will lead to a competitive position for the export of fruits. Because of this correlation, the final scenarios are defined by adding the throughput of all products for a specific scenario.

When calculating the total throughput, the empties are also included. The final container throughput is defined as the maximum of the import and export, times two.

$$T = \max\left(T_{import}, T_{export}\right) * 2$$

Where; T = container throughput

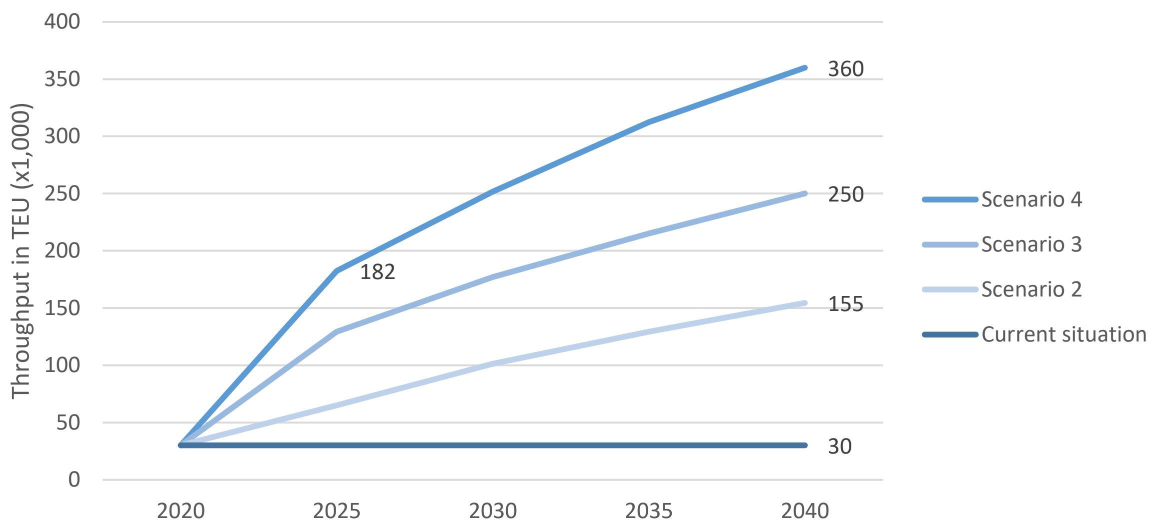


Figure 2.5 – Final four scenarios for future container throughput (own work)

2.5 Conclusion

To conclude, when including the cargo from the petrochemical cluster and the fruit sector, the expected container throughput is expected to range between 30 thousand and 182 thousand TEU/year in 2025. In 2040, the throughput due to these segments is expected to be maximum 360 thousand TEU/year whereas the other scenarios estimate container throughput at 250, and 155 thousand TEU/year respectively. As this estimation includes the petrochemical cluster and fruits only, outcomes are not fully representative for the future throughput. The estimation can be improved by adding more cargo segments. Segments that are not considered but do have potential are: (Arecco, Besson, van Drunen, & Sendra, 2017)

- Wines
- Refrigerated meat
- Wind turbine components

An extensive market analysis should be performed to acquire reliable estimations for these three segments. Besides, other yet unknown cargo segments regarding container throughput should be analysed as well.

Although the figures presented in this chapter only include the petrochemical cluster and fruits, they represent the largest share of the future container throughput. Therefore, the different trend lines are used in the additional part of the research as guidelines for container terminal capacity.

3 Analysis of the container terminal

Before researching the possible expansions of the container terminal, the current situation of the container terminal is analysed. This chapter focuses on the operations at the container terminal, which is operated by Patagonia Norte. Information on shipping lines, throughput, accessibility and capacity are provided to answer the first part of SQ2. In addition to interviews with the terminal operator, shipping lines and an infrastructure specialist from the CGPBB, a literature was conducted to analyse the current configuration.

3.1 Current operations Patagonia Norte

The container terminal in the Port of Bahía Blanca is operated by Patagonia Norte (Figure 3.1). Although it is officially called a Multipurpose terminal, container movement is the core business of Patagonia Norte. From the 221,000 tons of transported cargo in 2016, 215,000 tons were transported by containers. The total surface area of the terminal is 8ha, divided into an operational area of 1ha and a storage area of 7ha. The storage area has a capacity of 1,800 full and 2,000 empty TEU. In addition, the terminal offers space for 360 reefer containers and 80,000m^3 of cold storage for fruits (CGPBB, 2017c). The quay is a platform with a length of 270m and a width of 40m, suitable to berth ships up to 320m because of a dolphin located 50m next to the quay. The platform is connected to the storage area of the terminal with two bridges. The depth in front of the berth is 13.72m with respect to Mean Low Water Springs (Arecco, Besson, van Drunen, & Sendra, 2017).

Figure 3.1 – Location of the Multipurpose terminal in green with the length of the quay indicated (Arecco, Besson, van Drunen, & Sendra, 2017)

3.1.1 Throughput

The terminal is mainly an export terminal since only 2% of the imported TEU were filled. Due to these characteristics of the terminal, it is referred to as an export container terminal. In 2016, 32,450 TEU were moved of which approximately 87% of the containers were FEU. The exact data on container movement in 2016 can be found in Appendix E.

Considering number of TEU and amount of tonnage, the container throughput in the Port of Bahía Blanca fluctuates over the years, as shown in Figure 3.2. Especially the year 2015 shows a large decrease in throughput, which can be partly explained by the GDP drop of 4% for Brazil, the main export destination (The World Bank Group, 2017d). However, on average the throughput shows a small increase over the last five years.

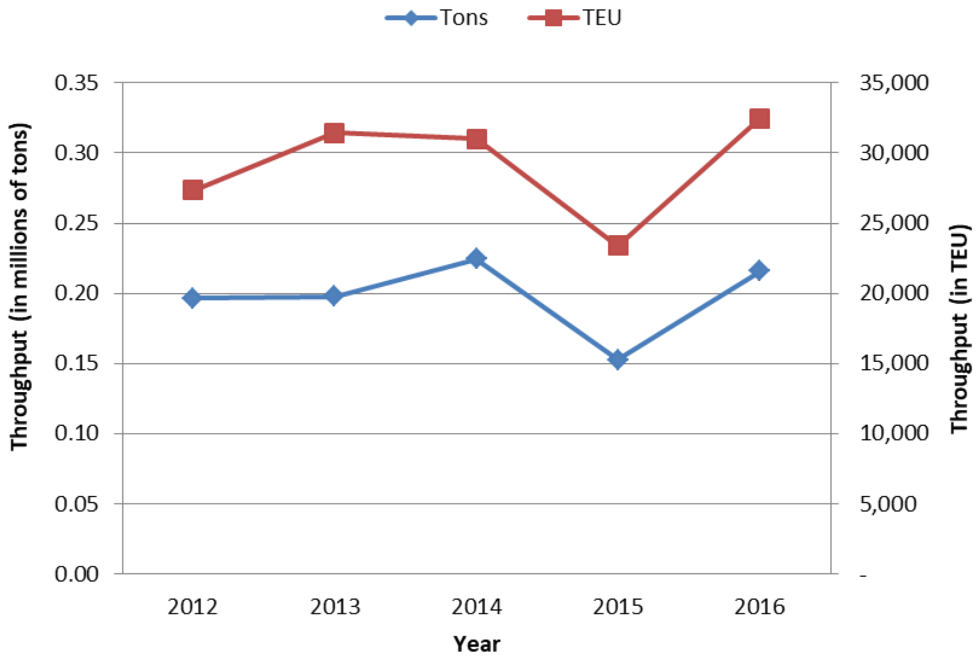


Figure 3.2 – Yearly container throughput in TEU and tons of Patagonia Norte 2012-2016 (Arecco, Besson, van Drunen, & Sendra, 2017)

3.1.2 Export products and destinations

Due to the large petrochemical cluster located in the Port of Bahía Blanca, the main export products are PVC (polyvinylchloride) and polyethylene. These two products together form 75% of the total tons of export. Other significant products are alfalfa, organic wheat, semola wheat, juices and flour bags.

The main destination of the containers that are exported is Brazil. In 2016, they imported 64% of the total containerized cargo of the port, which is significantly more than the second largest importer, India (Figure 3.3). In Appendix E an overview of the products that are exported to the countries of Figure 3.3 is provided.

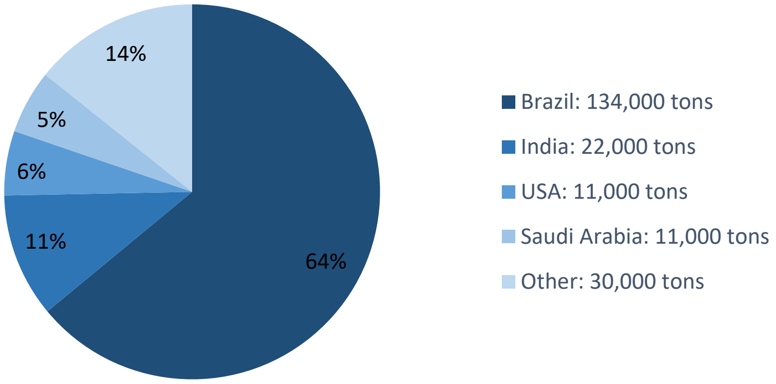


Figure 3.3 – Most important countries for container export from the Port of Bahía Blanca (CGPBB, 2017a)

3.1.3 Shipping lines

The shipping route which calls the Port of Bahía Blanca is called ABAC-CONOSUR. It is a weekly service between ports in Ecuador, Peru, Chile, Argentina and Brazil as shown in Figure 3.4. The service is skipped occasionally when bad weather conditions close to Cape Horn occur. The two shipping lines responsible for this route are Hamburg Süd and HAPAG Lloyd, who are operating as a joint venture. After calling the Port of Bahía Blanca, the vessels sails to Itapoa, Brazil. The vessels have a capacity of 1,500 to 2,000 TEU, a length of 250m and a width of 30m (Larralda, 2017).

Figure 3.4 – Shipping route of Hamburg Süd and HAPAG Lloyd (Hamburg Süd, 2017a)

3.1.4 Equipment of Patagonia Norte

The equipment at the terminal is sufficient for the current operations. The ship-to-shore (STS) transport of the containers is executed with one mobile crane together with the crane of the container vessel itself. When the container is placed on the shore, it is further transported by a reach stacker which puts the container in the right stack. Below an overview of the available equipment is given:

1. **Multipurpose Mobile Crane**

   This crane is used for the loading and unloading of vessels. It has a reach of 43m, which is the same as the width of 13 containers. The lifting capacity is 104 tonmeter and the net crane productivity is 20 moves/hour.

- **1 Reach stackers for empty containers**

  This reach stacker has a height limit of 5 containers and a lifting capacity of 20 tons.
- **2 Reach stackers for full containers**

  These reach stackers also have a height limit of 5 containers and a lifting capacity of 40 tons.
- **Several electric forklifts**

  The forklifts are for movement of palletized goods.
- **Capacity for 32 plug-ins for reefer containers**

3.2 Infrastructure

In this section, the accessibility of the container terminal is analysed. Although rail tracks are present at the container terminal, the terminal is currently only accessed by trucks. One reason is the inefficient rail entrance, blocking operations when over 10 wagons are used. In addition, railway operators indicated the limited urge to enter and operate at the container terminal (Arecco, Besson, van Drunen, & Sendra, 2017). Regarding the road network, the Port of Bahía Blanca is only accessible via the Ruta Nacional 3 (RN3) in the North, mentioned in the port analysis (Appendix A). The container terminal itself, is only accessible from the Vélez Sársfield which is connected to the RN3 via 18 de Julio (Figure 3.5). This former road is also used by trucks going to the terminals of Cargill and Profertil S.A., which are located at both sides of the container terminal. Since Cargill and Profertil S.A. together transport around 300 trucks per day, the Vélez Sársfield is mainly used by those terminals (CGPBB, 2016a). An increase in container throughput will generate more traffic on the access roads and hinterland connections. Currently, the port and therefore the container terminal has multiple road and rail connections with important distribution areas within the hinterland. A further analysis of the hinterland connections is given in Appendix F.

Figure 3.5 – Infrastructure in and around the container terminal area (Adapted from Google, 2017)

3.3 Capacity of the terminal

In this subchapter, the current capacity of the container terminal is investigated. The handout ''Ports & Terminals Handout Chapter 7: Container terminals'' is used as a reference for formulas and predetermined data throughout this subchapter (Quist & Wijdeven, 2014). The capacity of the container terminal depends on several components; available storage area, average dwell time, required area per TEU, ratio of average stacking over nominal stacking height and average occupancy rate. The current container terminal includes a storage area of approximately 7ha and is mainly used for export. Therefore, the terminal only requires storage area for export containers and empties. When the terminal handles some import containers, these will be stored in a specific location in the export storage area. The surface area requirements for the different stacks (export, empties) can be calculated as follows:

$$A = \frac{N_c \cdot \overline{t_d} \cdot A_{TEU}}{r_{st} \cdot 365 \cdot m_c}$$

where:

A = area required [m^2]

N_c = number of container movements a year per type of stack [TEU]

t_d = average dwell time [days]

A_{TEU} = required area per TEU including equipment travelling lanes [m^2]

r_{st} = $\frac{\text{average stacking height}}{\text{nominal stacking height}}$ (0.6 to 0.9) [-]

m_c = acceptable average occupancy rate (0.65 to 0.7) [-]

Using this formula, a proper estimation of the current capacity of the container terminal is executed. The capacity of the container terminal consists of a summation of the maximum container movements a year of both type of containers, expressed in TEU. The maximum container movements a year per type of stack can be calculated using the available surface area and the input data as in the formula above:

$$N_c = \frac{A \cdot r_{st} \cdot 365 \cdot m_c}{\bar{t_d} \cdot A_{TEU}}$$

In the following, first the maximum container movements a year of export containers and after that of empty containers are determined. Because the container terminal almost exclusively handles export and empty containers, the container movements a year of both type of containers should be equal. Therefore, the required area of the export and empty containers are iteratively determined until an equal maximum container movements a year is obtained.

3.3.1 Export

The average dwell time should be considered separately for export and empty containers. Generally, export containers have the lowest dwell time, because the processing of these containers can be well regulated. The typical dwell time function is showed in Figure 3.6 with the quantity of containers which are still in the terminal, divided by the total number of unloaded containers in one period, plotted against time. At the maximum dwell time ($t_{d,max}$), all the containers that entered the port in a particular period, have left the container terminal. The shape of the typical dwell time function suggests that every day a vessel is calling the terminal. In contrast, the shape of the dwell time function of the container terminal in Bahía Blanca is different, as a container vessel is calling the container terminal every week. However, the equation for dwell time can be used to obtain a proper approximation of the average dwell time of containers in the terminal of Patagonia Norte:

$$\bar{t_d} = \frac{(t_{d,max}+2)}{3}$$ (Quist & Wijdeven, 2014)

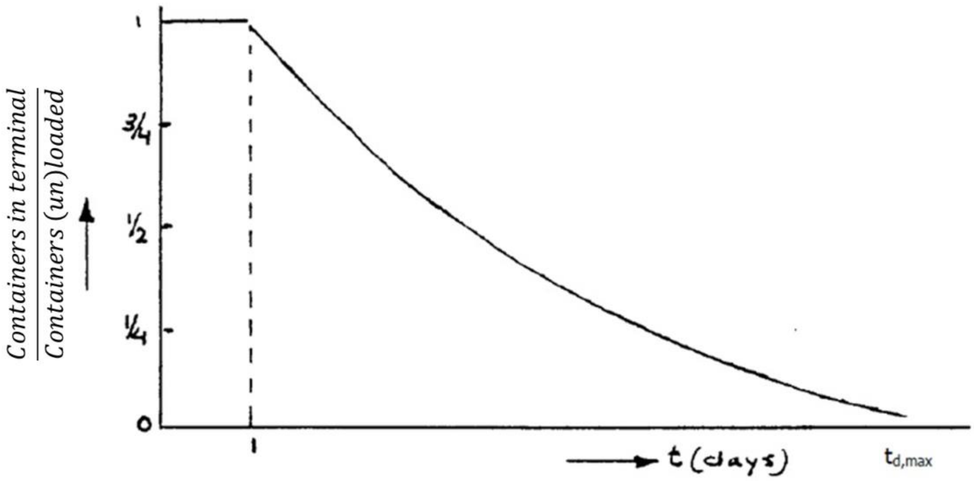


Figure 3.6 – Typical dwell time function (Quist & Wijdeven, 2014)

It is common that the vessels do not pick up all the stacked export containers, due to differences in production-, delivery- and shipping line schedules. Assumed is that the export containers will utmost miss two shipping calls, indicating that $t_{d,max}$ of the export containers is approximately 21 days. General values for $t_{d,max}$ in Western Europe are around 10 days and for less developed countries, between 20 and 30 days. Using the estimation of $t_{d,max}$ as 21 days and the equation of the typical dwell time function, the average dwell time is determined:

$$\bar{t_d} = \frac{(t_{d,max} + 2)}{3} = \frac{(21 + 2)}{3} \cong 8\ days$$

So, the average dwell time of the export containers is estimated at 8 days.

The containers are transported by reach stackers and can be stacked up to five containers. Using the empirical data from

Table 3.1 the required area per TEU can be determined.

Table 3.1 – Storage area per TEU for different types of equipment (Adapted from Quist & Wijdeven, 2014)

System	Nominal stacking height [containers]	A_{TEU} [m^2/TEU]
Straddle carrier	2	15-20
	3	10-13
Gantry crane (RTG/RMG)	2	15-20
	3	10-13
	4	7.5-10
	5	6-8
Forklift truck or reach stacker	2	35-40
	3	25-30
	4 (extrapolated)	19-23
	5 (extrapolated)	15-18

From Table 3.1 it follows that the storage area per TEU for reach stackers with a nominal stacking height of three containers is 25-30m^2/TEU. When extrapolating these numbers to a nominal stacking height of five containers, the required area per TEU is between 15m^2 and 18m^2. Considering the narrowing in the layout of the storage area, the required area per TEU is determined at 18m^2. As the general value of the ratio average stacking height over nominal stacking height of export containers is 0.8, this value is used. Looking at the acceptable average occupancy rate, there is a large variation in the arrival and departure of containers. Because of this, the acceptable average occupancy rate is relatively low and determined at 0.65. Using all data derived in this section the capacity of the container terminal for the storage of export containers can be estimated using the following equation:

$$N_{c,export} = \frac{A_{export} \cdot r_{st} \cdot 365 \cdot m_c}{\bar{t_d} \cdot A_{TEU}} = \frac{A_{export} \cdot 0.8 \cdot 365 \cdot 0.65}{8 \cdot 18}$$

Because the required storage area of export containers to have equal storage capacity of export and empty containers, this equation cannot be solved yet.

3.3.2 Empties

In this section, the current capacity of the container terminal for the storage of empty containers is calculated. The dwell time of the empties is significantly longer than that of the export containers, because these containers can be stored in the terminal without a purpose. Following the guidelines from 'Ports and Terminals', the dwell time of empties is about 2.5-3 times longer than export containers. From this the dwell time of empties is estimated at 22 days. The required area per empty TEU is equal to the required area per export TEU, approximately 18m^2. In contrast, the ratio average stacking height over nominal stacking height of the empties is higher. The general value for the ratio average stacking over nominal stacking height of empty containers is used, which is 0.9. The acceptable average occupancy rate of the terminal is already determined at 0.65. Using this data, the current capacity of the container terminal for the storage of empty containers can be estimated using the following equation:

$$N_{c,empties} = \frac{A_{empties} \cdot r_{st} \cdot 365 \cdot m_c}{\bar{t_d} \cdot A_{TEU}} = \frac{A_{empties} \cdot 0.9 \cdot 365 \cdot 0.65}{22 \cdot 18}$$

3.3.3 Capacity estimation

Using the capacity estimations for export and empty containers storage areas for both types are determined. They are found iteratively when the capacities of the storage areas for both container types are equal. The results are showed in Table 3.2.

Table 3.2 – Required storage area and capacity per type of container

Type of container	A [ha]	N_c [TEU]
Export	2	26,500
Empties	5	26,500
Total	**7**	**53,000**

The current capacity of Patagonia Norte is estimated at approximately 53,000 TEU/year, based on the assumption that the terminal will stay in the current configuration. According to throughput figures for terminals using reach stackers, an average throughput of 10,000-12,000 TEU per ha (storage area) can be reached (PIANC, 2014). For this terminal, this would result in a throughput of 70,000-84,000 TEU. The estimated capacity of 53,000 TEU is significantly lower than the average values. This difference can be explained by the large share that empties have in the throughput, in combination with their relatively long dwell time.

3.4 Conclusion

The current capacity of Patagonia Norte is estimated at approximately 53,000 TEU/year. This capacity is limited by the required area per TEU, the dwell time and available storage area. The required area per TEU depends on the equipment used for terminal processes whereas the dwell time depends on the call frequency of the vessels. The available storage area can be increased by expanding the current container terminal area.

When container throughput increases above 53,000 TEU/year, the terminal requires improvements to handle this throughput. Considering the scenarios outlined in chapter 2, this throughput is exceeded in all but the base scenario in 2023 or even before. Following these scenarios, the terminal requires improvements in the coming years. In the next chapter these possible improvements, such as increasing the quality of equipment and decreasing the dwell time, are discussed and proposed.

4 Adjustments Patagonia Norte S.A.

In this chapter, the possible improvements of the current Multipurpose terminal Patagonia Norte, referred to as container terminal, are investigated. First, improvements to the terminal in its current configuration are discussed, followed by infrastructural expansions to enlarge the stacking yard and thus the capacity of the terminal. The capacity of the terminal can be restrained due to multiple factors, which are discussed as well. At the end of this chapter, SQ2 is fully answered. This part of the research is important for determining whether and when the development of a new container terminal is required.

4.1 Capacity increase in current configuration

To increase terminal capacity, one or multiple of the following components should be improved: available storage area, average dwell time, required area per TEU, ratio average stacking height over nominal stacking height and/or the average occupancy rate (Quist & Wijdeven, 2014). In the current configuration, improvements can be made in all aspects except for the available storage area. The ratio of the average stacking height over the nominal stacking height has a relatively low impact on the capacity of the terminal. Besides, increasing this ratio will increase the need for re-positioning of the containers, reducing the efficiency of the handling equipment. The average occupancy rate is also difficult to influence, because the pattern of arrivals of containers to the terminal is stochastic by nature. In contrast, improvements in the average dwell time and required area per TEU are expected to increase the capacity of the container terminal significantly.

4.1.1 Dwell time

The average dwell time in the container terminal depends on the frequency of:

- the export containers that are brought into the terminal
- the empties to be handled
- the container vessels calling the Port of Bahía Blanca

The terminal operator has only limited influence on the first two components. With respect to the third component, currently once a week a vessel is calling the Port of Bahía Blanca. With an increasing throughput, one, or both, of the following aspects will change: the call size and/or the call frequency. The call size represents the average number of moved TEU per call and the call frequency is the number of calls per unit of time. Increasing the call frequency, the dwell time of the container terminal will decrease, because the containers are stored in the terminal for a shorter time. When the dwell time of the containers decreases, the terminal can handle more containers and the capacity increases. It is assumed that when the throughput increases, first the capacity of the current shipping line calling the terminal is used. After, a larger vessel or an increase in call frequency is required. For the current shipping line these are complicated matters, because other ports on the shipping route probably do not require larger vessels or extra calls, resulting in overcapacity on a large part of the shipping route. Additionally, certain ports on the shipping route do not have STS cranes and therefore rely on the cranes of the vessel, which are often not available on larger container vessels. These issues can be solved by the implementation of a new shipping route between Bahía Blanca and the main country for export, Brazil. The exact developments of shipping routes calling the Port of Bahía Blanca are hardly predictable, because many factors are influencing the decision of shipping lines to change their existing or implement a new shipping route.

Therefore, assumptions are made regarding future call frequencies and call sizes to be able to determine the average dwell time for an increased throughput. The assumed future scenario is divided into the following stages:

1. The call size of the current shipping line is used to its capacity. The current call size is on average 530 TEU/call, which can increase up to 900 TEU/call, resulting in a maximum throughput of about 45,000 TEU/year (de Ortuzar, 2017).

2. Reaching this throughput, the second stage will be the introduction of a new shipping line which will compete with the current shipping line. The vessel, with a capacity of 1,200 TEU, will call Bahía Blanca once every 14 days with an expected maximum call size of 1,800 TEU. The yearly maximum throughput is about 90,000 TEU.

3. When the throughput is going to be higher than 90,000 TEU, the new operator will start increasing their operations to a weekly service on top of the existing service.

4. In the final situation, Bahía Blanca is called three times a week, once by the existing service and twice by another operator/(other operators). After this stage, there will be an increase in vessel size to handle the growing throughput.

The four stages are summarized in Table 4.1 and used to determine the dwell time of the container terminal. The dwell times, required for the remainder of this chapter, are calculated in Appendix G. The average dwell time for export is expected to decrease with three days when reaching the fourth stage, while for empties a decrease of nine days is expected.

Table 4.1 – Four stages of the future call pattern

Stage	Description	Max throughput [TEU]	Max call size [TEU/call]	Call frequency [calls/year]
1	Current service (CS) to full capacity	45,000	900	50
2	CS + extra service once in 2 weeks	90,000	900 or 1,800	75
3	CS + extra weekly service	135,000	900 or 1,800	100
4	CS + two extra weekly services	225,000	900 or 1,800	150

4.1.2 Operation system

To handle an increase in throughput it is important that the terminal operation system can handle this increase as well. For determining the optimal equipment at the terminal, all terminal processes are considered. Equipment is required to transport the containers between the quay and the storage areas, handle the containers within the storage areas and transport the containers between the storage areas and the truck or train. As mentioned in section 3.1.4, nowadays all these processes are performed using two reach stackers for full containers and one reach stacker for empty containers.

The most convenient adjustment to handle an increase in throughput is increasing the amount of reach stackers. As a rule of thumb, three to four reach stackers are required for each STS gantry crane (Böse, 2011). The current system has a relatively low operation rate and therefore already an increase in number of reach stackers is advised. When the throughput increases more STS cranes and therefore more reach stackers are required. The reach stackers have a relatively slow transport speed between quay and stacking yard, so upgrading the current operational system is required when the operation system with only reach stackers cannot handle the throughput. A first upgrade is the addition of multi-trailers (terminal tractors with several trailers) to the system. These multi-trailers transport the containers between the quay area and the stacking area, where they are (un)loaded by reach stackers. With this improvement to the system, the reach stackers work more efficient as they remain within the stacking yard. Other advantages of this upgraded system are the relative low investment- and maintenance cost and the fact that no high-skilled personal is required for the use of the equipment. However, the improvements only solve bottlenecks to reach the potential capacity of the terminal and do not increase the potential capacity itself as the required area per TEU does not decrease.

The next step is the reduction of the required area per TEU with the use of an operation system with straddle carriers (SC) or Road Tyred Gantries (RTG). This equipment is compared in Appendix H. Comparing the different equipment, the RTG can handle more throughput than the SC. The biggest advantages of the SC are their flexibility and the fact that they do not require additional equipment. The RTG is also flexible and competitive when the storage area is large enough to stack the container in long rows. The determination of the most appropriate equipment is depending on the lay-out and amount of throughput of the terminal.

4.2 Capacity improvements with infrastructural adjustments

This section focuses on large infrastructural adjustments of the container terminal to increase capacity, by expansion of the storage area, developments in dwell time and upgrading the terminal operation equipment. An advantage of the expansion of the storage area is the direct increase in surface and thus capacity. A disadvantage is the associated costs of the adaptations. In this analysis, a cost estimation of the terminal expansions is included, however, further investigation into the profitability of the expansion(s) is required.

When considering the terminal area of Figure 4.1, expansion to the west side is restricted because of the Yacht Club "Club Náutico". At the east side, the Public Harbour is located as is a cold storage for fish and fruits and a general area. These facilities make an expansion of the terminal area complicated. The expansion process is divided into four phases, which are further elaborated below.

Figure 4.1 – Possible expansion areas (Adapted from Google, 2017)

4.2.1 Expansion 1: Commissioning General area

The general area north of the cold storage for fish and fruits consists of two blocks (Figure 4.1). The western block consists of a parking area for trucks and a small green area, all owned by the CGPBB. On the eastern block, several small offices and other buildings are present. A part of the buildings can be purchased for an approximate amount of U$D 2-2.5 million (Ginés, 2017). In addition, cost for molesting the buildings and the construction of terminal pavement are associated to the expansion. Acquiring the two blocks will result in 2.2ha extra area for empties. Proposed is to use this 2.2ha as storage area for empties, because it is far away from the berth. As investment and additional preparation costs are relatively low, it is advised to execute this expansion first.

Using the scenario for dwell times, the maximum capacity of the terminal is determined Appendix I. The result is an increase of 19,000 TEU to a total maximum capacity of 110,000 TEU.

4.2.2 Expansion 2: Reclamation Public Harbour

The reclamation of the Public Harbour should be the second step in expanding the container terminal, increasing storage for full containers. This area is already owned and operated by the CGPBB. The quays in this area are currently used as mooring places for fishing vessels. However, it is essential that when this area will be claimed for the expansion of the terminal, the relocation of the mooring places is done correctly and fair with respect to the fisherman.

The preparation of this area consists of different steps. First, the new quay wall should be constructed, able to bear the high surface loads of the terminal equipment and stacked containers. Second, the old quay a deck on piles, should be removed as they do not have enough bearing capacity with respect to the future design load. After this, the area behind the quay wall should be reclaimed and pavement should be constructed. The total cost of this expansion is roughly estimated at U$D 11 million (Appendix J). The relocation of the mooring place is not considered within this estimation.

The expansion would lead to an increase of the storage area by approximately 2.0ha. This results in an increase in capacity of 40,000 TEU to a total of 150,000 TEU (Appendix I).

In addition, an extra berth of 240m can be constructed on the east side of the terminal by extending the current quay to the location of the dolphin and from that point create a quay wall perpendicular to the current quay as shown in white in Figure 4.2. The extra land reclamation and especially the construction of a new quay wall makes it an expensive improvement, while the berth will be only long enough for vessels up to a length of approximately 200m (PIANC, 2014). In addition, the strong tidal current along the access channel requires the need for a tidal window for berthing operations. Lastly, due to siltation in this corner of the port basin, extra maintenance dredging cost should be considered as well. To conclude, the construction of an extra berth on this side is not recommended unless really needed.

Figure 4.2 – Location of the extra berth (Adapted from Google, 2017)

4.2.3 Expansion 3: Cold storage

After expansion 1 and 2, the cold storage will be almost fully surrounded by the container terminal. Adding this area to the terminal is a logical next step. One option is involving the cold storage facilities into the terminal area. In case of an increase in export of fruits via Bahía Blanca, the cold storage might be useful. A second option is the relocation of the cold storage somewhere else in the port area. However, for both options an appropriate solution should be found with respect to the employment in the cold storage. Currently around 100 people are employed in this business. Especially in the case of a relocation a suitable new location should guarantee this employment.

When this is succeeded, the expansion of the stacking yard results in an increase of 1.4ha in area. The maximum capacity will grow to 165,000 TEU (Appendix I).

4.2.4 Expansion 4: Club Náutico

The final expansion possibility is the relocation of the Yacht Club. This is a complicated matter as the CGPBB is responsible to find and finance a suitable new location for the Yacht Club. Moving the Club without full consensus of the members, will generate a negative image of the port.

When the relocation is accomplished, it would be a significant improvement for the container terminal. The quay wall can be extended to the west by 240m and the layout of the terminal will be almost squared, which is more convenient for a container terminal area. The total cost for this expansion are roughly estimated at U$D 30 million (Appendix J). It is important to note, that the cost for relocation of the Yacht Club are not considered in this estimation.

The obtained area of removing the Yacht Club can result up to 5.2ha of extra surface. Not all area will be used for storage as space for STS-transport and equipment is required close to the quay. The length of this apron area is approximately 60m to the quay. Due to this restriction, the resulting extra storage capacity is 3.6ha. This is equivalent to almost 50,000 TEU of extra capacity.

When all four expansions are realized, the total capacity grows to approximately 215,000 TEU, considering an upgraded operation system with multi-trailers and reach stackers.

The total terminal area will increase to a total size of 22ha with 16ha of stacking yard (Figure 4.3). With this size and lay-out, the use of a new operation system with SCs or RTGs can be considered. As concluded in Appendix H, RTGs are the best solution for large terminals due to their high stacking density. An upgrade to this type of equipment requires a large investment and the need for skilled personnel. However, the terminal can more than double its capacity to approximately 480,000 TEU compared to a system with reach stackers. This capacity estimation is based on the available stacking area, equipment, and dwell time while other aspects such as crane capacity and berth occupancy are not considered. These aspects can be bottlenecks for the growth in capacity of the terminal and will be discussed in the next subchapter.

Figure 4.3 – Total terminal area after maximum expansion (Adapted from Google, 2017)

4.3 Potential bottlenecks

When increasing the capacity of the container terminal, also the potential bottlenecks of the terminal should be considered. Bottlenecks are components already working at its full capacity and which, therefore, cannot handle any additional demand. Because of these bottlenecks the terminal is not able to reach its full potential capacity. In this section possible bottlenecks are indicated, however, a more in depth study is required to conclude upon the limitation due to these factors.

To start, potential bottlenecks are in the operations of the container terminal. These consists of terminal processes and equipment at the quay, between the quay and storage yard, within the storage yard and between the storage yard and the hinterland transport. As discussed above, nowadays a mobile crane is used as STS crane and reach stackers for all additional terminal operations. The number or type of equipment should increase or upgrade before it becomes and obstructs the terminal capacity increase. The current mobile crane can be supported or replaced by STS gantry cranes with higher net productivity rates, which is further elaborated on in chapter 4.4. The terminal operations equipment can be improved by increasing the number of reach stackers or upgrade the equipment, as discussed in chapter 4.1.2.

Furthermore, the infrastructure in and around the terminal should be able to handle the increasing throughput. A potential bottleneck of the terminal are the connections of the quay apron with the storage area. Currently this connection is provided by two bridges of about 12m wide. Due to a potential increase in throughput, the bridges should handle a high intensity of transport equipment and congestion of reach stackers or multi-trailers is undesirable. Possible improvements to prevent congestion are increasing the number of bridges, widening the bridges or connecting the whole quay apron with the storage yard. An additional potential bottleneck is the capacity of transport between the terminal and the hinterland and should be considered when the terminal expands significantly. Possible improvements in rail infrastructure are required when the capacity cannot be handled by trucks solely. Moreover, the access road to the terminal should be improved when the intensity of trucks is exceeding the capacity of the road.

Also, congestion at the gate of the terminal due to the high number of trucks entering the terminal could be a bottleneck when throughput increases. The gate is the central element of the terminal where the import containers leave and export containers arrive at the terminal. It is the place where all entrees and departures are recorded and customs formalities are dealt with. Possible improvements are advanced information technology, such as X-ray equipment, to avoid frequent queues and long waiting times for the trucks.

Finally, by increasing the throughput, the number of berths are a potential bottleneck. It is desirable to prevent long waiting times for vessels calling the container terminal. The current berth length is 270m and the terminal can receive one vessel a time for ships with a length between 120m and 270m. When the Yacht Club is relocated and the berth is extended to a total length of 560m, the terminal can receive two vessels with a limited length. When the average container vessel length, calling the container terminal, is 230m or lower, it is possible to berth two vessels simultaneously. However, the length of the current container vessels calling the Port of Bahía Blanca are over 230m already. In that matter, the limitation of expansion possibilities of the berth length is undesirable. In the next section, the queuing theory, the necessity of a second berth is researched.

4.4 Queuing theory

The queuing theory describes, studies and explains the phenomena that occur in waiting systems, systems in which customers should wait for operation. In this section, the queuing theory proposed by D.G. Kendall is used to determine the required number of berths to guarantee a certain maximum waiting time for the vessels (Groeneveld, 2001). In addition, the theory can be used to develop more efficient queuing systems that reduce the waiting time of customers and increase the number of customers that can be served. The queuing theory requires input data that is depending on the amount of throughput. For instance, when the container throughput is growing significantly, the call size will probably increase and the current mobile crane can be supported or replaced by STS gantry cranes. In this section, the development of the queuing system of the single berth of Patagonia Norte is analysed and some improvements at the terminal are proposed, before a second berth is required.

4.4.1 Current situation

Patagonia Norte currently uses a mobile crane and one of the cranes of the vessel to (un)load the vessels. Furthermore, the terminal can receive vessels 18 hours a day, 365 days a year, so the operational time is about 6,600 hours/year. The remaining input data for the queuing theory with the values of 2017 are explained in Appendix K and provided in Table 4.2.

Table 4.2 – Input data of the queuing theory of the container terminal of the Port of Bahía Blanca in 2017 (CGPBB, 2017d)

Input data	Value
Call frequency [calls/year]	50
Operational time [hours/year]	6,600
TEU-factor [-]	1.7
Net crane productivity [moves/hour]	10.8

Using this input data and the throughput of the container terminal in 2016, 32,500 TEU/year, the queuing theory is elaborated and attached in Appendix K. The maximum desirable waiting time for a container vessel is 10% of the service time and the queuing theory is used to determine whether this requirement is met. From the calculations follows that the current terminal does not meet this requirement and needs improvement(s) to guarantee a waiting time of 10% of the service time. Further increasing of throughput would increase the waiting time of the vessels even further and this is not desirable.

4.4.2 Improvements current berth

To avert the realisation of a second berth, the current berth should be upgraded to its full potential capacity. Upgrading the current berth is possible by increasing the operational time, net crane productivity and/or call frequency. As explained in this chapter, the call frequency and call size will develop, with increasing throughput. The call frequency will increase with certain steps and the call size is depending on the total throughput and the call frequency. These developments are included in this analysis and further explained in chapter 4.1.1.

First improvement

At first the net productivity of the cranes can be increased from 10.8 to approximately 20 moves/hour, by retraining current personnel (crane operators) of the container terminal. With this development, the container terminal can handle a throughput of approximately 50,000 TEU/year to have an average waiting time below 10% of the service time.

Second improvement

When the throughput exceeds 50,000 TEU/year, a second improvement is the extension of the operational time is required. By increasing the operation hours per day an operational time of about 8,750 hours/year can be accomplished. With this development, the terminal can handle a throughput of approximately 70,000 TEU/year. This improvement is relatively expensive due to the high labour costs at night, required to increase the operational time of the terminal.

Third improvement

When the container throughput is increasing above 70,000 TEU/year, the net productivity of the cranes is the only input value that can still be improved. The net productivity can be improved by placing a STS gantry crane on the quay, which replaces the (un)loading activities of one of the cranes of the vessel. With this development, the net productivity rate of the cranes increases to approximately 30 moves/hour and the terminal can handle a throughput of approximately 100,000 TEU/year. It should be investigated if the STS gantry cranes are able to (un)load the vessels, calling the Port of Bahía Blanca, due to the hinder of the existing cranes of the vessels.

Final improvements

A next development of the (un)loading activities of the container terminal is the replacement of the mobile crane by a second STS gantry crane. With this development, the terminal can handle a throughput of approximately 140,000 TEU/year. Finally, a third STS gantry crane can be placed on the quay, leading to a handling capacity of approximately 200,000 TEU/year. For all capacity calculations only one berth is considered.

When the throughput increases above 200,000 TEU/year, the terminal requires a second berth to guarantee a waiting time of the vessels below 10% of the service time. Increasing this throughput, the waiting times for the vessels will be longer, which is undesirable. In addition, the terminal operations, storage area and other potential bottlenecks (discussed in chapter 4.3) of the terminal itself should be able to handle this amount of throughput as well.

4.5 Conclusion

In this section, the terminal and berth adjustments and their increase in terminal capacity are compared with the throughput scenarios outlined in chapter 2. The current capacity of the terminal is estimated at approximately 50,000 TEU/year. However, the berth cannot handle this throughput currently. By retraining the personnel (crane operators), the production rate of the cranes can increase and the berth capacity can increase to an approximate throughput of 50,000 TEU/year. In this analysis, developments of the call rate, call size and dwell time are considered as well. This first berth improvement is relatively low in price; hence it is recommended as first. In scenario 1 of the future throughput estimations no growth is expected, therefore, no adjustments on the terminal are required. In scenarios 2, 3 and 4 this throughput is already exceeded in or before 2023. Indicating that improvements of the terminal are required rather fast.

Thereafter, the first terminal expansion is commissioning of the general area, which would increase the terminal capacity to approximately 110,000 TEU/year. This terminal expansion is recommended as first, because it is the cheapest expansion. For the berth to have almost the same capacity, it requires two improvements. Increasing the operational time and placement of a STS gantry crane on the berth in addition to the existing STS mobile crane. Increasing the operational time including night shifts will increase the labour costs continuously. In contrast to this, the placement of a STS gantry crane includes high investments and lower maintenance costs. With these adjustments, the berth and thus the terminal, can handle approximately 100,000 TEU/year. In scenario 2 this throughput is exceeded around the year 2030, but for scenarios 3 and 4 this happens in or before 2024.

Furthermore, the reclamation of the public harbour is the following proposed adjustment of the terminal, which is a relatively expensive terminal expansion and can increase the terminal capacity to approximately 150,000 TEU/year. Replacing the STS mobile crane by a second STS gantry crane, will increase the berth capacity to approximately 140,000 TEU/year. By executing both improvements, the terminal capacity would increase to approximately 140,000 TEU/year. In scenario 2 this capacity would be sufficient until 2037, in scenario 3 around 2026 the throughput would exceed capacity and for scenario 4 this would happen already in 2024.

Final adjustment to the current berth is the implementation of a third STS gantry crane, increasing the berth capacity to approximately 200,000 TEU/year. When the throughput increases above 200,000 TEU/year, the terminal requires a second berth to guarantee a waiting time of the vessels below 10% of the service time. Expansion of the terminal area by using the current cold storage as container storage, would increase the terminal capacity to approximately 165,000 TEU/year. Additionally, replacement of Club Náutico can increase the terminal capacity to approximately 215,000 TEU/year. It is important that both the cold storage as Club Náutico should be assigned to a new location in the port area. From this point, further capacity improvements of the terminal are opposed by the berth capacity, so upgrading the equipment of the terminal operations is not advised. A feeder vessel of 1200 TEU has an approximate length of 180m. When calculating future throughput, it is assumed that a feeder connection between Brazil and Bahía Blanca is present. In this specific configuration, the second berth will be sufficient when throughput increases. However, it is important to note that flexibility is limited in this situation. Two vessels of the current size cannot berth simultaneously, limiting the possibility to adapt to future events. In scenario 2 the throughput of 200,000 TEU/year will not be exceeded before 2040, in scenario 3 will be exceeded around 2033 and in scenario 4 throughput will exceed the final capacity in 2026. An overview of the discussed increases in throughput is shown in Figure 4.4.

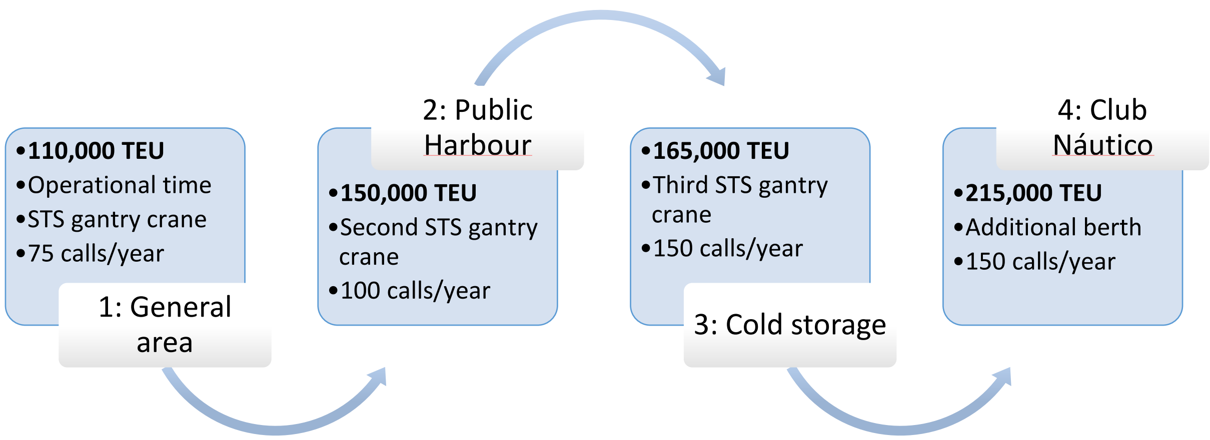


Figure 4.4 - Overview of capacity increase due to increase in area size and the necessary changes within the terminal area.

In addition, the terminal operations, storage area and other potential bottlenecks (discussed in chapter 4.3) of the terminal itself should be able to handle this amount of throughput as well. For instance, the number of equipment should increase by increasing the net productivity of the cranes, because every STS gantry crane requires about 3-4 reach stackers to have an almost equal net productivity rate.

The throughput scenarios differ a lot and the terminal adjustments should be adapted to the development of increase in throughput. The potential berth capacity of approximately 200,000 TEU/year is limiting the potential terminal capacity. Further terminal improvements, like upgrading equipment or stacking empty containers outside the terminal, intended to increase the terminal capacity are useless using only one berth. When the terminal requires a second berth it is advised to relocate the terminal elsewhere in the port. The most suitable location for a potential new container terminal is investigated in the next chapter.

5 Location of the potential new container terminal

When the throughput of the container terminal transcends the (potential) capacity of the current container terminal, it is possible that the terminal relocates to another location. In this chapter, the most suitable location for a potential new container terminal in the Port of Bahía Blanca is determined answering sub question 3. The CGPBB already considered this question using a multi-criteria analysis (MCA). In this MCA, the costs were taken implicitly into account using cost-related criteria. For the MCA performed by the CGPBB reference is made to Appendix L. In this chapter, in addition to an MCA, a cost-analysis is performed to determine the most suitable location. With this approach, the costs are more strictly separated from non-cost related aspects. This MCA is filled in by all four researchers, Pedja Zivojnovic, Pablo Arecco and specific members of the CGPBB; Carlos Gines, Juan Linares and Edgardo Spagnolo. The method of including multiple experts is used to achieve a reliable outcome.

5.1 Potential locations

Multiple areas around the existing port are currently unused and available for a possible port expansion. The areas which are suitable for a possible port expansion are depicted in blue in Figure 5.1. The green area represents the current port area and the yellow areas are high valuable environmental areas.

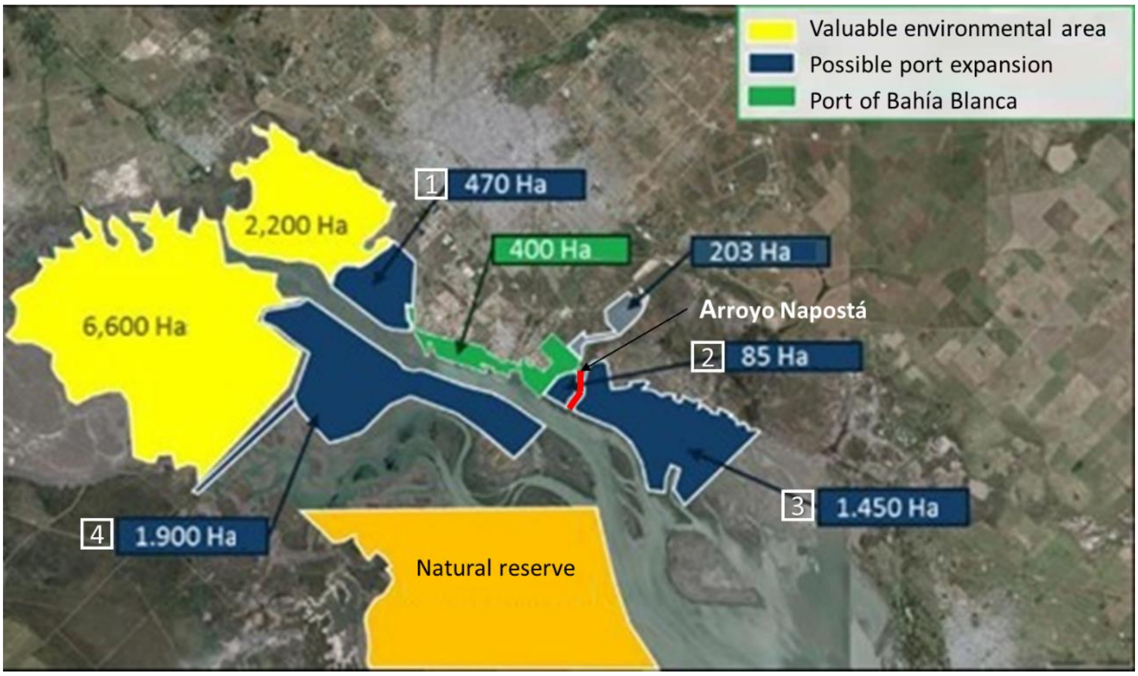


Figure 5.1 – Areas of possible port expansion (Adapted from Arecco, Besson, van Drunen, & Sendra, 2017)

Since the Port of Bahía Blanca is enclosed by the city of Bahía Blanca in the north, the possible areas of expansion are west, south or east of the port. The southern potential expansion area and the current terminals of the Port of Bahía Blanca are separated by the access channel. The two eastern areas are divided by the river Arroyo Napostá which provides cooling water for the adjacent company. Due to the large size of each area, especially for the southern area, the exact location for the terminal within each available area is given and numbered in Figure 5.2.

The different locations are:

1. **Location 1**
   The possible expansion area surrounding location 1 has a total surface of 470ha. The exact location (Figure 5.2) within this area is chosen close to existing port to reduce the extra dredging costs for the access channel. Furthermore, this location is located close to the jetties which transports inflammable cargo and the area is not owned by the CGPBB.
2. **Location 2**
   Due to the channel that provides cooling water for the power plant of Pampa Energia, the total size of this area is restricted to 85ha. This channel can be redirected if needed, but against certain costs and with certain limitations. The main advantage is its beneficial location with respect to the existing port and its infrastructure.
3. **Location 3**
   This area has a significantly larger area available than location 2, namely 1,450ha. However, it is located further away from the existing infrastructure. By choosing for this location the area of location 2 will be enclosed and less useful for other large port expansion projects.
4. **Location 4**
   Southern of the existing port and access channel, about 1,900ha is available for a new container terminal. This area is currently completely unused and at a large distance of existing infrastructure. Due to the large size of this area, one specific location within this area is chosen (Figure 5.2). Choosing for the west side would imply a lengthening of the access channel and therefore the location in the middle of the available area on top of an existing sand bank is chosen.

Figure 5.2 – Exact locations for the construction of the new container terminal (Adapted from Google, 2017)

5.2 Description of the methodology

The four locations have been analysed with a MCA to generate a preferable location. First, all the general criteria are described and the weight factor of each criteria is determined. All criteria are compared with each other, and weighed by each all four researchers to obtain the distribution of weight factors of the criteria. The outcome of the determination of the weight factors can be found in Appendix M After this, every combination of criterion and location is graded with a score ranging from 1 to 4 by the involved experts. The explanation of every score is showed in Table 5.1. After that, the cost-related criteria are described. Because it is difficult to estimate the (absolute) costs for each criterion, also the costs are compared relative to each other, but slightly different than the methodology of the general criteria. Location 1 is taken as a reference location and every cost-related criterion received the score 100. The other three locations have received scores depending on the relative difference in costs compared to the reference location, with low values for low costs and the other way around for high costs. Thereafter, the total scores of the MCA are divided by the total scores of the cost-related analysis and the location with the highest final score is obtained as the most suitable location.

Table 5.1 – Explanation scores MCA

Expected performance	Score
The alternative presents ideal conditions regarding the analysed criterion	+4
The alternative presents good conditions regarding the analysed criterion, with some problems which can be solved	+3
The alternative presents problems regarding the analysed criterion, which are difficult to resolve	+2
The alternative presents challenging issues that could even proscribe the design	+1

5.3 Criteria MCA

In the following section the different criteria, used in the MCA, are explained. The cost-related criteria are separated from the general criteria to get a fair comparison with respect to the quality of a location. An overview of the general criteria with the associated weight factor is given in Table 5.2. An overview of the different cost-related criteria is given in Table 5.3

Table 5.2 – General criteria MCA

Aspect	General criterion	Weight factor
Environmental impact	Nuisance to flora and fauna	7.4%
	Loss of flora and fauna	8.3%
Safety	Proximity of inflammable terminals	9.6%
	Vessel collision	2.9%
Technical factors	Expansion possibilities	13.5%
	Construction process	2.9%
	Capacity of the access channel	3.2%
Operational factors	Wind and wave conditions	9.9%
	Connection with the port area	8.7%
	Connection with the hinterland	9.0%
	Nautical access	4.8%
	Masterplanning of the Port of Bahía Blanca	7.1%
Third parties	Liveability of the residents	12.8%

Table 5.3 – Cost-related criteria

Cost-related criteria
Land reclamation terminal
Construction of railway
Construction of road
Dredging costs
Soil improvements
Expropriation land
Facility connections

5.3.1 General criteria

Environmental impact

The realisation of a container terminal will have different adverse effects on the environment caused by the construction and the operation of the terminal. Because of the construction of the terminal, fertile swamp area will disappear and the use of the terminal can cause substance in the environment. In the MCA a criterion about nuisance to flora and fauna due to the construction and operation of the new container terminal and a criterion about the loss of flora and fauna due to the construction of the new container terminal are considered.

Safety

The safety of the container terminal depends on the terminal itself, but also on the surrounding of the terminal. Other terminals of the Port of Bahía Blanca can be located close to the potential container terminal. Not only the distance to the other terminal influence the score of the different locations, but also the type of cargo of that terminal. Especially terminals that handle inflammable cargo can strongly increase the risk for the container terminal. Furthermore, the location of the terminal can influence the risk of vessel collision. For example, higher risks occur when the terminal is located in a curve of the access channel. In the MCA, a criterion about the risk due to adjacent inflammable terminals and a criterion about the risk of vessel collision mutually or with the berth(s) of the new container terminal are considered.

Technical factors

The Port of Bahía Blanca has a lot of opportunities to increase the container throughput, because of the export increase of petrochemical products due to the developments of Vaca Muerta and possibly the attracting of other containerized products. When the container terminal is relocated, the container throughput may grow further, so future expansion should be considered. When container throughput increases, the number of vessels calling the Port of Bahía Blanca will increase as well. The location of the new potential terminal can influence the required capacity of the access channel and port basin. During the construction of the new terminal, the other port users can be hindered. Especially during land reclamation, because the dredging vessels will use the access channel during these activities. In the MCA, a criterion about the flexibility to expand the container terminal in the future, a criterion about the time and hindrance of the construction of the new container terminal and a criterion about the possible delay for vessels due to the increasing number of port calls of the new container terminal is considered.

Operational factors

Determining the most suitable location of the new terminal, the wind currents and wave agitation in the port should be considered. Wave agitation inside or just outside the port is important to require the safety for vessels in approach, berthing and cargo handling stages. For container handling port berthing areas, maximum acceptable significant wave height is in the order of 0.50m, based on PIANC recommendations (Ligteringen & Velsink, 2012). An analysis about the possible wave generation is attached in Appendix N. Another important criterion in the determination of the most suitable location is the accessibility of the potential new container terminal. The terminal requires accessibility with respect to the production plants of containerized products such as Dow Argentina and Unipar Indupa. Furthermore, the terminal requires proper nautical access and accessibility to the hinterland to guarantee transportation of cargo as fast as possible. Also, the master planning of the Port of Bahía Blanca needs to be considered, to cluster or separate certain type of terminals. In the MCA, a criterion about the possible downtime of the new container terminal due to wind and/or wave impact, a criterion about the connection of the new container terminal with the existing port area, a criterion about the connection of the new container terminal with the hinterland, a criterion about the accessibility of the new container terminal for calling container vessels and a criterion about the long-term development and lay-out of the port of Bahía Blanca is considered.

Third parties

Planning an expansion of the port also social considerations should be taken into account. The realisation of a container terminal will have different adverse effects on the residents caused by the construction and the operation of the terminal. In the MCA, the nuisance of the residents due to the construction and operation of the new container terminal is considered.

5.3.2 Cost-related criteria

Land reclamation terminal

On each of the locations, the construction of the new terminal requires land reclamation. The amount of land reclamation depends on the current ground level. More elevated areas require less reclamation works and therefore receive a higher grade.

Construction of railway

The costs for the construction of the railway depends also on the required land reclamation. For this aspect, the ground level close to the proposed new railway connection is of importance. This is however not the only component; the distance to the existing rail connection and the need for bridges or tunnels is considered as well.

Construction of road

Similar to the previous criterion, these costs depend on the required reclamation, the length of the proposed new road and the crossing of rivers on the route.

Dredging costs

This criterion takes the extra maintenance dredging costs that comes with each specific location into account. A location west of the port requires lengthening of the access channel and an extra turning circle which is less beneficial.

Soil improvements

Depending on the soil profile, soil improvements are required to improve the bearing capacity, because heavy lifting and handling equipment cause high pressures on the foundation. Besides, for the design of the quay wall the soil profile is also of large importance. In case of a retaining wall, the length can be shorter with a better soil profile, which reduces material costs.

Expropriation land

Not all the area of possible port expansion is owned by the CGPBB. The area in the west does not belong to the CGPBB and therefore should be bought from a private institution, which can be costly.

Facility connections

A container terminal requires a lot of energy but also other facilities like water supply. Locations far from the current facility network of the port require larger investments.

5.4 MCA

The general criteria are scored by the different experts and results are shown in Appendix O. Some of the involved experts did not fill in the whole MCA, but only the criteria within their field of knowledge. The average of all the scores are multiplied by the weight factors to and showed in Table 5.4 to conclude upon the finding. The scores of locations 1, 2 and 3 are slightly different, in contrast to location 4 which is much lower. The results have to be compared with the cost analysis to conclude upon the findings.

Table 5.4 - Results MCA

Aspect	#	Criterion	Score for each criterion			
			Location 1	**Location 2**	**Location 3**	**Location 4**
Environmental impact	1	Nuisance to flora and fauna	18.4	24.0	21.2	18.4
	2	Loss of flora and fauna	21.9	22.9	22.9	19.8
Safety	3	Proximity of unflammable terminals	23.5	33.1	35.3	34.2
	4	Vessel collision	9.7	9.0	8.7	7.9
Technical factors	5	Expansion possibilities	47.9	32.9	46.4	49.4
	6	Construction process	7.6	7.6	7.2	6.9
	7	Capacity of the access channel	8.0	10.8	11.6	8.4
Operational factors	8	Wind and wave conditions	33.5	26.1	26.1	33.5
	9	Connection with the port area	26.9	27.9	22.1	9.6
	10	Connection with the hinterland	28.9	27.9	25.9	14.0
	11	Nautical access	12.6	15.6	16.2	15.0
	12	Masterplanning of the Port of Bahía Blanca	20.3	17.6	21.2	14.1
Third parties	13	Liveability of the residents	35.3	35.3	38.5	43.3
			295	**291**	**303**	**275**

In Table 5.4 the results of the MCA with the cost-related criteria are shown. The explanation of the values of every criterion is attached in Appendix P. Again, every criterion received a weight factor, representing the relatively costs of that criteria with respect to the other criteria. Location 1 is taken as a reference location and received the score 100 for each criterion. The other scores are depending on the relative difference in costs compared to the reference location, leading to an average score of the costs of the locations. Location 1 has the highest score, followed by location 2 and 3. The costs of realising a container terminal in location 4 is significantly higher than the other locations, concluded from the highest score. This analysis requires further research to determine more reliable costs, influencing the final scores of the locations.

Table 5.5 - MCA with cost-related criteria determining the location of the potential container terminal

Cost-related criteria	Weight factor	Location 1	Location 2	Location 3	Location 4
Land reclamation terminal	20	100	60	60	60
Construction of railway	15	100	180	180	400
Construction of road	10	100	80	100	300
Maintenance dredging costs	20	100	80	80	80
Soil improvements	20	100	180	180	120
Expropiation land	10	100	70	70	70
Facility connections	5	100	120	140	300
Score	**100**	**100**	**112**	**115**	**164**

The final score of each location is determined by dividing the score of the general criteria by the cost-related score and is shown in Table 5.6. The score of location 1, 2.95 is the highest, followed closely by location 3 and 2 and finally location 4.

Table 5.6 - Final score of MCA determining the location of the potential container terminal

	Location 1	Location 2	Location 3	Location 4
Final score	3.0	2.6	2.6	1.7

To verify the results, a sensibility analysis is executed where weight factors are not considered. In all the analyses location 4 has the lowest score, indicating that this location is not suitable as potential location for a new container terminal. The results of locations 1, 2 and 3 of the MCA without using weight factors are no more than 2.5 percent different. Moreover, the results of the MCA including the weight factors are also not more than 3 percent apart. These differences are rather small and because of error margins in the analysis no convincing best score was obtained. Taking the costs into account, location 1 has the most favourable score with and without including the weight factors. The difference between location 1 and locations 2 and 3 is slightly bigger now. However, the cost-related scores are very rough estimations and further research is required to be able to conclude what is the most suitable location for a potential new container terminal.

5.5 Conclusion

Since the results of the MCA of locations 1,2 and 3 are close to each other, a conclusive advice for the best location for a new container terminal cannot be provided. It can be concluded that the new container terminal should be designed and constructed either west or east of the port complex. The main advantage of the west location is that the terminal can be integrated into the petrochemical cluster, which is still developing. A fully efficient cluster can be constructed, in which companies benefit from each other’s presence. When the terminal is built in the West, the terminal will be located close the inflammable terminals increasing the risks. The location in the East is less hindered by the proximity of inflammables and is more favourable when separation of clusters is desired.

The opinions within the CGPBB and their advisors about the most suitable location of a possible new container terminal has been deeply divided. Independent assessment by a professional organization of location 1 and 3 is recommended. Especially including a more thorough research into the cost differences between the options.

6 The competitiveness of the Port of Bahía Blanca

Taking the possible relocation of the container terminal into account, the Port of Bahía Blanca can play a significant role regarding the future container throughput in Argentina. For this development, shipping via or to the Port of Bahía Blanca should be financially competitive to shipping via other ports. This chapter provides an analysis of the competitiveness of the container terminal in Bahía Blanca. First, the motivation for this analysis is substantiated. Hereafter, the Port of Buenos Aires (PoBA), responsible for the highest container throughput in the country, and the Port of Bahía Blanca (PoBB) are compared on a general level after which the cost for calling both ports are analysed. Finally, the current shipping routes are analysed and the possibilities of Bahía Blanca are examined. At the end of this chapter, sub question 4 is fully answered.

6.1 Container throughput of Argentina

When analysing the container throughput of Argentina, it strikes that the country is ranked sixth of South America in terms of number of TEU transported, accounting for only 7% of the total throughput. In contrast, 13% of the total tons exported of the continent is from Argentina and it is the third largest economy in this aspect (Figure 6.1). Additionally, the country is ranked second in South America when considering Gross Domestic Product (GDP), after Brazil and just before Chile (The World Bank Group, 2017c). In fact, Argentina shows the lowest ratios when considering the number of TEU per inhabitant and the number of TEU per GDP, for the whole continent (BancoMundial, 2017).

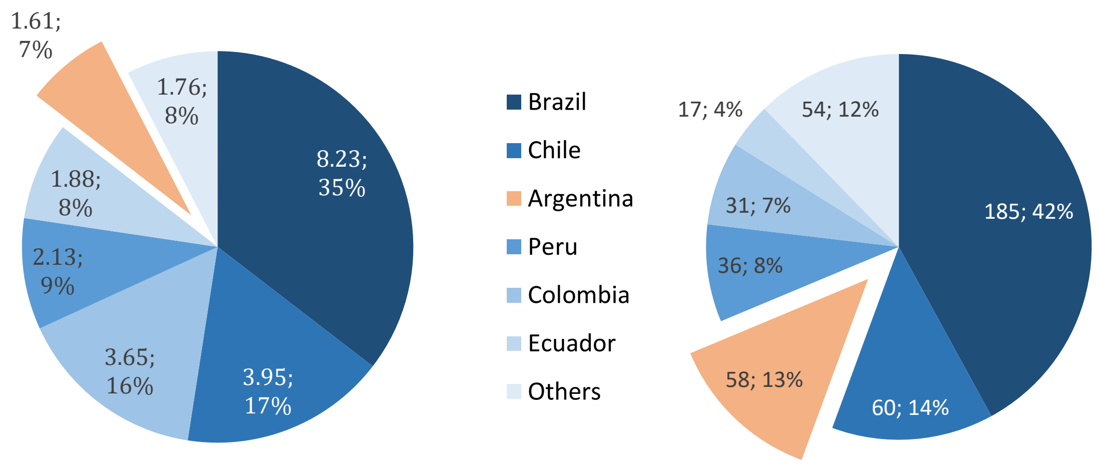


Figure 6.1 – Total container throughput in 2015 in million TEU (left) and relative contribution of biggest economies to the total export of 2016 in U$D billion (right) in South America (Workman, 2017; CEPAL, 2015). Argentina is highlighted in both figures

Even though the figures above might indicate little potential for the container industry in Argentina, a different conclusion can be drawn as well. Namely, the significant potential of the country to increase its container throughput. To highlight this potential, a comparison between Chile and Argentina is made. Both countries have a GDP per capita which is rather similar. In Figure 6.2 the number of inhabitants and GDP of both countries are compared relative to the container throughput. The numbers show that the container throughput of Chile is approximately 2.5 times that of Argentina, whereas the number of inhabitants is approximately 2.5 times less. Trade agreements of Chile with other countries, for example, import and export with the USA and China is duty free, play a significant role in cost reduction and thus in the amount of container throughput (export.gov, 2017). Argentina has been more conservative with comparable agreements. However, this might change when increasing container throughput will be more important from a political point of view. When throughput indeed increases, container handling in the ports located in Buenos Aires city will become a challenge. The limited draught might lead to inefficient operations of the shipping lines.

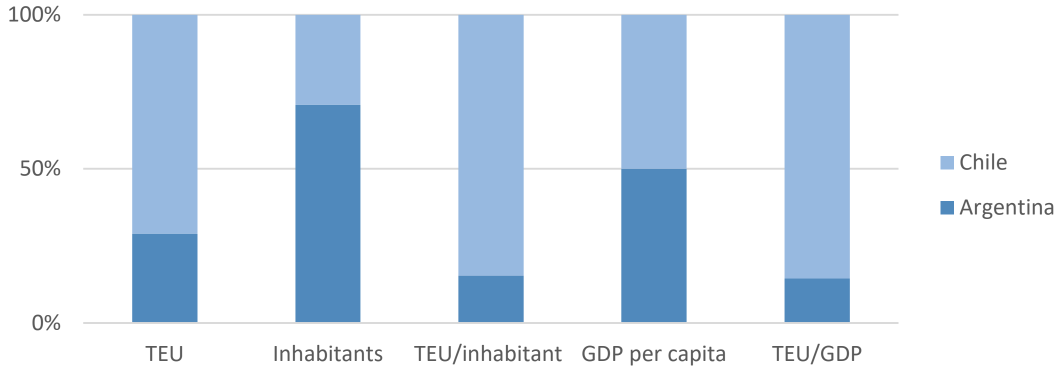


Figure 6.2 – Comparison of container throughput between Argentina and Chile in 2016 (BancoMundial, 2017)

A possible efficient and economically profitable alternative to the current situation might exist. In contrast to the ports located in Buenos Aires city, and the Port of Zárate, the depth in the Port of Bahía Blanca is significantly larger and has the potential to increase even further. As such, the Port of Bahía Blanca might be able to attract more containerized cargo to their port. The associated costs of the current and alternative shipping routes via the Port of Bahía Blanca is therefore addressed. It is essential that this alternative route is economically competitive for the Port of Bahía Blanca to be an option at all.

6.2 The Port of Bahía Blanca compared to the Port of Buenos Aires

In this section, the main characteristics of both ports are compared to give an overview of the differences between both ports and the opportunities for the PoBB. Most of these characteristics will also lead to cost differences between the two ports which are further analysed in the next sub chapter.

6.2.1 Management structure

As stated, the PoBB is managed and operated by the CGPBB. This consortium is a non-state public entity which differ from the organisation of the PoBA, which is state-owned. The advantage for an autonomous port like Bahía Blanca is the independency, leading to a reduction of response times for investment analyses and decision making. Since the financing originates of funds from its own management, the port is not dependent on the public budget from the state. State-owned ports do not enjoy these benefits.

6.2.2 Geographical location

One of the most important aspects of a port is its geographical location, in specific the distance to the main consumption and production areas. For both aspects, the PoBA is more conveniently located compared to the PoBB. Approximately 12 million people live in the agglomeration Buenos Aires city, which makes it the most important consumption area of the country. The PoBB is located

600km South which is a drawback considering its distance to the hinterland. One of the main geographical advantages of the PoBB, with respect to the PoBA, is the length of the access channel; 97km versus 239km for Buenos Aires. This results in lower access costs in terms of sailing time for vessels calling the PoBB.

6.2.3 Hydraulic conditions

With respect to the hydraulic conditions of both ports, the PoBB has two important benefits compared to Buenos Aires where the port is currently not able to take advantage of. The first one is the draught; the access channel to Bahía Blanca has a depth with respect to the MLWS of minimum 12.8m, while Buenos Aires only has a depth of 10.4m with respect to the port its local zero. Therefore, container vessels calling the PoBA cannot be fully loaded, while this is not a problem in Bahía Blanca. The depth in the PoBA can be deepened to 11m with extra dredging, but still the port is limited to have fully loaded vessels calling. The second advantage is the amount of required yearly dredging. Buenos Aires is located at the estuary Rio de la Plata, which is confluence of the Paraná River and the Uruguay River. These rivers supply large volumes of sediment to the access channel of Buenos Aires. Significant amount of dredging is required of which the costs are included in the use of the waterway.

6.3 Financial analysis of port calling

In this section, the cost of calling the PoBB and the PoBA are compared to increase understanding of the competitiveness of the container terminal in Bahía Blanca. Research is done into the composition of the total costs for calling a port. These costs can be mainly divided into costs related to the vessel and costs related to the cargo (Figure 6.3). A further explanation of the different cost and how they are composed can be found in Appendix Q. Only the main cost components, of which most significantly differ between the two ports, are considered in this financial analysis. These components are depicted in bold in Figure 6.3.

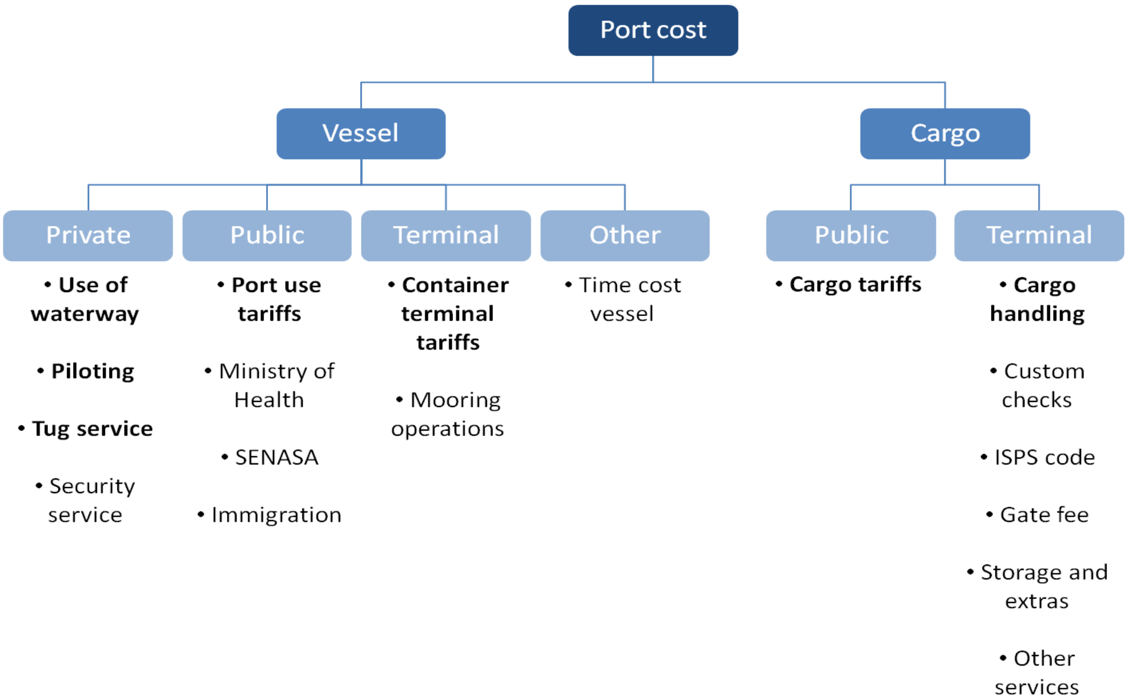


Figure 6.3 – Port calling cost divided in categories (Adapted from Secretaría de Política Económica y Planificación del Desarollo, 2014)

6.3.1 Reference situation

Executing a fair cost calling comparison of both ports, it is important to choose a reference vessel and a reference operation. First the reference vessel will be elaborated on after which the reference operation is explained.

Reference vessel

For the operations considered in the remainder of this chapter, the Cap San Nicolas is chosen as reference vessel (Figure 6.4). This Post-Panamax vessel operated by Hamburg Süd, currently calls for Terminal Rio de la Plata in Buenos Aires within a shipping route to Europe via other ports along the South American coast (Maersk Line, 2017). Since the access channel of the PoBB already can handle these seizes of vessels, cost for both ports can be estimated. The characteristics of the reference vessel are shown in Table 6.1.

Figure 6.4 – Cap San Nicolas (MKPhotography, 2017)

Table 6.1 – Characteristics of the Cap San Nicolas (Aliancia, 2017)

CAP SAN NICOLAS	
Gross Register Tonnage (GRT)	118,938
Net Register Tonnage (NRT)	51,759
Deadweight Tonnage (DWT)	124,458 tons
Nominal capacity	9,600 TEU
Length x Breadth x Max. Draught	333.0m x 48.2m x 14.0m

Reference operation

The reference operation that is considered contains the transportation of cargo from an unknown destination to the storage area of the container terminal. To analyse the competitiveness of the PoBB two scenarios are distinguished. In the first scenario, the reference vessel is calling the container terminal in the PoBB. In the second scenario, the reference vessel is calling the Terminal Rio de la Plata in the PoBA (Table 6.2). This terminal has, within the PoBA, the highest container throughput.

Since the depth in the PoBA is a limiting factor for container vessels, two situations will be considered which differ in load. One situation, where both ports can be called by one vessel, and one situation where the PoBA needs two vessels as result of the depth limitations of the access channel to the PoBA, whereas the PoBB can still handle the larger draught of one vessel (Table 6.2). The draught that a vessel can reach for different utilisation rates and vessel capacities were analysed for non-tailor-made vessels (Merk, 2017). Considering the fact that vessels calling for South America have a lower draught, the values of the aforementioned study were adapted according to the mutual ratio. The utilisation rate, for which our reference vessel is still able to call for Terminal Rio de la Plata, is 50%. In situation I, an operation with an utilisation rate of 45% is shown, while situation II an utilisation rate of 55% is described. These values are used to analyse the operations just before and just after the depth of 10.4m in the PoBA becomes a problem.

Table 6.2 – Overview of the reference operation

	Scenario I (to the PoBB)	Scenario II (to the PoBA)
Situation I (2,160 FEU)	 PoBB	 PoBA
Situation II (2,640 FEU)	 PoBB	 PoBA

Additional remarks regarding the reference operation:

- It is assumed that the reference vessel only transports and handles FEU. Currently significantly more FEU than TEU are handled at the analysed ports and this ratio is developing even further to more FEU. Moreover, reefer containers are excluded to make the calculation not too extensive.
- All FEU are assumed to have a total weight of 25 tons, including cargo. This value is determined from the number of tons and containers handled by Patagonia Norte in 2016 (CGPBB, 2017a).
- 51% of the FEU which are being handled by the vessel are exported and 49% is imported. These values represent the percentages of container import and export of the PoBA in 2016 (Puerto Buenos Aires, 2016). Of all the export containers, the ratio of full/empty containers is 52/48 respectively. For import this ratio is 90/10.
- For all port calls, each vessel is assumed to stay in the port for one day. Since the PoBA is called by two vessels in second situation, two days are considered here. The crane at Patagonia Norte is assumed to be upgraded so every vessel can be (un)loaded within one day.
- For situation II, where two vessels are calling for the PoBA, both vessels transport half the number of containers. Moreover, these two vessels are expected to be charged the same as our reference vessel.

6.3.2 Cost analysis

As stated before, not all costs related to the calling of a port, are included in the analysis. Since the aim of this chapter is to analyse the competitiveness between the two ports, only the most important cost components are considered. Here, those costs will be elaborated on and a value for each cost component is provided. Most of the costs components are composed of multiple elements which can be found in Appendix R with their value.

Calling the Port of Bahía Blanca

Container vessels calling for the PoBB have the advantage of being exempted or charged less for most of the port calling cost compared to other type of vessels. An increasing throughput in the PoBB might lead to the situation where container vessels will be charged the same as other type of vessels. Therefore, the cost for calling the PoBB will be calculated for both the container vessels and the other vessels. All values for calling the PoBB for the different utilisation rates are depicted in Table 6.3. Costs for which container vessels currently are exempted are the **use of waterway cost** and the **port use tariffs** (CGPBB, 2017b). The use of waterway cost for other vessels is charged per amount of cargo that is transported and is only charged for entering the port, not for exiting. Another advantage for container vessels are the **cargo tariffs,** where a discount of 50% is taken into account, for both the import and export containers (CGPBB, 2017b). **Piloting** and **tug service cost** are estimated by the operation manager of the PoBB, since vessels calling for Bahía Blanca nowadays are not comparable to the reference vessel considered (Linares, 2017). The piloting and tug service for both entering and exiting the port are included in these values. The **container terminal tariffs** are port specific and generated by the shipping line responsible for the operation, which is Hamburg Süd in this reference operation (Hamburg Süd, 2017c). For the PoBB a high tariff of U$D 320 per container is charged.

Table 6.3 – Calling cost for the PoBB with a 45% and 55% utilisation rate

Port of Bahía Blanca			Port of Bahía Blanca		
Situation I - Throughput 2,160 FEU			**Situation II - Throughput 2,640 FEU**		
	Container vessels	**Other vessels**		**Container vessels**	**Other vessels**
USE OF THE WATERWAY [USD]	-	41,662	**USE OF THE WATERWAY [USD]**	-	50,921
PILOTING (2 ways) [USD]	18,000	18,000	**PILOTING (2 ways) [USD]**	18,000	18,000
TUG SERVICE (2 ways) [USD]	62,000	62,000	**TUG SERVICE (2 ways) [USD]**	62,000	62,000
PORT USE TARIFFS [USD]	-	19,151	**PORT USE TARIFFS [USD]**	-	19,151
CONTAINER TERMINAL TARIFFS			**CONTAINER TERMINAL TARIFFS**		
Export [USD]	352,512	352,512	Export [USD]	430,848	430,848
Import [USD]	338,688	338,688	Import [USD]	413,952	413,952
CARGO TARIFFS			**CARGO TARIFFS**		
Export [USD]	4,654	9,309	Export [USD]	5,689	11,377
Import [USD]	17,503	35,007	Import [USD]	21,393	42,786
TOTAL [USD]	**793,358**	**876,328**	**TOTAL**	**951,881**	**1,049,034**
Price per container [U$D/TEU]	**184**	**203**	**Price per container [U$D/TEU]**	**180**	**199**

Calling the Port of Buenos Aires

The same factors of calling the PoBB are now analysed for the PoBA of which the values are shown in

Table 6.4. A previous study regarding the cost estimation for a vessel calling the PoBA has been executed by A. Filadoro and J. Sánchez (2016). Their aim was to identify and systematize the different costs for importing and exporting containers in the Port of Buenos Aires. Their reference vessel has a nominal capacity of 7,500 TEU, which is less than the reference vessel used in this report. The **piloting cost and tug service cost** are assumed the same for both vessels. These cost, differ significantly between both ports. The piloting cost are more advantageous in the PoBB, while in the PoBA the tug service costs are more economical. The cost for **use of waterway** have to be paid twice in the PoBA which resulting in a significant cost component for calling the port (Temer, 2017). This is in contrast with the cost structure in the PoBB where the use of waterway is charged only once. The **port use tariffs** and **cargo tariffs** are provided by the port (Puerto Buenos Aires, 2017). Especially the cargo tariffs, are significantly higher compared to the tariffs charged in the PoBB. For both the import and export containers, the tariff in the PoBA is six times as high as the tariffs charged in the PoBB. As mentioned before, Hamburg Süd provides the **container terminal tariffs** which are cheaper for the PoBA (Hamburg Süd, 2017c). The shipping line charges only U$D 220 per container in the PoBA, probably due to the economies of scale and agreements mutually.

In situation II, where two vessels are necessary to call for the PoBA due to the draught limitation, cost are associated to this additional call. All cost that depend on the number of containers or on the number of tons being transported are not considered twice, since this amount is still the same in both scenarios. Besides cost for the use of waterway, piloting and tug service cost, other cost related to the additional vessel do not result in a significant difference.

Table 6.4 – Calling cost for the PoBA with a 45% and 55% utilisation rate

Port of Buenos Aires	
Situation I - Throughput 2,160 FEU	
USE OF THE WATERWAY [USD]	101,000
PILOTING (2 ways) [USD]	45,000
TUG SERVICE (2 ways) [USD]	39,000
PORT USE TARIFFS [USD]	24,068
CONTAINER TERMINAL TARIFFS	
Export [USD]	242,352
Import [USD]	232,848
CARGO TARIFFS	
Export [USD]	28,642
Import [USD]	95,256
TOTAL [USD]	**808,166**
Price per container [U$D/TEU]	**187**

Port of Buenos Aires	
Situation II - Throughput 2,640 FEU	
USE OF THE WATERWAY [USD]	202,000
PILOTING (2 ways) [USD]	90,000
TUG SERVICE (2 ways) [USD]	78,000
PORT USE TARIFFS [USD]	48,136
CONTAINER TERMINAL TARIFFS	
Export [USD]	296,208
Import [USD]	284,592
CARGO TARIFFS	
Export [USD]	35,006
Import [USD]	116,424
TOTAL [USD]	**1,150,366**
Price per container [U$D/TEU]	**218**

Additional remark regarding the reference operation:

- The **cargo handling** costs, which were indicated as main cost component, are not taken into account in the determination of the port calling cost. These costs are charged by the terminal operator to transport containers between the storage area and the mode used for transportation inland, which is commonly done by truck. Since the reference operation is considered until the storage area, the cargo handling cost for imported containers do not have to be included. Moreover, the origin of the containers which are being exported is not known. The containers could have arrived via sea or via land, but assumed is that containers are already located at the storage area for transport, excluding the cargo handling cost for imported containers as well. It should be mentioned that Patagonia Norte is able to charge a higher tariff, of U$D 151 per container, due to a lack of competition from other container operators (CGPBB, 2017b). Terminal Rio de la Plata charges a different tariff for containers being exported or imported, U$D 122 and U$D 161 respectively (Terminales Rio de la Plata, 2017).

Looking at the results, even though some of the port calling cost are in favour of the PoBB, the price per container is almost the same as in the PoBA when calling with one vessel; U$D 184 and U$D 187 per container respectively. When the draught of the vessel becomes a limitation for the PoBA, the price per container is becoming more advantageous for the PoBB, U$D 180 for calling the PoBB and U$D 218 for calling the PoBA. However, increasing the utilisation rate of the vessel becomes less profitable for the PoBB compared to the PoBA (Table 6.5). Since the use of waterway cost are charged per tons in the PoBB, increasing the utilisation rate of the vessel also increases this cost factor. On the other hand, in the PoBA the use of waterway cost remain the same since they are charged per vessel. Moreover, the difference of the container terminal tariffs between both ports is U$D 100 per FEU, having a large impact on the average price per container between both ports. Both cost aspects will disadvantage the PoBB when throughput is increasing.

Table 6.5 - Port calling cost for higher utilisation rate values

Utilisation rate [%]	Port calling cost PoBB (container vessels) [U$D/TEU]	Port calling cost PoBB (other vessels) [U$D/TEU]	Port calling cost PoBA [U$D/TEU]
60	179	197	211
70	177	195	201
80	176	193	193
90	174	191	187
100	173	190	182

6.4 Shipping route analysis

Although the financial analysis did not show a significant advantage to transport containers via the PoBB, the port might become competitive with the PoBA, when the current shipping routes are taken into consideration. Within the current shipping routes between South America and other continents, the PoBA is called last, before the vessel returns to continent of origin (Hamburg Süd, 2017b). Analysing the shipping routes in further detail, shows some striking observations. For instance, the Port of Santos is called in every shipping route twice. Moreover, multiple ports are called on both ways. One of the shipping routes, coming from Asia, is shown in Figure 6.5 and visualizes the aforementioned observations.

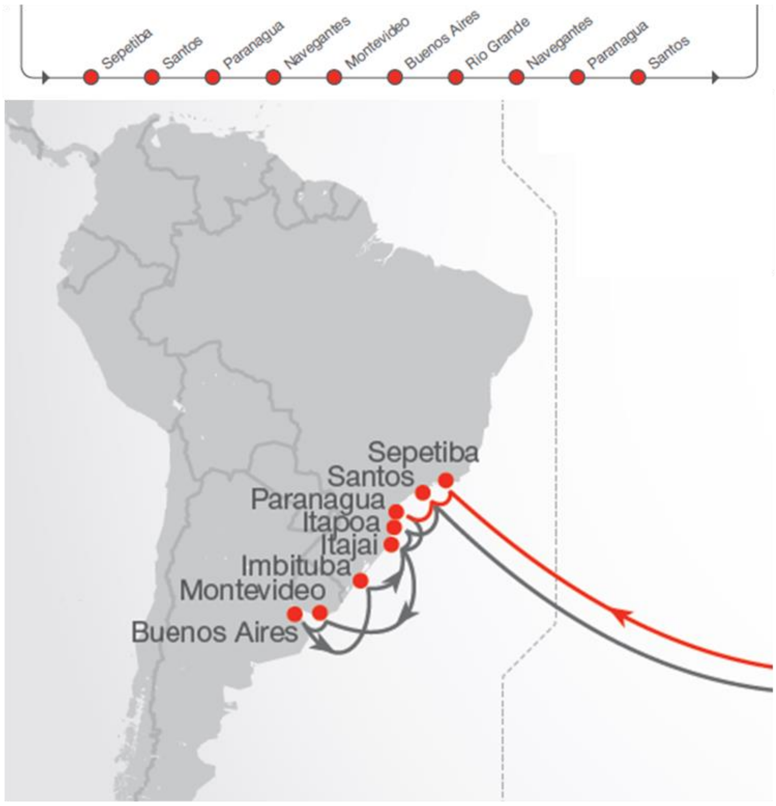


Figure 6.5 - Shipping route between Asia and South America (Hamburg Süd, 2017b)

The double call in the ports with a sufficient throughput along the route, can be the consequence of the draught restrictions in the PoBA. This would imply that the vessel is being unloaded on its way to Buenos Aires, and being loaded on the way back. The disadvantage of such an operation is that vessels are only partially loaded when sailing along the South American coast and extra port calling cost should be considered. Since the container export of Brazil, in number of tons, is more than the container import of the country, the number of calls on the way back is higher (OEC, 2017). Still, the current shipping lines call for all these ports instead of introducing a local route or feeder service to reduce the amount of port calls on the main shipping route.

6.5 Conclusion

In this chapter, the potential of attracting containerized cargo transported via the ports located around Buenos Aires city to the Port of Bahía Blanca was analysed. The hydraulic conditions of the Port of Bahía Blanca are more favourable compared to those of Buenos Aires. The possibility to increase depth in the port offers opportunities when national throughput will increase significantly. However, the Port of Buenos Aires is currently not operating at capacity and is in the position to increase the current throughput. Development of a new transhipment hub is therefore not a necessity now. Three additional reasons make it unlikely that container transport will shift from the ports located around Buenos Aires city to the Port of Bahía Blanca;

- The Port of Buenos Aires has the advantage of currently handling most of the container throughput, and being most conveniently located close to consumption and production areas.
- Minimal differences between port calling costs of both ports are observed.
- It is unlikely that the shipping lines will change their route majorly.

7 Conclusion

This chapter aims to answer the main research question formulated in the introduction. Regarding the sub questions, these are not repeated here since they have been addressed throughout the report in the corresponding chapters. The findings of all the sub questions together, form the overall conclusion of the report and answers the main research question:

How can the Port Authority of Bahía Blanca adapt to the future developments in container throughput?

Regarding the expected container throughput and the current capacity of the container terminal, a new container terminal is possibly required. Even though this might be inevitable in the future, the current container terminal has many opportunities to increase in capacity. By means of four area expansions the capacity of the container terminal can reach a capacity of more than 200,000 TEU. These expansions range from a relatively simple and low in price expansion to larger and more expensive expansions. Next to the cost, the social aspect of the different expansions is of importance. Three of the four expansions require a relocation of current activities and facilities, which is a delegate process.

Compared to improving the current terminal, high costs are associated to the construction of a new terminal. It is advised to improve the current container terminal before relocation of the terminal is considered. Looking at the throughput trends, the current terminal can be in use for a long period of time when improvements are implemented.

The potential capacity of approximately 200,000 TEU is restricted by the number of berths. Transcending this throughput, waiting times for container vessels can become too high and relocating the terminal is advised. However, the advised maximum waiting time of 10% of the service time is not a hard restriction. The CGPBB should take this into consideration when deciding on their future steps. The location of the new container terminal should be either west or east of the port complex. There is significant disunity within the port authority considering the most suitable location for a new container terminal. The research conducted on the differences between the locations was not thorough enough to be able to advice on the most suitable location.

When in the future increase in throughput require the construction of a new container terminal, the container throughput in Patagonia Norte will most likely become close to zero. The purpose of the terminal should be decided upon before relocating the container terminal. Different options are likely; handling of general cargo and the creation of recreational area. In the first situation, an increased area and a convenient surface is of importance as well. Investing in the container terminal would therefore be an investment in its new purpose as well. In the latter situation, investments in area expansion are less important for the future purpose, increasing the importance of considering moving to a new container terminal.

8 Recommendations and reflection

Finalising this report several recommendations regarding our research are mentioned. These recommendations can be considered by the CGPBB to continue with the investigation of the future container throughput in the Port of Bahía Blanca and the adaptation of the container terminal to these developments.

- Advised is to monitor the throughput developments of the coming years and adapt the current terminal to these developments. The current terminal has potential to increase their capacity and handle up to approximately 200,000 TEU/year. Only when the throughput transcending above this order of magnitude, a new location is required.
- Production areas close to Bahía Blanca which can increase the container throughput of the port should be considered when making estimations regarding the future container throughput. Their destination, current shipping route, and the magnitude should be identified.
- Thorough financial analysis regarding the potential terminal expansions is required to determine if the proposed improvements within the current container terminal are profitable.
- Thorough financial analysis of the construction of a new container terminal as well as independent professional investigation in different criteria of the MCA are required to determine the most suitable location of the new terminal.
- When considering the possibility to attract cargo from different ports in Argentina, further analysis of the current study is required. First, port calling costs for all ports on the shipping routes should be estimated, as well as estimating the cost of operating a feeder service between the Brazilian and Argentinean ports. Additionally, the financial analysis can be improved and additional reference vessels should be included to compare the costs of the Port of Bahía Blanca and the Port of Buenos Aires.

Reflection

Looking back at the project there are several improvements that we could have made as a team. To start, we experienced difficulties setting the right scope as our interests and the necessities for the CGPBB where not always aligned. We decided to execute an exploratory study, including all phases of expansion. Looking back, focussing on only one subject could have given interesting results as well. In addition, allowing ourselves time to brainstorm in more depth about the feasibility of the proposed vision of the CGPBB could have saved time later in the project. However, there are several aspects on which we improved upon already during the project. Such as the strict preparation for any meeting, providing and receiving feedback from the additional team members and overviewing the project when working in detail.

Bibliography

Aliancia. (2017). *Cap San Nicolas*. Retrieved October 19, 2017, from http://www.alianca.com.br/alianca/en/alianca/product_services_alianca/fleet_alianca/vessel_1/index_922381.html

Arecco, P., Besson, V., van Drunen, E., & Sendra, L. (2017). *Port Scan; Plan Estratégico para el complejo portuario de Bahía Blanca.* Rotterdam & Buenos Aires: Port Consultants Rotterdam B.V.

BancoMundial. (2017, February). *Datos de libre acceso del Banco Mundial*. Retrieved from Banco Mundial: http://datos.bancomundial.org/

Böse, J. (2011). *Handbook of Terminal Planning.*

Bosso, D. (2017a, November 8). CGPBB. (Projectteam, Interviewer)

Bosso, D. (2017b, November 7). CGPBB. (Projectteam, Interviewer)

CEPAL. (2015). *Movimiento de contenedores en puertos de America Latina y el Caribe Ranking 2015*. Retrieved from CEPAL.

CGPBB. (2011). *Investigation of sedimentation of the access channel of the Port of Bahía Blanca.*

CGPBB. (2013/14). *Anuario Puerto Bahía Blanca.* Anuario Portuario y Maritimo.

CGPBB. (2016a). Camiones y vagones; Toepfer/TBB/Cargill/Moreno-Dreyfus/Profertil 2016.

CGPBB. (2017a). 19 Tipo de productos y cantidad de buques por terminales.

CGPBB. (2017b). *CAPITULO VIII.*

CGPBB. (2017c). *Muelle Multipropósito Sitio 21 Puerto Ing. White*. Retrieved October 5, 2017, from http://puertobahiablanca.com/muelle-multi.html

CGPBB. (2017d). Patagonia Norte 2017.

CGPBB. (2017e). *Plano General*. Retrieved October 5, 2017, from http://puertobahiablanca.com/plano-general.html

CGPBB. (2017f, September 17). Presentation. Bahía Blanca.

CGPBB. (2017g). *Visión Portuaria Bahía Blanca 2040.* Bahía Blanca: Consorcio de Gestión del Puerto de Bahía Blanca.

Container transportation. (2014). *World's largest container ship*. Retrieved November 9, 2006, from Container transportation: http://www.container-transportation.com/worlds-largest-container-ship.html

de Ortuzar, E. (2017, October 13). Sales Executive Hamburg Süd. (Projectteam, Interviewer) export.gov. (2017, 8 15). *Chile - Trade Agreements*. Retrieved from export.gov: https://www.export.gov/article?id=Chile-Trade-Agreements

Filadoro, A., & Sánchez, J. (2016). *Identificación y estimación del costo para una operación de comercio exterior en el Puerto de Buenos Aires.*

Ginés, C. (2017, November 14). CGPBB. (Projectteam, Interviewer)

Google. (2017, July 20). *Google Earth*. Retrieved October 16, 2017, from https://earth.google.com/web/

Groeneveld, R. (2001). *Service Systems in Ports and Inland Waterways.*

Hamburg Süd. (2017a, October 6). *ABAC*. Retrieved October 6, 2017, from https://www.hamburgsud-line.com/liner/media/hamburg_sud_liner_shipping/liner_services/mercosur/ABAC_HamburgSud.pdf

Hamburg Süd. (2017b). *Liner Services.* Retrieved November 9, 2017, from https://www.hamburgsud-line.com/liner/en/liner_services/liner_services_2/asia_north_south/index.html

Hamburg Süd. (2017c). *Tarife und Zuschläge*. Retrieved October 30, 2017, from http://ecom.hamburgsud.com/ecom/de/ecommerce_portal/tariffs_and_surcharges/thc_calc/ep_thc_calculator.xhtml

International Monetary Fund. (2017). *Real GDP growth - Annual percentage change*. Retrieved November 8, 2017, from imf: http://www.imf.org/external/datamapper/NGDP_RPCH@WEO/OEMDC/ADVEC/WEOWORLD/ARG

Larralda, G. (2017, October 5). Patagonia Norte S.A. (Projectteam, Interviewer)

Ligteringen, H., & Velsink, H. (2012). *Ports & Terminals.*

Linares, J. (2017, October 24). CGPBB. (Projectteam, Interviewer)

Maersk Line. (2017). *Maersk Line Schedules*. Retrieved October 19, 2017, from https://my.maerskline.com/schedules/vesselresults?b.voyageCode=CAP+SAN+NICOLAS+++&b.vesselFromDate=03%2F05%2F2017&b.vesselToDate=28%2F06%2F2017&b.vesselCode=0PP

Marchionni, M. (2017, October 20). YPF. (Projectteam, Interviewer)

Merk, O. (2017). *The container port of Buenos Aires in the mega-ship era.* Internation Transport Forum.

MKPhotography. (2017). *FleetMon*. Retrieved October 24, 2017, from https://www.fleetmon.com/vessels/cap-san-nicolas_9622203_8321575/

Moffatt & Nichol. (2015). *Port pavement design guide*. Retrieved from https://www.portoflosangeles.org/pdf/Port_Pavement_Design_Guide.pdf

OEC. (2017). *Brazil statistics*. Retrieved November 9, 2017, from https://atlas.media.mit.edu/en/profile/country/bra/

PIANC. (2014). *Masterplanning for the development of existing ports.*

Pirillo, J. (2017, October 6). Dow Argentina. (Projectteam, Interviewer)

Puerto Buenos Aires. (2016). *Puerto de Buenos Aires Informe Estadístico Año 2016.*

Puerto Buenos Aires. (2017). *Tarifas por uso de puerto.* Retrieved October 23, 2017, from http://www.puertobuenosaires.gov.ar/tarifario-/68

Quist, P., & Wijdeven, B. (2014). *Ports & Terminals Handout chapter 7: Container terminals.*

Schäfer, D. (2014). *Container Terminal Foresite 2020*. Retrieved from ctf2020: http://www.ctf2020.info/

Secretaría de Política Económica y Planificación del Desarollo. (2014, October). Puerto de Buenos Aires: Cadena logística de una operación de comercio exterior.

Temer, L. (2017, November 8). Hidrovía S.A. (Projectteam, Interviewer)

Terminales Rio de la Plata. (2017). *Tarifario de Exportacion y Importacion.*

The World Bank Group. (2017a). *Container port traffic (TEU: 20 foot equivalent units)*. Retrieved November 10, 2017, from The World Bank Group: https://data.worldbank.org/indicator/IS.SHP.GOOD.TU

The World Bank Group. (2017b). *GDP (current U$D)*. Retrieved November 10, 2017, from The World Bank Group: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD

The World Bank Group. (2017c). *GDP (current U$D)*. Retrieved from The World Bank Group: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?year_high_desc=true

The World Bank Group. (2017d). *GDP Growth*. Retrieved November 9, 2017, from https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=BR

TheStatisticsPortal. (2017). *Volume of container cargo handled in the ports of Argentina from 2012 to 2016 (in million TEU)*. Retrieved from The Statistics Portal: https://www.statista.com/statistics/735083/container-port-cargo-volume-argentina/

Vrijling, J. B. (2015). *Manaul Hydraulic Structures.*

Weeden, S. L. (2011, October 3). *Argentina's Shale-Gas Plays Bring Back Majors*. Retrieved from EPMAG: https://www.epmag.com/argentinas-shale-gas-plays-bring-back-majors-668176#p=3

Workman, D. (2017, 07 8). *Top South American Export Countries*. Retrieved from World Stop Exports: http://www.worldstopexports.com/top-south-american-export-countries

Appendices

Appendix A – Port analysis

This appendix analysis the Port of Bahía Blanca on several aspects. First the different terminals are being categorized and for each terminal the throughput is given to get an overview of their scale. Hereafter, the accessibility of the Port of Bahía Blanca is analysed, looking into both the road and the rail network.

Terminals within the Port of Bahía Blanca

The Port of Bahía Blanca provides space to 13 terminals. An interruption in investment suspended the building of the fourteenth terminal, the Vale terminal aimed to process minerals from the mining industry. The existing terminals are, as said in the introduction, rather diversified. Table i depicts all the terminals located in the Port of Bahía Blanca together with their industry.

Table i - Terminals within the Port of Bahía Blanca (CGPBB, 2013/14)

	Terminals	Industry
Puerto Galván	Posta de inflamables - Posta 1 - Posta 2 - Posta 3	Petrochemical industry
	Oleaginosa Moreno S.A.	Agro-industry
	Sitio 5 y 6	General cargo
Cangre-jales	Louis Dreyfus Commodities	Agro-industry
	MEGA S.A.	Petrochemical industry
	Profertil S.A.	Petrochemical industry
Ingeniero White	Multipurpose terminal	Containers
	Cargill S.A.	Agro-industry
	Ministro Carranza	General cargo
	Terminal Bahía Blanca S.A.	Agro-industry
	Toepfer	Agro-industry

The throughput of the port is mainly generated by the agro- and petrochemical industry. The Multipurpose terminal only transported 221,000 tons of cargo via containers in 2016, corresponding with 1% of the total throughput of the whole port. The next figures show the throughput for 2016 of all other terminals within the Port of Bahía Blanca, divided into three different categories (Figure i).

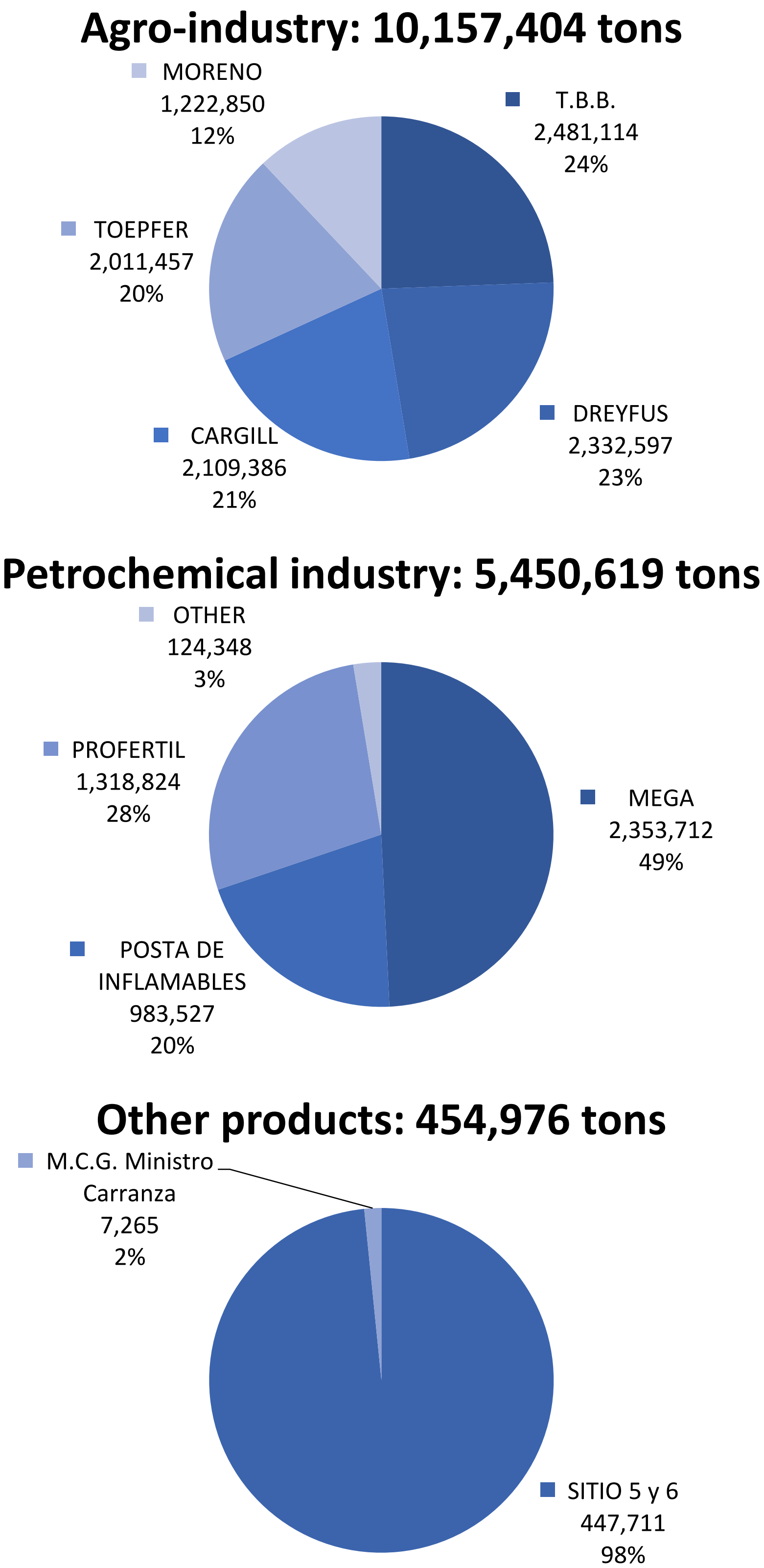


Figure i – Throughput of the different terminals located in the Port of Bahía Blanca (CGPBB, 2013/14)

Road network

Since the main mode of transportation to and from the Port of Bahía Blanca is by truck, the road network is the most important and most used infrastructure. Within the Port of Bahía Blanca there are only two access roads; Ruta Nacional 252 (RN252) and street 18 de Julio (Figure ii). Both routes are connected to Ruta Nacional 3 (RN3), which makes this national route the only possible access route of the Port of Bahía Blanca for trucks. In 2016, about 700 trucks per day entered the port on average (CGPBB, 2016a). This amount fluctuates over the year and is measured only for the terminals with a significant share of road transportation.

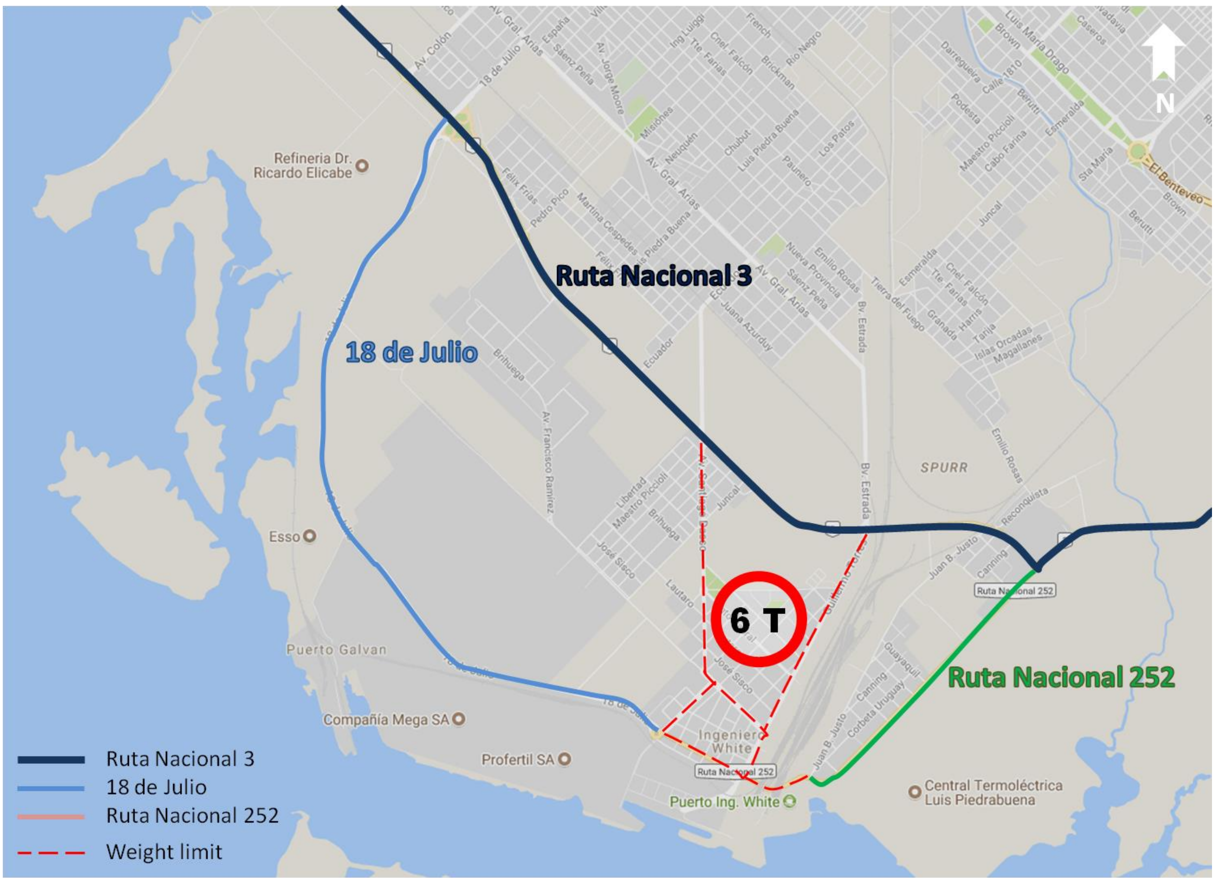


Figure ii – Road network around the Port of Bahía Blanca (Adapted from Google, 2017)

The RN252 is the only possible access road for two of the terminals within the Port of Bahía Blanca; Terminal Bahía Blanca and Toepfer. All other terminals are only accessible via 18 de Julio. Due to an axle weight limit of 6 tons in between the two access roads, trucks are not able to cross from the one road to the other. Moreover, the roads that connect the port area of Ingeniero White with the RN3 via the city, have the same weight restriction to prevent heavy vehicles from taking a short cut via the residential area (Figure ii).

Rail network

A second mode to transport cargo from and to the port is by train. Currently, 30% of the total throughput of the port is transported by rail to the hinterland (CGPBB, 2017g). Although not all terminals are connected to the rail network, the majority of the terminal operators are able to transport cargo by train (Table ii).

Table ii – Rail accessibility for the different terminals (CGPBB, 2017e)

Terminal	Access to rail infrastructure
Posta de inflamables (Posta 1, 2 y 3)	×
Oleaginosas Moreno S.A.	✓
Sitio 5 y 6	✓
Louis Dreyfus Commodities	✓
MEGA S.A.	×
Profertil S.A.	✓
Multipurpose terminal	✓
Cargill S.A.	✓
Ministro Carranza	✓
Terminal Bahía Blanca S.A.	✓
Toepfer	✓

The railway line enters the port area at Ingeniero White in the East and branches of to the terminals which were listed in the table above (Figure iii). On average, 165 wagons entered and left the port each day in 2016 (CGPBB, 2016a). As for trucks, this amount fluctuates over the year and has high and low peaks depending on the crop season.

Figure iii - Rail network in the Port of Bahía Blanca, terminals in green are accessible by rail (Arecco, Besson, van Drunen, & Sendra, 2017)

Appendix B – Activities YPF in the Port of Bahía Blanca

In the Port of Bahía Blanca, YPF is the biggest shareholder (38%) of the MEGA S.A. terminal and together with the Canadian company Agrium is owner of the terminal Profertil S.A. The different plants on the MEGA S.A. terminal fracture natural gas and produce the following products: ethane gas, liquid propane, liquid butane and gasoline. Profertil S.A. produces granular urea and ammonia from gas and carbon dioxide.

Sand import

Since 2013 projects are exploiting the shale gas by the method of hydraulic fracturing (fracking). The fracking process requires large amounts of hard siliceous sand, which is mostly imported in containers from China and the United States. At the end of 2017 a total of 3 million tons of sand will be imported, all via the Port of Dock Sud (Buenos Aires). Cleaning the sand is a delegate process and around Vaca Muerta only YPF executes this process. Due to this monopoly, their estimations for future import of sand are expected to be rather accurate. As the storage area of sand in Vaca Muerta itself has sufficient capacity, YPF plans to expand their stock of sand locally. Therefore, an increase of import of sand is expected, to as much as 6 million tons in 2022. Both YPF and the port are considering the possibilities of shifting the import of sand to Bahía Blanca due to its convenient location. However, even though the transport of sand is currently in containers, this will shift to bulk transport when railway lines between Bahía Blanca and Neuquén improve significantly. New investments in this project make it credible that the improvements will happen soon and the Port of Bahía Blanca will not handle the containers.

Appendix C – Future throughput estimation petrochemical cluster

Dow Argentina

Dow Argentina is part of The Dow Chemical Company and is an industry leading company, specialised in chemical-, pre-chemical- and agriculture science and materials. In the complex located in Bahía Blanca, Dow Argentina produces ethene and several types of polyethene for different applications. Ethene is obtained by steam cracking of refinery hydrocarbons (ethane, propane, naphtha and diesel). In this process, gaseous or light liquid hydrocarbons are heated up to 750-950 °C in ovens transforming into ethene. This ethene gas is used as a raw material to produce solid polyethene pellets and PVC. These latter products are worldwide the most common plastics for manufacturing of everyday objects like plastic bags, water and gas pipes, silos et cetera.

Dow Argentina in Bahía Blanca has a production capacity of 780,000 tons ethene and 660,000 tons polyethene per year. For this, two ethene- and four polyethene plants are available. In 2016, Dow Argentina produced 603,000 tons polyethene (Arecco, Besson, van Drunen, & Sendra, 2017). The polyethene is transported in FEU loaded with 27 tons. An increase of polyethene production of 1-2% is planned in 2018. In addition, Dow Chemicals is planning to invest in one of their three production locations in 2018. For Dow Argentina this would imply a duplication of the current production of polyethene.

Current model split export Dow Argentina

Currently, 70% of the production of polyethene is intended for the domestic market (Pirillo, 2017). The additional 30% is exported, mainly to Brazil. An overview of the markets and the modes of transport for the current production of polyethene is shown in Figure iv. When Dow Argentina indeed expands their capacity, the additional production will be mainly for export to Brazil.

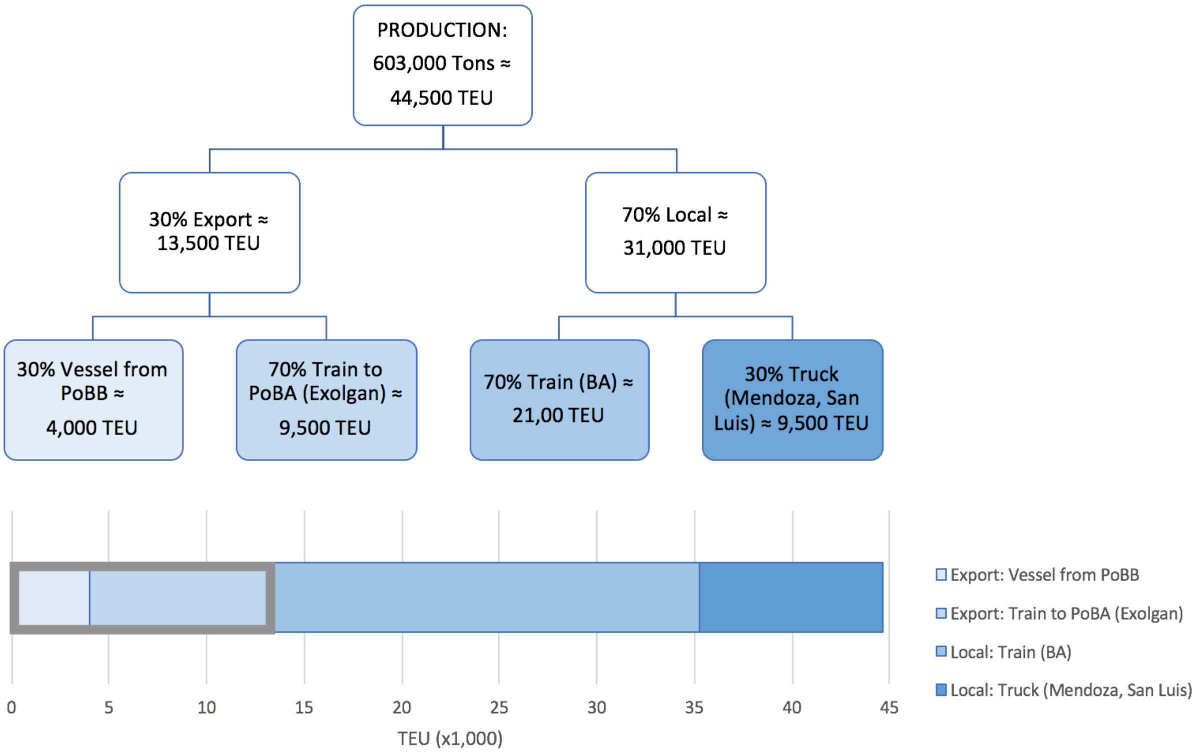


Figure iv –Tree showing the current markets and transport modes of Dow Argentina. On the bottom the total production that is exported is highlighted

For Dow Argentina it is economically more attractive to export their cargo via Buenos Aires compared to shipping it directly to Brazil from the Port of Bahía Blanca. There are two main reasons for the difference in costs between the two options. First, the contract of Dow Argentina with their logistical operator offers free empty containers when transporting by train to Buenos Aires. As the Port of Bahía Blanca does not import FEU, it is costly to arrange empties for Dow Argentina. Second, the shipping line via the Port of Bahía Blanca calls a less favourable port in Brazil compared to the shipping line from the Port of Buenos Aires. Even though the first mile costs of export via Buenos Aires are larger, the last mile costs are significantly less compared to exporting via Bahía Blanca. Therefore, Dow Argentina uses the full capacity of the railway line between Bahía Blanca and Buenos Aires to transport their cargo to the capital. The capacity of the railway line is 44 wagons per day which might be improved to 50 wagons per day in the future (Pirillo, 2017).

Future situation

First, some important numbers, expressed in TEU (x1,000) (Pirillo, 2017):

Weight per FEU	27 tons
Current capacity Dow Argentina	44.5
Expected increase production in 2-3 years of 1-2%	45.5
Possible expansion doubling production	89
Expansion railway capacity from 32,000 TEU to	36
No growth in local supply is expected, stays	31.5
Local transport by truck stays	9.5

The assumptions that underlie the four different scenarios for Dow Argentina are in Table iii. The corresponding model split for the four scenarios in 2040 is shown in Figure v. The range of the container throughput in the port is between 4,900 TEU when the situation stays unchanged, to 62,100 TEU in scenario 4.

Table iii - Assumptions for the different scenarios for Dow Argentina

	Assumptions to estimate future container throughput	TEU (x1,000)
Current situation	current situation	4.9
Scenario 2	no investment all export via the Port of Bahía Blanca increase of export 2% annually (GDP growth Brazil) until capacity	17.6
Scenario 3	investment in 3 new plants in 2018 optimal use capacity train network production spark after investment	47.5
Scenario 4	investment in 3 new plants in 2018 all export via the Port of Bahía Blanca higher growth rate compared to scenario 3	62.1

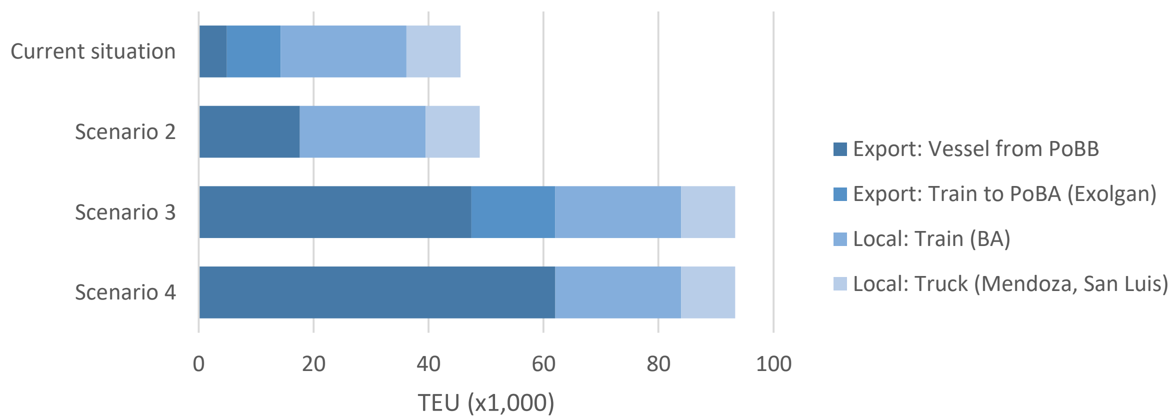


Figure v - Different scenarios for Dow Argentina in 2040. Indicated is the expected production and the model split per scenario

For all scenarios, an estimation is made for the progression container throughput in the port until 2040 (Figure vi).

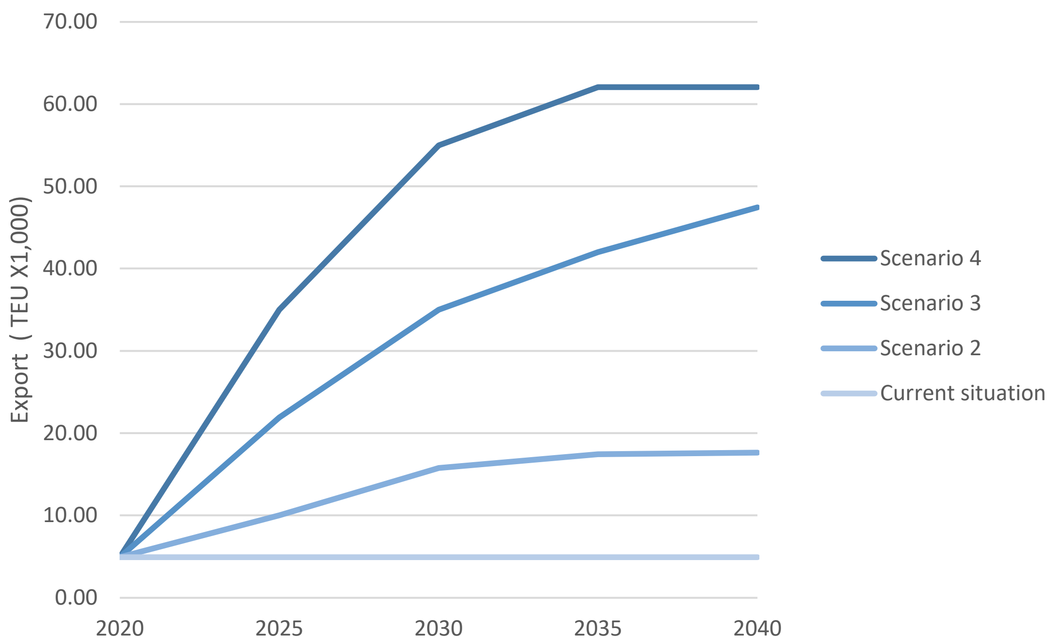


Figure vi – Container throughput in the Port of Bahía Blanca due to Dow Argentina's production for the four scenarios 2020-2040

Unipar Indupa

Unipar Indupa has three plants in Bahía Blanca producing; chlorine soda, vinyl chloride monomer (VCM) and polyvinylchloride (PVC), where the latter is the main product. The first plant produces chlorine, liquid caustic soda and sodium hypochlorite in pearls via electrolysis which uses salt. Liquid caustic soda and sodium hypoclorite in pearls are byproducts of this process. In the second plant the chlorine is reacting with ethylene coming from Dow Argentina resulting in the production of VCM. The third plant is producing PVC by the polymerization of VCM. PVC and caustic soda are basic inputs for various application: PVC is used for construction, electronics, medicine et cetera; caustic soda is used to produce soaps and detergents, chemical peeling of fruit, washing of returnable glass bottles et cetera.

The assumptions that underlie the four different scenarios for Dow Argentina are in Table iii. The range of the container export in the port is between 8,000 TEU when the situation stays unchanged, to 24,000 TEU in scenario 4. The four scenarios are shown in Figure vii.

Table iv - Assumptions for the different scenarios for Unipar Indupa

	Assumptions to estimate future container throughput	TEU (x1,000)
Current situation	current situation	8
Scenario 2	no investment produce at capacity in 2004	16
Scenario 3	growth of the company capacity increases with 25%	20
Scenario 4	investment in the company capacity increases with 50%	24

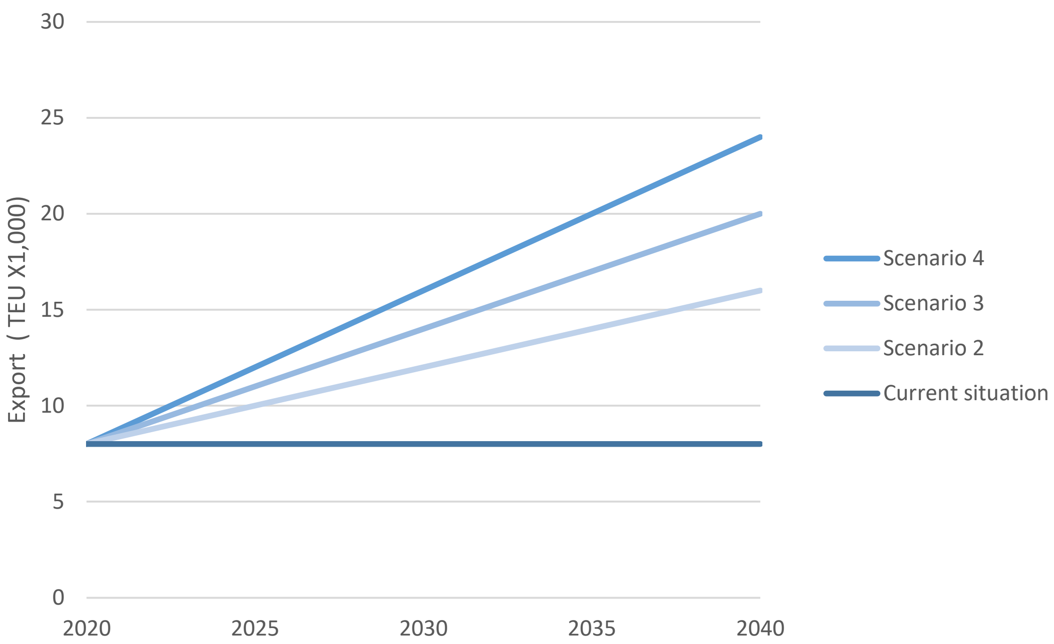


Figure vii – Container export in the Port of Bahía Blanca due to Unipar Indupa for the four scenarios 2020-2040

Other companies

Figure viii shows a different graph compared to the throughput of Dow Argentina. The reason for this difference in possibilities of increase in container throughput due to the development of a petrochemical cluster. When Vaca Muerta exploits significantly, more companies are expected to vestige in Bahía Blanca increasing the capacity and production of the cluster gradually.

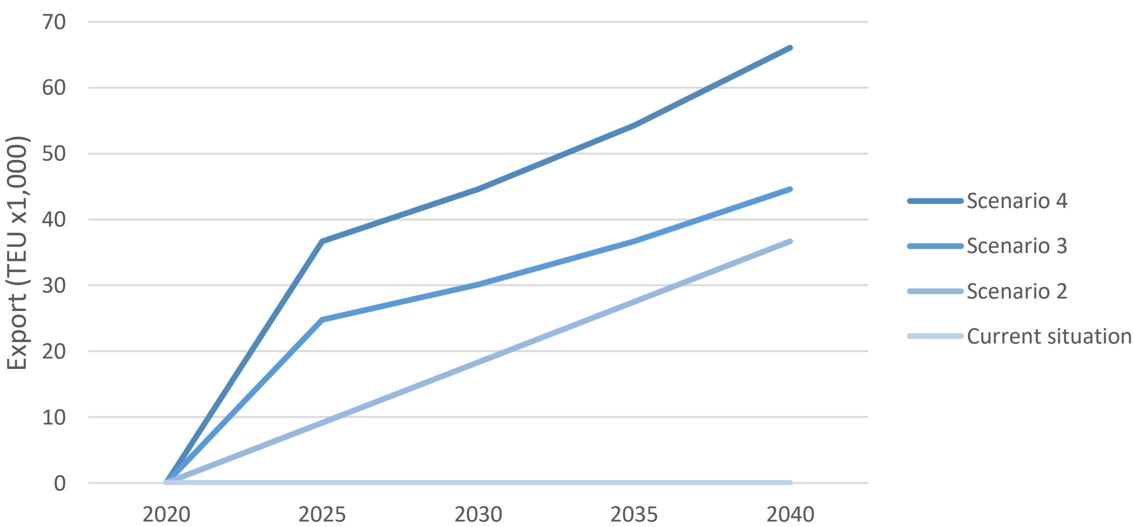


Figure viii – Container export in the Port of Bahía Blanca due to other companies for the four scenarios 2020-2040

Appendix D – Future throughput estimation food

For fruits, it is assumed that the cargo by truck slowly attracted to the Port of Bahía Blanca. In contrast, only in scenario 4 the fruits transported via the Port of San Antonio Este are included as cargo for the Port of Bahía Blanca. In the different scenarios, the percentage of fruits that is transported via the Port of Bahía Blanca varies between 0% and 50% in the first years. In Figure ix four different scenarios for food fruit are shown.

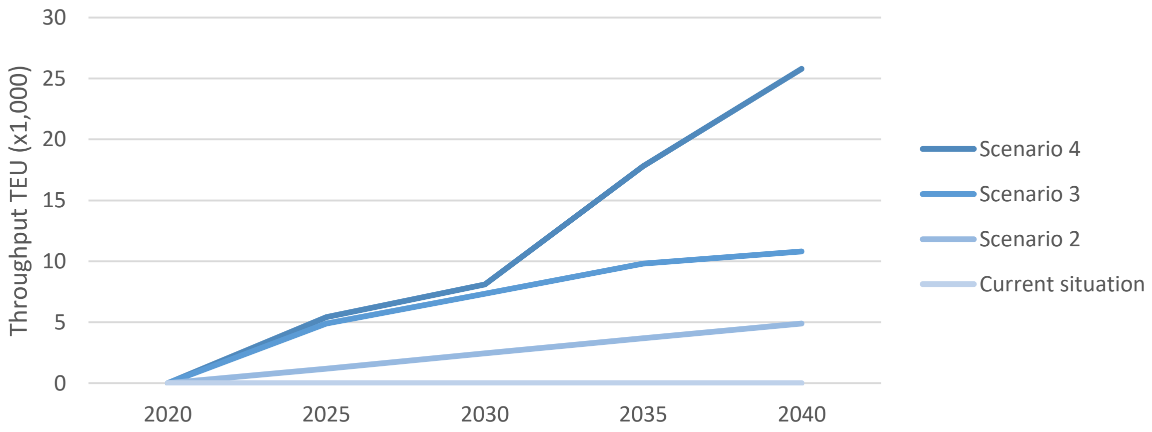


Figure ix – Estimation of export for the food-industry

Appendix E – Throughput and destinations

This appendix gives an overview of the container throughput of Patagonia Norte. In addition, the main export products and their destinations are given. The import volume is small compared to the export and consist for 95% of sand, in total a volume of 36,000t.

Table v – Overview of the container throughput in 2016 (CGPBB, 2017a)

	20ft	40ft	TEU	Tons
Imported Empties	898	7,477	15,852	
Imported Filled	241	43	327	6,077
Exported Empties	12	148	308	
Exported Filled	1,163	7,400	15,963	209,650
TOTAL	**2,314**	**15,068**	**32,450**	**215,727**

Table vi – Main destinations of the containerized cargo in tons (CGPBB, 2017a)

Destination	Brazil	India	USA	Saudi Arabia	Other
Juices			9,700		
Flour	4,937				
PVC	78,405	20,690	134		4,737
Polyethene	48,767				11,517
Caustic Soda	345		23		46
Alfalfa				11,475	3,602
Semola wheat	1,229		263		1,402
Barley		1,241	199		608
Other	449	498	1.331	24	7,992
Total	**134,132**	**22,429**	**11,650**	**11,499**	**29,904**

Appendix F – Hinterland connections

In this appendix, the hinterland connections of the Port of Bahía Blanca are elaborated on which are of importance for the distribution area of the container terminal. As mentioned in the report, all transportation to and from the container terminal takes place by truck. However, since rail infrastructure is present, the hinterland connections of the rail network are analysed as well.

Road network

Ruta Nacional 3 (RN3) is, as said before, the only access route of the Port of Bahía Blanca. However, the city of Bahía Blanca itself is connected to the hinterland via several routes as indicated in Figure x. To connect the many production areas in the hinterland with the Port of Bahía Blanca these roads and their condition are important.

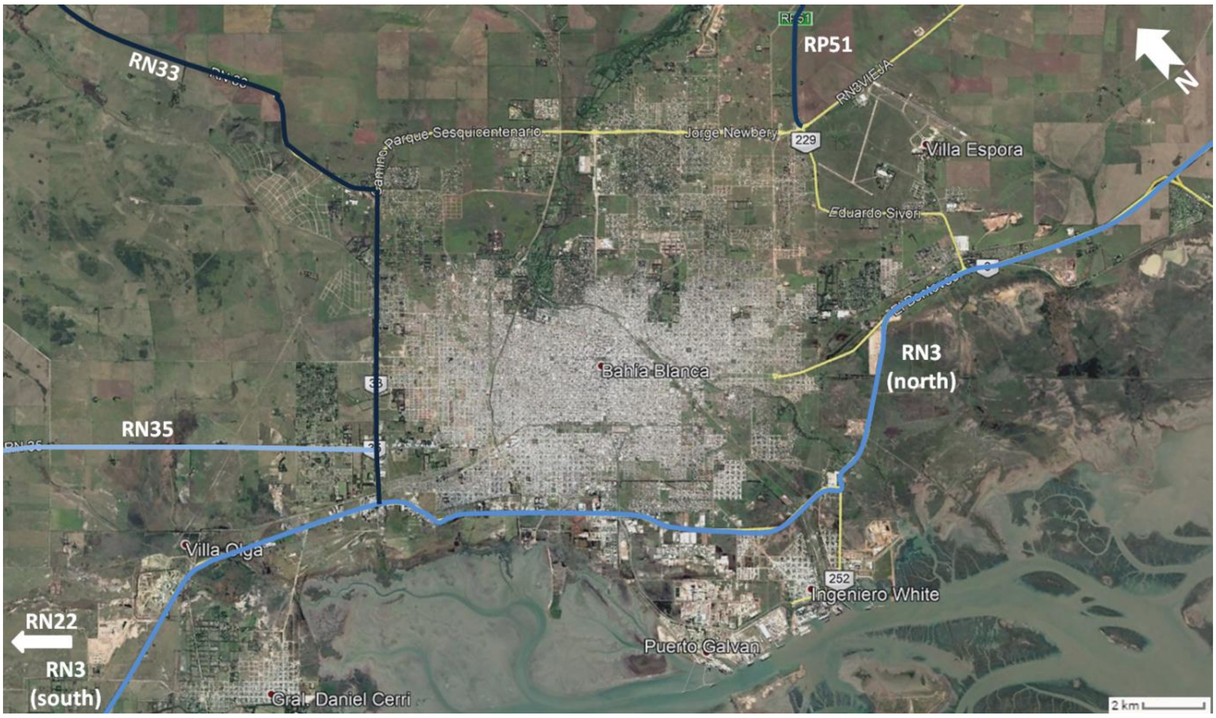


Figure x – Road network around the Port of Bahía Blanca (Adapted from Google, 2017)

Studies, executed by the CGPBB, showed that 70% of the trucks entering Bahía Blanca come from the RN33, while the other 30% uses the RN3. Table vii gives an overview of the different routes connecting Bahía Blanca with the hinterland, the provinces that are crossed and the type of cargo which makes the route important for the port.

Table vii – Hinterland connections Bahía Blanca by road

Route	Length [km]	Connected provinces
RN3 (north)	677	Buenos Aires
RN3 (south)	2,383	Rio Negro, Chubut, Santa Cruz
RN22	685	La Pampa, Rio Negro, Neuquén
RN33	795	Buenos Aires, Santa Fé
RN35	701	La Pampa, Córdoba
RP51	735	Buenos Aires

Ruta Nacional 3 (RN3): RN3 has a total length of 3,060km and is the main access road to Bahía Blanca. The route can be divided into two parts; the RN3 North to Buenos Aires and the RN3 South to Ushuaia, the most Southern point of Argentina.

Ruta Nacional 22 (RN22): RN22 has a total length of 685 km and connects Bahía Blanca with the west of Argentina. The route is not directly connected to Bahía Blanca but is connected to the RN3, 20km south of Bahía Blanca. Neuquén is an important destination along this route and of interest because of Vaca Muerta.

Ruta Nacional 33 (RN33): RN33 has a total length of 795km and connects Bahía Blanca with Rosario in the North. Rosario's main manufacturing sector is the agro industry which is transported via the port complex Rosario-Santa Fe.

Ruta Nacional 35 (RN35): RN35 has a total length of 701km and connects Bahía Blanca with Río Cuarto via the inland cities in the northwest through the Pampa region, the production area of many grains.

Ruta Provincial 51 (RP51): This provincial route lies in between RN3 North and RN33 runs through the province of Buenos Aires from Bahía Blanca to the North. The route ends in between the city of Buenos Aires and Rosario where it is connected with another provincial road. The route is heavily used by cars and trucks and various sections along the route are in a bad state.

Rail network

Although many tracks are present around Bahía Blanca, the rail network in the country is generally in very poor condition (Figure xi). Little maintenance was executed in the last decades as transport by truck was dominantly chosen for money reasons. The current rail network is operated by different companies which led in the past to inefficiencies, leaving the network unused for containerized transport..

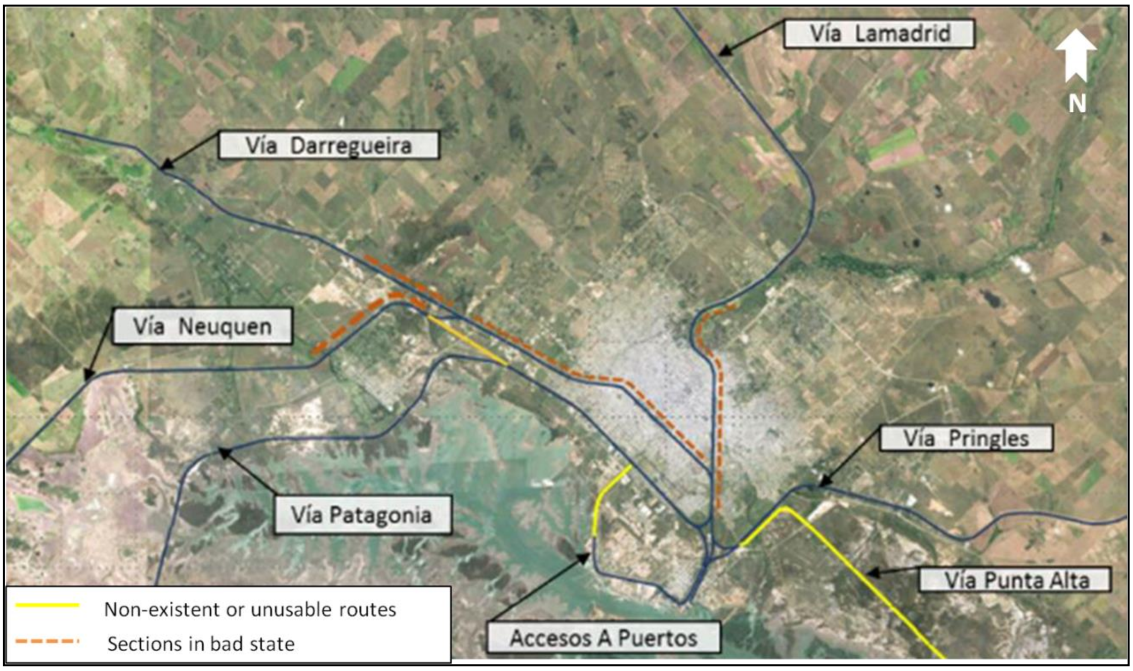


Figure xi – Rail network Bahía Blanca with the hinterland. blue: existing, yellow: non-existent or unusable, orange: poor condition (Arecco, Besson, van Drunen, & Sendra, 2017)

Due to bad conditions of the infrastructure, speed and weight are limited on most of the tracks. In addition, some routes are not complete anymore and thus inaccessible (Table viii). Currently four tracks are in operation from the city of Bahía Blanca. The port is connected with the city of Buenos Aires via two routes, with the important province Neuquén and with the Pampa province.

Table viii – Hinterland connections Bahía Blanca by train

Route	Status of operation	Connections
Vía Darregueira (North)	Operating	Track goes via the Pampa province to the south of Cordoba. Via this route approximately two million tons of grain cargo is brought to the port each year.
Vía Lamadrid (North)	Operating	Track goes via Cnel Suaréz to Olavarría. Olavarría is connected with the city of Buenos Aires via one track.
Vía Pringles (North)	Operating	Track goes via Pringles to Olavarría. Olavarría is connected with the city of Buenos Aires via one track.
Vía Patagonia (Southwest)	Not in operation	
Vía Neuquén (West)	Operating	Track goes via Río Negro to Neuquén. As mentioned when in the road network analysis, Neuquén is an important destination and of interest because of Vaca Muerta.

Appendix G – Determination of dwell times

In this appendix, the average dwell times are estimated for the four stages of the scenario described in Chapter 4.1.1. The same method as described in Chapter 3.3 for estimating average dwell times is used in this appendix.

The formula for the dwell time of export containers is:

$$\overline{t_{d,export}} = \frac{(t_{d,max}+2)}{3} \text{ (Quist \& Wijdeven, 2014)}$$

For the dwell time of empties is assumed: $\overline{t_{d,empties}} = 2.5 * \overline{t_{d,export}}$

The average dwell times for the current situation are already determined in Chapter 3.3. For stage 2 the above formulas are applied. Applying these formulas to stage 3 and 4 result in unrealistic low values for the dwell time. Therefore, it is assumed that the average dwell time for export containers for these two stages is five days, a value often given as lower limit for dwell times. The results are given in Table ix.

Table ix – Dwell times for the four stages

	Stage 1	Stage 2	Stage 3	Stage 4
Calls/year	50	75	100	150
Inter arrival time [days]	7.3	4.9	3.7	2.4
Dwell time Export [days]	8	5.5	5.0	5.0
Dwell time Empties [days]	22	13.8	12.5	12.5

Appendix H – Comparison straddle carrier and gantry crane

This appendix describes the advantages and disadvantages of the operating systems consisting of straddle carriers (SC) or gantry cranes.

SCs stack the containers in rows, separated by lanes wide enough for the legs and tyres of the equipment. The equipment can stack the containers up to three containers on top of each other. The storage area can be used efficiently because of the flexibility of the SC. A straddle carrier can handle high amounts of throughput and another considerable advantage is that there is only one type of equipment required for the entire terminal. For the SC, highly qualified personnel is needed and the investments and maintenance costs are high. The straddle carrier can reduce the required area per TEU to 10-13m^2, even though the SC can stack containers only up to a height of three. An example of a straddle carrier is shown in Figure xii.

Figure xii – Straddle Carrier (SC) (Quist & Wijdeven, 2014)

Gantry cranes have a good space utilisation and are able to stack the containers up to five containers. There are two types of gantry cranes; rubber tyred gantry (RTG) and rail mounted gantry (RMG). The RTG cranes are flexible, but require good subsoil conditions or a track with adequate foundation in view of relatively high wheel loads. Where the subsoil conditions are less favourable, the RMG crane is preferable, because the rails spread the load better. Therefore RMG cranes usually are wider and used when higher container throughput needs to be handled. Using the gantry cranes, another equipment is required to transport the containers from and to the storage areas. The current reach stackers can handle this transport. The use of a gantry crane can reduce the required area per TEU to 7.5-10 or 6-8m^2, for respectively a stacking height of four and five containers. A RTG crane is shown in Figure xiii.

Figure xiii – Rubber tyred gantry (RTG) crane (Quist & Wijdeven, 2014)

The current pavement and subsoil can bear surface loads up to 5-10tons/m^2 (Larralda, 2017). The critical wheel load of a RTG crane over a block of containers of 6 wide and 5 high, can be up to 25 tons. With a wheel area of about 1m^2 this leads to a surface load up to 25tons/m^2, so this exceeds the current bearing capacity (Moffatt & Nichol, 2015). Before implementing RTG's, further investigation of the bearing capacity of the soil and pavement is required. If it is decided that RTG's are implemented, probably soil and pavement improvements are required.

Comparing the two different equipment, the RTG can handle more throughput than the SC. The investment costs of both equipment are relatively high, as well as the maintenance costs. The largest advantages of the SC are that they are very flexible and do not require other equipment. The RTG is also flexible and competitive when the storage area is large enough when the containers can be stacked in long rows. The determination of the most appropriate equipment is depending on the lay-out and amount of throughput of that particular terminal.

Appendix I – Throughput capacity for all expansion stages

In this appendix the throughput capacity of the terminal is estimated for the four expansion stages described in Chapter 4.2. The process of capacity estimation is an iterative process, as throughput and dwell time are related to each other. An increase in throughput often requires a higher call frequency, resulting in lower dwell times. Subsequently, lower dwell times result in a larger capacity. For the estimation of the capacity increase the following assumptions are used:

- The call frequency of vessels follows the scenario described in Chapter 4.1
- Crane productivity and operation system are improved if needed to handle the increase in throughput
- The current ratio in throughput of export, empties and import containers continues to be valid for the future. The current figures are:
    - Export (+/-15,000 TEU)
    - Empties (+/-15,000 TEU)
    - Import (+/-0)

Therefore the throughput ratio (export:empties:import) 1:1:0 is used from this point onwards.

The capacity is determined in the same way as in Chapter 3.3:

$$N_c = \frac{A \cdot r_{st} \cdot 365 \cdot m_c}{\overline{t_d} \cdot A_{TEU}}$$

where:

N_c = number of container movements a year per type of stack in TEU
A = area required (m^2)
t_d = average dwell time (days)
A_{TEU} = required area per TEU including equipment travelling lanes (m^2)
r_{st} = ratio $\dfrac{\text{average stacking height}}{\text{nominal stacking height}}$
m_c = acceptable average occupancy rate (0.65)

Below, the increase in capacity and the new total capacity for each expansion stage is further elaborated.

Expansion 1: Commissioning General area

This expansion results in an increase of storage area of 2.2ha. With this expansion the total stacking area increases to 9.2ha (92,000m^2). The size of the area dedicated for the export containers is adjusted in Excel to hold on to the throughput ratio 1:1:0 as assumed above. First, the capacity is determined with the dwell times of the current terminal. Subsequently this new capacity is linked to the correct vessel scenario with corresponding dwell times. With the changed dwell times the capacity is determined again. This process is repeated until a new iteration gives the same results as the previous one.

Figure xiv shows the final outcomes.

Figure xiv – Capacity after expansion 1

	Area [m^2]	Dwell time [days]	Capacity [TEU]
Total	92,000	-	110,000
Export	29,000	5.5	55,000
Empties	63,000	13.8	55,000

Expansion 2: Reclamation Public Harbour

In the same way as for expansion 1, the capacity after expansion 2 (+2.0ha) is determined and given in Figure xv.

Figure xv - Capacity after expansion 2

	Area [m^2]	Dwell time [days]	Capacity [TEU]
Total	112,000	-	150,000
Export	35,000	5.0	75,000
Empties	77,000	12.5	75,000

Expansion 3: Cold storage

In the same way as for expansion 1 and 2, the capacity after expansion 3 (+1.4ha) is determined and given in Figure xvi.

Figure xvi - Capacity after expansion 3

	Area [m^2]	Dwell time [days]	Capacity [TEU]
Total	126,000	-	165,000
Export	39,000	5.0	82,500
Empties	87,000	12.5	82,500

Expansion 4: Club Náutico (+3.6ha)

For expansion 4 the capacity is estimated for two operation systems:

1. An operation system with reach stackers and multi-trailers
2. An operation system with RTGs

The second option, an operation system with RTGs, is considered because after this final expansion the squared layout and the large size of the terminal can be suitable for more advanced equipment.

For the operation system with reach stackers and multi-trailers the results are given in Figure xvii.

Figure xvii - Capacity after expansion 4 (Reach stackers and multi-trailers)

	Area [m^2]	Dwell time [days]	Capacity [TEU]
Total	162,000		215,000
Export	51,000	5.0	112,500
Empties	111,000	12.5	112,500

For the operation system with RTGs the results are given in Figure xviii.

Figure xviii - Capacity after expansion 4 (RTGs)

	Area [m^2]	Dwell time [days]	Capacity [TEU]
Total	162,000		480,000
Export	51,000	5.0	240,000
Empties	111,000	12.5	240,000

Appendix J – Cost estimation expansions

In this appendix, the cost of two of the four proposed expansions of the current terminal are estimated, being expansion 2 and 4. The estimations are based on rough figures for land reclamation, construction of pavement and quay walls as shown in Table x.

Table x – Cost estimations

Type	Cost
Quay wall [U$D/m]	30,000
Reclamation [U$D/m^3]	18
Pavement [U$D/m^2]	100

Expansion 2: Public Harbour

The second expansion is the reclamation of the Public Harbour. This involves the construction of a new quay wall of 100m in the first place. After that, the area behind the quay should be reclaimed. The volume of sand required for this is determined using the following figures:

- Water depth in Public Harbour: 6m with respect to Mean Sea Level (MSL)
- Ground level of the terminal: MSL +5m
- Area to be reclaimed: 17,000m^3

The next step is the construction of the pavement. It is assumed that all the current pavement around the existing quays is not useable. Therefore 20,000 m^2 of new pavement should be constructed. The costs of this three aspects, together with an additional 25% to the total cost for the overall project management costs, are given in Table xi,. This results in a rough estimation of U$D 11 million in total. It must be stated that the cost of relocation of the Public Harbour is not encountered in this estimation.

Table xi - Cost estimation Public Harbour

Component	[U$D]
Quay wall	3,000,000
Reclamation	3,366,000
Pavement	2,100,000
General project costs (+25%)	2,116,500
Total	10,582,500

Expansion 4: Club Náutico

The last and largest expansion is the acquisition of the area of Club Náutico. With this expansion an extra area of 5.2ha becomes available. The expansion requires reclamation in the West of the expansion area as this is currently still part of port basin. Also, besides a quay wall along the access channel, a quay wall is required on the west side of the area to use the area optimally. All required quay walls are shown in white in Figure xix. Finally the pavement have to be constructed on 5.2ha of the area.

Figure xix – Expansion 4

When considering costs, it is assumed that 430m of quay wall is required together with reclamation of half of the area, being 2.6ha. Finally the pavement should be constructed on the 5.2ha.These costs together with project management costs are given in Table xii. The most important cost, the relocation of the Yacht Club itself, is not taken into account in this calculation as this is difficult to express in monetary value. This said, the total construction costs can be roughly estimated at U$D 30 million.

Table xii - Cost estimation Club Náutico

Component	[U$D]
Quay wall	12,900,000
Reclamation	4,680,000
Pavement	5,200,000
General project costs (+25%)	5,695,000
Total	28,475,000

Appendix K – Queuing theory

Current situation

In the current situation almost once a week a container vessel is calling the Port of Bahía Blanca, so the call frequency is about 50 calls/year. The throughput of the Port of Bahía Blanca in 2016 was about 32,500 TEU and the throughput of the Port of Bahía Blanca in 2017 so far is about 23,500 TEU. Furthermore this throughput in 2017, expressed in containers, is about 13,700 containers (CGPBB, 2017d). The container terminal is able to receive vessels 18 hours a day, 365 days a year, so the operational time is about 6,600 hours/year. The mooring time per vessel is estimated at one hour for berthing and one hour for deberthing per vessel. The TEU-factor, required for the determination of the number of containers moved in the port, is calculated as follows:

$$f_{TEU} = \frac{N_{20'} + 2 \cdot N_{40'}}{N_{20'} + N_{40'}} = \frac{23293}{13723} = 1.7 \text{ (Ligteringen \& Velsink, 2012)}$$

Where:

f_{TEU} = TEU-factor (-)

$N_{20'}$ = number of TEU

$N_{40'}$ = number of FEU

The current terminal uses a mobile crane and one of the cranes of the vessels to (un)load the vessels. The peak rates of these cranes are 20 moves/hour per crane, but the net productivity is significantly lower. The net crane productivity is the average number of containers moved from ship to shore and vice versa during the total berthing period. This period is depending on the skills of the personnel and includes all sort of unproductive intervals such as repositioning of cranes, time loss between shifts and simple repairs of the cranes. Because of these unproductive intervals the net productivity of the cranes is easily reduced to half of the peak rate, which would mean 10 moves/hour for both of the cranes. In 2017 so far the net productivity of these cranes together is 10.8 moves/hour, so there is room for improvement (CGPBB, 2017d).

With these input values the queuing theory can be applied. The queuing theory proposed by D.G. Kendall covers a wide range of queuing systems in which vessels require a single service before departure from the system. The book “Service Systems in Ports and Inland Waterways” is used as a reference for formulas and predetermined data throughout this chapter (Groeneveld, 2001). The factors determining the behaviour of such a system are:

- The arrival pattern of the vessels
- The service time of the vessels
- The service system

The arrival pattern of the vessels and service time of the vessels are expressed as statistical distributions and the service system can be described by the number of berths in the system and the queue discipline. In this theory the queue discipline is taken as ‘first come, first served’. The queuing system can now be described by specifying the inter arrival time distribution of vessels, the distribution of service times and the number of vessels in the system.

Both the statistical distributions of the arrival pattern of the vessels and the service time of the vessels can be described by the negative exponential (M), Erlang (E_k) or Deterministic (D) distribution. For the two aspects the most appropriate distribution has to be chosen in order to model the aspects in a proper way. The negative exponential distribution is used to model inter arrival times or service times when these are completely random. In contrast, the deterministic distribution is used when there is no variation in the certain aspect at all. The Erlang distribution is a more general distribution and is used as regular distribution with some variation. The inter arrival times of the vessels are modelled using the Erlang distribution, because the arrivals are scheduled but can have some variation. The service time of the vessels is also modelled using the Erlang distribution, because the call sizes of the vessels are almost similar, but can have some variation as well.

First the average call size is calculated as follows:

$$call\ size = \frac{throughput}{\frac{calls}{year}} = \frac{32{,}500}{50} = 650\ TEU/call$$

The arrival rate (λ) is the average number of calls per hour and can be calculated as follows:

$$\lambda = \frac{\frac{calls}{year}}{\frac{operational\ hours}{year}} = \frac{50}{6{,}570} = 0.008\ calls/hour$$

The number of containers per call can be calculated by dividing the call size by the TEU-factor:

$$\frac{(un)loading}{call} = \frac{call\ size}{TEU - factor} = \frac{650}{1.7} = 383\ containers/call$$

The average (un)loading time can be calculated as follows:

$$(un)loading\ time = \frac{\frac{(un)loading}{call}}{(un)loading - rate} = \frac{383}{10.8} = 35\ hours$$

For the total service time the 2 hours of mooring time have to be added by this number, so the total service time of a vessel is 37 hours. The service rate (μ) is a performance metric at which customers (vessels) are served in the system and can be calculated as follows:

$$\mu = \frac{1}{total\ service\ time} = \frac{1}{37} = 0.03\ vessels/hour$$

The occupancy of the terminal can be calculated as follows:

$$\rho = \frac{\lambda}{\mu} = \frac{0.009}{0.03} = 0.29$$

The maximum acceptable waiting time for a container vessel is 10% of the service time. The used queuing system in this case is $E_2/E_2/n$ with E_2 as the reference to the Erlang distribution and n as the number of berths. In Figure xx the average waiting time of vessels, by different number of berths and utilisation are given for the queuing system $E_2/E_2/n$ is showed. The average waiting time is given in units of average service time, so the average waiting time of vessels needs to be below 0.1 in order to be able to guarantee a waiting time for a container vessel of 10% of the service time.

The utilisation is the occupancy per berth and can be calculated as follows:

$$utilisation = \frac{\rho}{n} = \frac{0.29}{1} = 0.29$$

utilisation (u)	number of servers (n) 1	2	3	4	5	6	7	8	9	10
0.1	0.0166	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.2	0.0604	0.0065	0.0011	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.3	0.1310	0.0235	0.0062	0.0019	0.0007	0.0002	0.0001	0.0000	0.0000	0.0000
0.4	0.2355	0.0576	0.0205	0.0085	0.0039	0.0019	0.0009	0.0005	0.0003	0.0001
0.5	0.3904	0.1181	0.0512	0.0532	0.0142	0.0082	0.0050	0.0031	0.0020	0.0013
0.6	0.6306	0.2222	0.1103	0.0639	0.0400	0.0265	0.0182	0.0128	0.0093	0.0069
0.7	1.0391	0.4125	0.2275	0.1441	0.0988	0.0712	0.0532	0.0407	0.0319	0.0258
0.8	1.8653	0.8300	0.4600	0.3300	0.2300	0.1900	0.1400	0.1200	0.0900	0.0900
0.9	4.3590	2.0000	1.2000	0.9200	0.6500	0.5700	0.4400	0.4000	0.3200	0.3000

Figure xx - Average waiting time of vessels in the queue $E_2/E_2/n$ (in units of average service time) (Groeneveld, 2001)

In Figure xxi the average waiting time of vessels in the queuing system $E_2/E_2/n$ using one berth, adapted from Figure xx, is shown. From the graph it follows that the maximum utilisation, in order to have an average waiting time below 0.1, is about 0.26. The current utilisation of 0.29 is higher than 0.26, so the current terminal needs improvements in order to guarantee a waiting time of 10% of the service time.

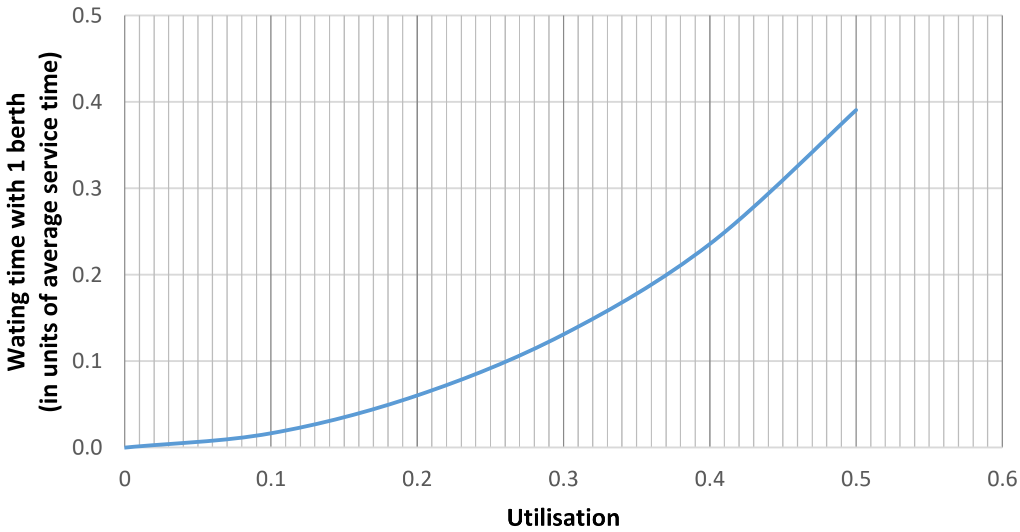


Figure xxi - Average waiting time of vessels in the queue $E_2/E_2/n$ using 1 berth (in units of average service time) (own work)

First improvement

At first the net productivity of the cranes can be increased, because the mobile crane and the crane of the vessels are both operated by the terminal and there is room for improvements. Retraining current personnel (crane operators) can increase the net productivity of the cranes to about half of the peak rate of the cranes, so about 10 moves/hour per crane (Ligteringen & Velsink, 2012). Using the mobile crane and the crane of the vessel the net productivity will be about 20 moves/hour. Changing the input value of the net productivity of the cranes, the queuing theory as described above is applied in the same way. With this development the container terminal can handle a throughput of approximately 50,000 TEU/year in order to have a waiting time below 10% of the service time.

Second improvement

When the throughput is increasing above 50,000 TEU/year, a next improvement is the increase of the operational time. If the waiting times of vessels increase the container terminal is required to also operate at night, what is possible in the (near) future according to the CGPBB and Patagonia Norte. Increasing the ability for the container terminal receiving vessels 24 hours a day, 365 a year, the operational time is 8,760 hours/year.

Furthermore, by increasing the throughput approximately above the 45,000 TEU/year, the current shipping line capacity is reached and probably a second shipping line is calling the Port of Bahía. Due to this development the call frequency increases to 75 calls/year. The call size is also developing by increasing the throughput and is calculated by dividing the throughput by the call frequency.

Changing these input values, the queuing theory as described above is applied in the same way. With these developments in increasing the operational time of the terminal and the call frequency, the terminal is able to handle a throughput of approximately 70,000 TEU/year.

Third improvement

When the container throughput further increases above the 70,000 TEU/year, the input value(s) have to be improved again. The operation time is already the maximum value and the TEU-factor is a stable factor. Because of this, the only input variables left are the call frequency and the net productivity of the cranes that can be improved.

When the throughput approximately transcends the 90,000 TEU/year, probably the second shipping line is increasing their call frequency and the total call frequency increases to 100 calls/year. The call size is also developing by increasing the throughput and is calculated by dividing the throughput by the call frequency.

A next step is to place a STS gantry crane on the quay, replacing the activities of one of the cranes of the vessels. The STS gantry crane, operated by skilled personnel, can have a peak rate of about 40-50 moves/hour, so the net productivity of the gantry crane will be approximately 20 moves/hour. Using the mobile crane with a net productivity of about 10 moves/hour and the STS gantry crane with a net productivity of about 20 moves/hour, the combined net productivity is about 30 moves/hour. Changing the input value of the net productivity of the cranes, the queuing theory as described above is applied in the same way. Using this development the terminal is able to handle a throughput of approximately 100,000 TEU/year. It should be investigated if the STS gantry cranes calling the Port of Bahía Blanca are able to (un)load the vessels due to the hinder of the existing cranes of the vessels.

Final improvements

A next development of the (un)loading activities of the container terminal is the replacement of the mobile crane by another STS gantry crane. Using two gantry cranes a net productivity of approximately 40 moves/hour can be reached. When the throughput approximately transcends the 135,000 TEU/year, probably a third shipping line is calling the Port of Bahía and the call frequency increases to 150 calls/year. The call size is also developing by increasing the throughput and is calculated by dividing the throughput by the call frequency. Using this development the terminal is able to handle a throughput of approximately 140,000 TEU/year.

Finally, a third STS gantry crane can be placed on the quay, which increases the net productivity of the container terminal to about 60 moves/hour. Using this productivity the terminal is able to handle a throughput of approximately 200,000 TEU/year. When the throughput increases above 200,000 TEU/year, the terminal requires a second berth in order to guarantee a waiting time of the vessels below 10% of the service time.

Appendix L – Determination of the most suitable location by the CGPBB

In Figure xxii the MCA performed by the CGPBB is showed. The CGPBB scored the western, eastern and southern area and according to this analysis the western area is the most suitable for port expansion.

ALTERNATIVE TERMINAL LOCATIONS

Item	value of item	%	WEST	EAST	SOUTH
shoreline restrictions	4	7,4%	8	5	10
needs for improvement	3	5,6%	7	5	6
dredging investment	3	5,6%	5	6	6
maintenance dredging	2	3,7%	6	5	5
aids to navigation	2	3,7%	5	6	5
navigation distance	2	3,7%	5	5	5
available Area	4	7,4%	9	5	8
reclamation needs	4	7,4%	5	5	5
soil quality	3	5,6%	8	2	8
distance to rail and road networks	4	7,4%	8	6	1
energy, water, etc.	3	5,6%	8	6	1
roads connection	4	7,4%	8	8	1
rail connection	4	7,4%	8	6	1
environmental impact	5	9,3%	8	7	5
expropriation difficulties	4	7,4%	6	8	8
proximity to logistic areas	3	5,6%	8	7	1
Result	54	1	7,2	5,9	4,8

Figure xxii – MCA performed by the CGPBB

Appendix M – Determination of the weight factors

In this analysis the weight factors of the general criteria, intended for the MCA, are determined. The criteria are compared and in every combination of criteria it is considered which one of the criteria is more important with respect to the other criterion. The weight factors used in the MCA are the averages of the weight factors per person and are showed in Table xiii.

Table xiii – Weight factors MCA

Aspect	#	Criteria	Anniek	Bas	Thijs	Robbin	Average
Environmental impact	1	Nuisance to flora and fauna	7.7%	5.1%	9.0%	7.7%	7.4%
	2	Loss of flora and fauna	6.4%	7.7%	7.7%	11.5%	8.3%
Safety	3	Proximity of inflammable terminals	1.3%	14.1%	9.0%	14.1%	9.6%
	4	Vessel collision	3.8%	1.3%	1.3%	5.1%	2.9%
Technical factors	5	Expansion possibilities	14.1%	11.5%	15.4%	12.8%	13.5%
	6	Construction process	9.0%	0.0%	0.0%	2.6%	2.9%
	7	Capacity of the access channel	2.6%	5.1%	3.8%	1.3%	3.2%
Operational factors	8	Wind and wave conditions	12.8%	6.4%	10.3%	10.3%	9.9%
	9	Connection with the port area	9.0%	9.0%	7.7%	9.0%	8.7%
	10	Connection with the hinterland	10.3%	9.0%	11.5%	5.1%	9.0%
	11	Nautical access	0.0%	10.3%	7.7%	1.3%	4.8%
	12	Masterplanning of the Port of Bahía Blanca	7.7%	5.1%	9.0%	6.4%	7.1%
Third parties	13	Liveability of the residents	15.4%	15.4%	7.7%	12.8%	12.8%
			100.0%	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Appendix N – Wave generation

Favourable wind and wave conditions are of large importance for container handling operations between ship and shore. The maximum acceptable significant wave height (H_s) is in the order of 0.50m, based on PIANC recommendations (Ligteringen & Velsink, 2012). This wave height criterion is quite crude, because wave periods and the effects of the mooring system on ship movements are not taken into account. The Port of Bahía Blanca is sheltered from the sea waves by several sand banks in the sea-inlet, so the most important waves are waves locally generated by wind. Because of the lack of wave height measurements, these are estimated using equations as proposed by Charles L. Bretschneider and improved by Young and Verhagen (Vrijling, 2015). More accurate wave penetration models have to be applied for the detailed design of the port lay-out, in order to obtain more reliable wave heights translated into ship motions. The equations for the estimation of significant wave height are as follows:

$$\tilde{H} = \tilde{H}_{\infty} \cdot \left\{ \tanh\left(0.343\tilde{d}^{1,14}\right) \cdot \tanh\left(\frac{4.41 \cdot 10^{-4} \tilde{F}^{0.79}}{\tanh(0.343 \cdot \tilde{d}^{1.14})}\right) \right\}^{0.572} \quad \text{(Vrijling, 2015)}$$

where:

$$\tilde{H} = \frac{g \cdot H_{m0}}{{U_{10}}^2}$$

$$\tilde{F} = \frac{g \cdot F}{{U_{10}}^2}$$

$$\tilde{d} = \frac{g \cdot d}{{U_{10}}^2}$$

and

F	=	Fetch (m)
d	=	Water depth (m)
U_{10}	=	Wind velocity at an altitude of 10 m (m/s)
$\tilde{H}_{\infty}$	=	Dimensionless wave height at deep water = 0.24
H_{m0}	=	Significant wave height (m)

The fetch is defined as the horizontal distance over which wave-generating winds blow. In Figure xxiii the distribution of the wind intensity and direction for the period January till December 2001 at the Meteorological station of Puerto Rosales is shown. The wind characteristics are representative for the Port of Bahía Blanca, because the distance between Puerto Rosales and the Port of Bahía Blanca is only about 20km. In the figure it is shown that the most common wind directions are N, NNW and NW. About 38% of the time wind is coming from these directions, and in 26% of the time wind is coming from these directions with a wind speed above 5m/s. These wind directions only have a significant large fetch for locations 2 and 3. Locations 1 and 4 have a convenient position with respect to the wind directions and the associated fetch, so the wind is not able to generate waves which can hinder container handling operations.

In the same figure the fetches of the most common wind directions (N, NNW and NW) for locations 2 and 3 are shown. The maximum fetch of the N-wind is 4km, NNW-wind is 12km and NW-wind is 3.5km, so especially with NNW-wind waves are able to generate over a significant distance.

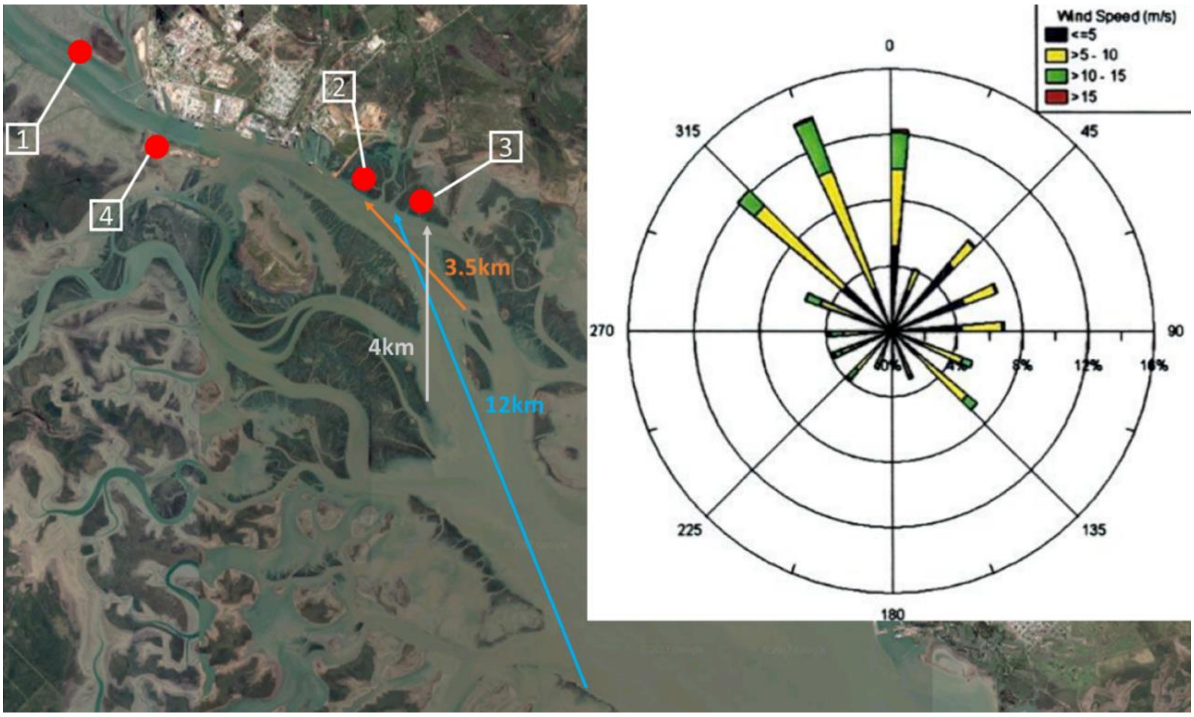


Figure xxiii - Distribution of wind intensity and direction for the period January till December 2001 at the Meteorological station of Puerto Rosales and the fetches of the different wind directions (Adapted from Google, 2017) & (CGPBB, 2011)

In order to estimate the significant wave height for a certain wind speed, also the water depth is required. The largest part of the fetch lines are positioned on top of the access channel, which has a channel depth of 13.5m, referring to Mean Low Water Springs. Using this value, this water depth is almost always guaranteed.

With the help of the equations above, for each of the three most important wind directions is estimated for which wind speed the significant wave height will exceed the 0.5m. As been said, with the exceedance of the this wave height, the crane operator is not able to (un)load the container vessel safely. With N-wind this wind speed have to be minimally 11.5m/s, with NNW-wind minimally 7.5m/s and with NW-wind minimally 12m/s. Assuming the ranges of wind speed in Figure xxiii to be directly proportional, an estimation of the occurrence of these wave speeds can be executed. The results of these calculations are showed in Table xiv.

Table xiv – Wave generation for different wind directions

Wind direction	Fetch (km)	Wind speed (m/s) (H_s > 0.5m)	P (H_s > 0.5m)
N	4	11.5	2%
NNW	12	7.5	6.5%
NW	3.5	12	0.5%
			9%

From Table xiv it follows that in about 9% of the time the significant wave height will exceed 0.5m in locations 2 and 3 and the container terminal will not be able to (un)load the container vessels. This downtime of the terminal is undesirable and too much in order to operate as a reliable terminal. A possible solution for locations 2 and 3 is to protect the berths of the terminal from the waves, for instance by designing the berths of the terminal not along the access channel, but sheltered. Obviously this solution is more costly. These wave height results are rough estimations, so further research (with the help of model simulation) is required in order to receive more reliable values.

Appendix O – MCA results

In this appendix the MCA's completed by the different involved are showed. The final scores for each of the locations are determined by the average of the total scores per person and showed in Table xxiv.

Table xv – MCA Anniek Munters

Aspect	Nr.	Criterion	Score for each criterion			
			Location 1	Location 2	Location 3	Location 4
Environmental impact	1	Nuisance to flora and fauna	3	3	3	3
	2	Loss of flora and fauna	2	3	2	2
Safety	3	Proximity of inflammable terminals	2	4	4	4
	4	Vessel collision	4	3	3	3
Technical factors	5	Expansion possibilities	4	2	4	4
	6	Construction process	2	3	2	2
	7	Capacity of the access channel	4	2	2	2
Operational factors	8	Wind and wave conditions	4	2	2	4
	9	Connection with the port area	2	3	3	1
	10	Connection with the hinterland	3	2	2	1
	11	Nautical access	3	4	4	4
	12	Masterplanning of the Port of Bahía Blanca	3	1	3	1
Third parties	13	Liveability of the residents	3	2	3	3

Table xvi – MCA Bas Stam

Aspect	Nr.	Criterion	Score for each criterion			
			Location 1	Location 2	Location 3	Location 4
Environmental impact	1	Nuisance to flora and fauna	2	3	2	2
	2	Loss of flora and fauna	3	2	3	2
Safety	3	Proximity of inflammable terminals	4	3	3	4
	4	Vessel collision	3	3	3	2
Technical factors	5	Expansion possibilities	2	3	4	4
	6	Construction process	2	2	3	3
	7	Capacity of the access channel	2	3	3	2
Operational factors	8	Wind and wave conditions	3	3	3	3
	9	Connection with the port area	3	3	2	1
	10	Connection with the hinterland	3	3	3	2
	11	Nautical access	3	3	3	2
	12	Masterplanning of the Port of Bahía Blanca	4	3	3	2
Third parties	13	Liveability of the residents	3	3	3	4

Table xvii – MCA Thijs van der Wel

Aspect	Nr.	Criterion	Score for each criterion			
			Location 1	Location 2	Location 3	Location 4
Environmental impact	1	Nuisance to flora and fauna	3	3	3	3
	2	Loss of flora and fauna	3	3	3	3
Safety	3	Proximity of inflammable terminals	2	3	3	3
	4	Vessel collision	4	3	3	3
Technical factors	5	Expansion possibilities	4	3	4	4
	6	Construction process	3	2	2	3
	7	Capacity of the access channel	2	4	4	3
Operational factors	8	Wind and wave conditions	4	2	2	4
	9	Connection with the port area	4	3	3	1
	10	Connection with the hinterland	3	4	4	1
	11	Nautical access	4	4	4	4
	12	Masterplanning of the Port of Bahía Blanca	4	3	3	1
Third parties	13	Liveability of the residents	3	3	3	4

Table xviii – MCA Robbin Wesstein

Aspect	Nr.	Criterion	Score for each criterion			
			Location 1	Location 2	Location 3	Location 4
Environmental impact	1	Nuisance to flora and fauna	2	3	2	2
	2	Loss of flora and fauna	3	2	3	2
Safety	3	Proximity of inflammable terminals	1	2	3	4
	4	Vessel collision	4	3	2	3
Technical factors	5	Expansion possibilities	4	3	2	4
	6	Construction process	4	2	2	3
	7	Capacity of the access channel	2	4	4	3
Operational factors	8	Wind and wave conditions	3	1	1	3
	9	Connection with the port area	4	4	3	1
	10	Connection with the hinterland	3	3	3	2
	11	Nautical access	2	3	3	3
	12	Masterplanning of the Port of Bahía Blanca	2	3	3	2
Third parties	13	Liveability of the residents	3	2	2	3

Table xix – MCA Pablo Arecco

Aspect	Nr.	Criterion	Score for each criterion			
			Location 1	Location 2	Location 3	Location 4
Environmental impact	1	Nuisance to flora and fauna	2	3	3	2
	2	Loss of flora and fauna	2	2	2	3
Safety	3	Proximity of inflammable terminals	2	4	4	4
	4	Vessel collision	2	3	2	3
Technical factors	5	Expansion possibilities	3	3	3	3
	6	Construction process	3	4	3	2
	7	Capacity of the access channel	2	3	4	2
Operational factors	8	Wind and wave conditions	3	3	3	3
	9	Connection with the port area	2	3	2	1
	10	Connection with the hinterland	3	4	3	1
	11	Nautical access	2	3	3	2
	12	Masterplanning of the Port of Bahía Blanca	1	3	4	2
Third parties	13	Liveability of the residents	2	3	3	4

Table xx – MCA Carlos Gines

Aspect	Nr.	Criterion	Score for each criterion			
			Location 1	Location 2	Location 3	Location 4
Environmental impact	1	Nuisance to flora and fauna	3	3	3	3
	2	Loss of flora and fauna	3	3	3	3
Safety	3	Proximity of inflammable terminals	3	4	4	4
	4	Vessel collision	3	4	4	3
Technical factors	5	Expansion possibilities	4	3	3	2
	6	Construction process	2	2	2	1
	7	Capacity of the access channel	3	4	4	3
Operational factors	8	Wind and wave conditions	4	3	3	4
	9	Connection with the port area	2	3	2	1
	10	Connection with the hinterland	3	3	2	1
	11	Nautical access	2	2	2	3
	12	Masterplanning of the Port of Bahía Blanca	2	3	3	3
Third parties	13	Liveability of the residents	3	3	3	3

Table xxi – MCA Juan Linares

Aspect	Nr.	Criterion	Score for each criterion			
			Location 1	Location 2	Location 3	Location 4
Environmental impact	1	Nuisance to flora and fauna	3	4	4	3
	2	Loss of flora and fauna	3	3	3	2
Safety	3	Proximity of inflammable terminals	3	4	4	3
	4	Vessel collision	4	3	3	3
Technical factors	5	Expansion possibilities	4	2	4	4
	6	Construction process	3	4	3	2
	7	Capacity of the access channel	3	4	4	3
Operational factors	8	Wind and wave conditions	4	4	4	4
	9	Connection with the port area	4	4	3	2
	10	Connection with the hinterland	4	4	3	2
	11	Nautical access	3	4	4	4
	12	Masterplanning of the Port of Bahía Blanca	4	2	2	3
Third parties	13	Liveability of the residents	3	4	4	2

Table xxii – MCA Edgardo Spagnolo

Aspect	Nr.	Criterion	Score for each criterion			
			Location 1	Location 2	Location 3	Location 4
Environmental impact	1	Nuisance to flora and fauna				
	2	Loss of flora and fauna				
Safety	3	Proximity of inflammable terminals	3	4	4	4
	4	Vessel collision				
Technical factors	5	Expansion possibilities	4	1	3	4
	6	Construction process				
	7	Capacity of the access channel				
Operational factors	8	Wind and wave conditions				
	9	Connection with the port area	4	2	2	1
	10	Connection with the hinterland	4	3	4	3
	11	Nautical access				
	12	Masterplanning of the Port of Bahía Blanca				
Third parties	13	Liveability of the residents				

Table xxiii – MCA Pedja Zivojnovic

Aspect	Nr.	Criterion	Score for each criterion			
			Location 1	Location 2	Location 3	Location 4
Environmental impact	1	Nuisance to flora and fauna	2	4	3	2
	2	Loss of flora and fauna	2	4	3	2
Safety	3	Proximity of inflammable terminals	2	3	4	2
	4	Vessel collision	3	3	4	2
Technical factors	5	Expansion possibilities	3	2	4	4
	6	Construction process	2	2	3	3
	7	Capacity of the access channel	2	3	4	3
Operational factors	8	Wind and wave conditions	2	3	3	2
	9	Connection with the port area	3	4	3	1
	10	Connection with the hinterland	3	2	2	1
	11	Nautical access	2	3	4	3
	12	Masterplanning of the Port of Bahía Blanca	3	2	3	2
Third parties	13	Liveability of the residents	2	2	3	4

Table xxiv – MCA with average and total scores

Aspect	Nr.	Criterion	Score for each criterion			
			Location 1	Location 2	Location 3	Location 4
Environmental impact	1	Nuisance to flora and fauna	2.5	3.3	2.9	2.5
	2	Loss of flora and fauna	2.6	2.8	2.8	2.4
Safety	3	Proximity of unflammable terminals	2.4	3.4	3.7	3.6
	4	Vessel collision	3.4	3.1	3.0	2.8
Technical factors	5	Expansion possibilities	3.6	2.4	3.4	3.7
	6	Construction process	2.6	2.6	2.5	2.4
	7	Capacity of the access channel	2.5	3.4	3.6	2.6
Operational factors	8	Wind and wave conditions	3.4	2.6	2.6	3.4
	9	Connection with the port area	3.1	3.2	2.6	1.1
	10	Connection with the hinterland	3.2	3.1	2.9	1.6
	11	Nautical access	2.6	3.3	3.4	3.1
	12	Masterplanning of the Port of Bahía Blanca	2.9	2.5	3.0	2.0
Third parties	13	Liveability of the residents	2.8	2.8	3.0	3.4
			37.6	**38.5**	**39.3**	**34.4**

Appendix P – Cost analysis

The main cost items constructing a new container terminal are summed up and compared for each of the locations.

Land reclamation terminal

For location 1 land reclamation is required in order to locate the terminal next to the access channel. For the other locations some land is already located adjacent to the access channel, therefore these three locations need predominantly heightening of the land. Location 4 has already some hops of dredged material as preparation for future land use, in contrast with location 2 and 3.

Construction of railway

The best location with respect to the distance to the existing rail network is location 1 (Table xxv & Figure xxiv). After that connections 2 and 3 are almost similar in distance, but connection 2 requires two bridges and connection 3 one bridge over a small channel. Location 4 is the worst location; It requires about 27km of rail connection and also quite some land reclamation.

Table xxv - Approximate distances per location to existing infrastructure

	Location 1	Location 2	Location 3	Location 4
Distance to rail [km]	2.5	7.0	8.0	27.0
Distance to national road [km]	4.5	3.5	4.5	20.5

Figure xxiv - Road – and rail connection of different locations (Adapted from Google, 2017)

Construction of road

The approximate distances per location to the existing national road are given in Table xxv. Location 2 is the most close location to the RN3. However, location 1 and 3 are just slightly further away. Moreover, location 2 again requires two bridges and location 3 one bridge over a small river of about 15m, increasing the costs of these locations slightly. Location 4 is obviously at the largest distance from an existing road connection. This option also crosses lots of small river branches, resulting in high reclamation costs.

Dredging costs

With respect to capital dredging only location 1 needs a lengthening of the access channel and a new turning circle. The access channel ends at the last berth of Posta de Inflammables. Therefore the channel has to be extended with approximately 2km to the terminal of location 1. The current turning circle is 495m, so the new one has to be at least of this size as well. The other three locations are positioned adjacent to the current access channel and need only extra capital dredging close to the berth.

With respect to maintenance dredging the extra length of the access channel and the new turning circle will only result in a minimal increase in maintenance dredging costs. The total channel length is 97km meaning a lengthening by 2km will have only a minor impact.

Soil improvements

For a decent comparison between the soil quality of the different locations is it necessary to have soil data of these locations. Due to a lack of this data for all four locations, common sense have to be used to make an appropriate comparison. When a lot of river branches and flood plains are present at a certain location, it is more likely that the soil profile is made up from sediment deposits. Using this theory, location 2 and 3 will have the most sediment deposit and therefore the thickest layer of soft soil. Location 1 and 4 are larger plains with less river branches and therefore it is likely that these two locations have a thinner layer of soft soil.

Expropriation land

The area of location 1, western of the Port of Bahía Blanca, is currently owned by private institutions so before construction of the new terminal this area has to be bought by the CGPBB. The areas of locations 2, 3 and 4 are already (mostly) owned by the CGPBB, so this acquisition isn’t required if the new terminal is constructed at these locations. Because of this, the costs of expropriation land of location 1 is much higher than for the other locations.

Facility connections

The four terminal locations does all have a different distance to the current energy- and water infrastructure of the Port of Bahía Blanca. Location 4 is the most unfavourable location, because the facility connections have to cross the access channel, so the costs of these connections are the highest. Locations 1 and 2 are located just next to the port, so these connections are relatively short. The distance to most eastern location 3 is somewhat more than location 2, so the costs of these connections will be somewhat higher.

Appendix Q - Port calling cost components

This appendix gives an overview of the different cost components that have to be considered when calling a port with a container vessel. Each component is provided with a short explanation and the factors of where the cost depend on.

Use of waterway

[Costs depend on the size of the vessel and the sections being crossed]

The fee for using the waterway are mandatory costs intended to compensate for the dredging and beaconing of the waterway. The calculation of this tariff is specific per port. The tariff can be calculated via a formula, divided into a beaconing part and a dredging part. The beaconing cost are proportional to the size of the vessel and the for the dredging a correction factor is taken regarding the draught of the vessel. Other ports charge the tariff per amount of cargo that is transported into the port.

Piloting

[Costs depend on the size of the vessel and the sections being crossed]

These costs consist out of the tasks carried out in order to advise the captain on navigation, manoeuvres and regulations in the area.

Tug service

[Cost depends on the kind of vessel, the distance, the amount of tugs and the period of the day]

Tug boats ensure the safety of the vessels' manoeuvres. The amount of tug boats depend on the length of the vessel and the place where the manoeuvres take place.

Security service

[Cost depends on the type of load and the period of the day]

The security service (serene) is responsible for the general supervision of ships in the port, as well as the cargo placed on the docks. Each access to the vessel needs to be supervised by a guard who is responsible for the movement of persons and cargo entering and exiting the vessel.

Port use tariffs

[Per Net Registered Tonnage (NRT) and amount of days in the port]

The port use tariff includes fee for entering the port and usage of the lighthouse, wharfs and buys. The tariff is the sum of several rates, but one value because they are all calculated based on the NRT of the vessel. Moreover, the amount of days is important because the vessel uses the facilities of the port.

Ministry of Health

[Per vessel, depends on the size of the vessel]

The National Bureau of Registration, Inspection and Health of Borders issues a certificate, called Libre Plática, indicating that the vessel is free of infections and contaminations.

SENASA (Servicio Nacional de Sanidad y Calidad Agroalimentaria)

[Cost depends on the amount of days in the port]

The National Service of Agri-Food Quallity and Health does inspections on board to guarantee the hygienic conditions at different locations on the vessel. Moreover, the provisions and supplies on board for own consumption are checked as well. Since SENASA does inspection 24 hours a day, 365 days a year, the share of cost depends on the time that the vessel is in the port.

Immigration

[Per crew member]

The national immigration takes care of the people entering and exiting the country. Moreover, it is responsible for the right documentation of the crew to enter the country.

Container terminal tariffs

[Per container]

The handling and movements of the containers between the vessel and the dock, and between the dock and the storage area in the terminal. Fees are charged per container and are often a confidential trade arrangement between the terminal operator and the shipping line.

Mooring operations

[Per vessel, depend on the size of the vessel]

These cost are related to the service provided by a mooring company. It includes the attaching and detaching of a mooring line on arrival and departure of the vessel carried out by a special boat.

Time cost vessel

[Per amount of days in the port]

The daily operating cost of a vessel (fuel, electricity, water etc.) when the vessel is moored in the port.

Cargo tariffs

[Per ton]

This is a general fee for the use of the port and calculated per ton of cargo that is handled. The rate depends on the destiny of the cargo, export, import or inland transport.

Cargo handling

[Per container]

The handling and movements of the containers between the storage area in the terminal and the mode which is used to transport the containers inland.

Custom checks

[Per container]

These cost relate to the actions necessary to inspect the content of the container. There are several methods to verify the content depending on the type of cargo. After the custom check, the container is equipped with a seal.

ISPS code (International Ship and Port Facility Security)

[Per container]

The ISPS code is a set of measures to enhance the security of ships and port facilities. After the attacks on 9/11 in the United States, the scope of the code was more aimed on preventing attackers to use the cargo within the containers for terroristic attacks.

Gate fee

[Per container]

Charge by terminal for using the output control (export) and input control (import) at the gate.

Storage and extras

[Per container, depends on the operation]

Off-hours reception, refrigeration, containers which are out of order, dangerous cargo storage etc. The cost vary a lot depending on the type of operation and the extra .

Other services

[Per containers, depends on the operation and situation]

The terminal provides extra services as for example cleaning the containers.

Appendix R – Port calling cost

This appendix provides more information regarding the reference operation making a distinguish in the first and second situation. For both situations, first the operation details are shown after which a table is given with the cost components and all the corresponding values.

Table xxvi – Operation detail situation 1

Operation details situation 1		
Number of FEU	45%	2,160
Export of FEU	51%	1,102
Full	52%	573
Empty	48%	529
Import of FEU	49%	1,058
Full	90%	953
Empty	10%	106
Weight per FEU [ton]		25
Total cargo [ton]		38,135
Duration of stay [days]		1
Number of TEU (only for calculations)		4,320

	BAHIA BLANCA				**BUENOS AIRES**	
	Container vessels		Other vessels			
USE OF THE WATERWAY	**USD**	**-**	**USD**	**41.662**	**USD**	**101.000**
Total rate per unit load [U$D/ton]	USD	-	USD	1,09		
Rate per unit load [U$D/ton]			USD	0,95		
Ship capacity coefficient [-]				1,15		
Coefficient for navigation section [-]				1		
PILOTING (2 ways)	**USD**	**18.000**	**USD**	**18.000**	**USD**	**45.000**
TUG SERVICE (2 ways)	**USD**	**62.000**	**USD**	**62.000**	**USD**	**39.000**
Price per tugboat	USD	15.500	USD	15.500	USD	9.750
Number of tugboats		4		4		4
PORT USE TARIFFS	**USD**	**-**	**USD**	**19.151**	**USD**	**24.068**
Tariff per day [U$D/NRT/day]	USD	-	USD	0,37	USD	0,47
Dock service [U$D/NRT/day]					USD	0,10
Vessel fees [U$D/NRT/day]					USD	0,30
Lighting and beacons [U$D/NRT/day]					USD	0,07
CONTAINER TERMINAL TARIFFS						
Export	**USD**	**352.512**	**USD**	**352.512**	**USD**	**242.352**
Import	**USD**	**338.688**	**USD**	**338.688**	**USD**	**232.848**
Export [U$D/container]	USD	320	USD	320	USD	220
Import [U$D/container]	USD	320	USD	320	USD	220
CARGO TARIFFS						
Export	**USD**	**4.654**	**USD**	**9.309**	**USD**	**28.642**
Import	**USD**	**17.503**	**USD**	**35.007**	**USD**	**95.256**
Export [U$D/ton]	USD	0,33	USD	0,65	USD	2,00
Import [U$D/ton]	USD	0,74	USD	1,47	USD	4,00
TOTAL	**USD**	**793.358**	**USD**	**876.328**	**USD**	**808.166**
Price per container [U$D/TEU]	USD	184	USD	203	USD	187

Figure xxv – Port calling costs situation 1

Table xxvii – Operation details situation 2

Operation details situation 2		
Number of FEU	55%	2,640
Export of FEU	51%	1,346
Full	52%	700
Empty	48%	646
Import of FEU	49%	1,294
Full	90%	1.164
Empty	10%	129
Weight per FEU [ton]		25
Total cargo [ton]		46,609
Duration of stay BB [days]		1
Duration of stay BA [days]		2
Number of TEU (only for calculations)		5,280

	BAHIA BLANCA				BUENOS AIRES	
	Container vessels		Other vessels			
USE OF THE WATERWAY	**USD**	**-**	**USD**	**50.921**	**USD**	**202.000**
Total rate per unit load [U$D/ton]	USD	-	USD	1,09		
Rate per unit load [U$D/ton]			USD	0,95		
Ship capacity coefficient [-]				1,15		
Coefficient for navigation section [-]				1		
PILOTING (2 ways)	**USD**	**18.000**	**USD**	**18.000**	**USD**	**90.000**
TUG SERVICE (2 ways)	**USD**	**62.000**	**USD**	**62.000**	**USD**	**78.000**
Price per tugboat	USD	15.500	USD	15.500	USD	9.750
Number of tugboats		4		4		8
PORT USE TARIFFS	**USD**	**-**	**USD**	**19.151**	**USD**	**48.136**
Tariff per day [U$D/NRT/day]	USD	-	USD	0,37	USD	0,47
Dock service [U$D/NRT/day]					USD	0,10
Vessel fees [U$D/NRT/day]					USD	0,30
Lighting and beacons [U$D/NRT/day]					USD	0,07
CONTAINER TERMINAL TARIFFS						
Export	**USD**	**430.848**	**USD**	**430.848**	**USD**	**296.208**
Import	**USD**	**413.952**	**USD**	**413.952**	**USD**	**284.592**
Export [U$D/container]	USD	320	USD	320	USD	220
Import [U$D/container]	USD	320	USD	320	USD	220
CARGO TARIFFS						
Export	**USD**	**5.689**	**USD**	**11.377**	**USD**	**35.006**
Import	**USD**	**21.393**	**USD**	**42.786**	**USD**	**116.424**
Export [U$D/ton]	USD	0,33	USD	0,65	USD	2,00
Import [U$D/ton]	USD	0,74	USD	1,47	USD	4,00
TOTAL	**USD**	**951.881**	**USD**	**1.049.034**	**USD**	**1.150.366**
Price per container [U$D/TEU]	USD	180	USD	199	USD	218

Figure xxvi – Port calling costs situation 2