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The Panama Canal expansion: New Panamax container vessels and their implications for the basic port infrastructure in the container ports of Ecuador.

by

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Acknowledgments

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Abstract

The expected opening of the enlarged Panama Canal in 2016 and the introduction of the New Panamax container vessel bring in new advantages to global trade. The deployment of more vessel capacity is seen as a driver to reduce transportation costs based on the economies of scale. But this new vessel capacity is also seen as a major challenge for the ports in the region of the West Coast of South America since their basic port infrastructure, comprised of maritime access channel depth and quay wall length, have not been developed accordingly. The aim of this study is to evaluate the introduction of the New Panamax vessel in the container ports of Ecuador and propose some implications to be considered in the short term in order to improve the port system of this country. The theoretical model applied to this study shows that the ideal port capable of handling this type of vessel differs significantly from the actual situation of the ports in Ecuador. In the case of the Port of Guayaquil, the maritime access channel depth is below the average for the region, for this reason it requires urgent attention in order to have at least 14 metres of draught restriction to avoid it becoming an obsolete port upon the opening of the enlarged Panama Canal. In the case of the Port of Esmeraldas and the port of Puerto Bolivar, in addition to the deepening of their maritime access channel, the quay wall length is the variable that will be most affected therefore, expansion projects for the extension of the quay wall should be marked as priority in the to do list of these ports.

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1 Introduction

1.1 Objective and Relevance

The Panama Canal expansion and its expected opening in 2016 will be an important event in the shipping sector which will lead to a change in strategy and operation of the maritime industry in Latin America. All actors involved in the Panama Canal are called to take important decisions regarding their structure in order to be on par with the work currently underway in the canal.

According to the Panama Canal Authority, as of July 31, 2015, the work in the canal is 93% finished. Once the work is completed, the Panama Canal Authority expects to use its new facilities to double the current capacity of cargo handling. This new capacity will reach 508 million tonnes Panama Canal Universal Measurement System (PCUMS)[1] by the year 2025.

The use of a third lane and a new set of locks will enable the transit of larger vessels: the Post-Panamax vessel class or now called the New-Panamax vessel class. With the third lane in operation, it is expected that the volume of the cargo handled in the Panama Canal will increase through the application of the concept of economies of scale (Panama Canal Authority, 2015a). It is worth to emphasise that one of the most significant changes in the physical structure of the new lane is the increase in the allowable draught, which will go from 12.04 metres (39.5') to 15.2 metres (50'). Most studies of the ports on the East Coast of the United States (USEC) perceive the maritime depth and its dredging as the most important strategic point to be considered on investment projects facing the Panama Canal expansion (Rodrigue, 2010).

Taking the example of a container vessel, the current locks in the Panama Canal allow the transit of vessels carrying up to 5,000 TEUs; after the opening of the third lane the canal will allow the transit of Post-Panamax vessels carrying up to 13.000 TEUs depending on the stow of the cargo.

But managing the vessels of a new standard size transiting the Panama Canal suggests a change in the physical infrastructure necessary for the facilitation of this new type of vessel. Considering that the structural difference between the Panamax and the Post-Panamax vessel class is remarkable, it is recognisable that the ports that are not prepared to receive a vessel with bigger dimensions, mainly deeper draught, will fall behind the new traffic flow after the opening of the enlarged Panama Canal.

One of the main users of the Panama Canal is Ecuador (Table 1). It currently holds the ninth position among the busiest countries in terms of cargo movement through the canal, however it is in the least busy in comparison with the countries of the sub-

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[1] PCUMS: The volume of cargo transiting the Canal is measured in PCUMS tonnes, A PCUMS ton is equivalent to approximately 100 cubic feet of cargo space, and a 20-foot-long container is equivalent to approximately 13 PCUMS tonnes (Panama Canal Authority, 2006).

region of the West Coast of South America (WCSA) that includes Colombia, Ecuador, Peru and Chile.

Table 1: 2014 Ranking of users of the Panama Canal by countries by tonnes

Rank	Country	Origin	Destination	Total	Share
1	United States	99,330,031	54,813,235	155,515,811	44%
2	China	16,379,246	35,130,992	51,510,238	15%
3	Chile	13,464,023	15,990,159	29,454,182	8%
4	Japan	5,067,896	16,606,805	21,674,701	6%
5	Colombia	11,314,367	7,918,403	19,705,810	5%
6	South Korea	10,102,023	9,082,500	19,184,523	5%
7	Peru	7,080,322	9,455,582	16,535,904	5%
8	Mexico	7,559,352	7,070,380	15,150,717	4%
9	Ecuador	6,976,330	7,003,716	13,980,046	4%
10	Canada	7,131,042	3,172,406	10,303,448	3%

Source: Panama Canal Authority

Coincidentally Ecuador also holds the last place on what concerns the draught restriction in ports, as the average draught restriction in the main ports of the region is about 12.5 metres. Ecuador's main port located in the city of Guayaquil allows the entry of vessels of up to 9.75 metres draught. The city of Manta, the port with the greatest natural depth in the country, allows the entry of the vessels of up to 12 metres draught, however, this port is a secondary port in terms of cargo volume and it has a low share in the handling of containerised cargo.

The management of the draught restriction is part of the basic port infrastructure that is in the hands of the Port Authorities of each country in the region. In Ecuador this issue has not been addressed with enough sense of urgency. This is because, among others, due to the fact that the size of the Panama Canal itself has also acted as a limitation on the use of larger vessels in the region, thus delaying the deployment of bigger vessels. With the exponential and accelerated growth of vessel sizes, bigger vessels are being moved from main routes into secondary routes (Sanchez & Perroti, 2012) but this has not happened yet in the region.

Given the magnitude of importance of the Panama Canal for Ecuador, this study will explore the implications for basic port infrastructure that Ecuadorian ports, especially the ports that handle containers, would have to consider for the opening of the enlarged Panama Canal and the introduction of the New Panamax container vessels.

Therefore, this study will aim to answer the following main research question:

What are the implications for the basic port infrastructure of Ecuador's container ports considering the Panama Canal expansion and the introduction of the New Panamax container vessels?

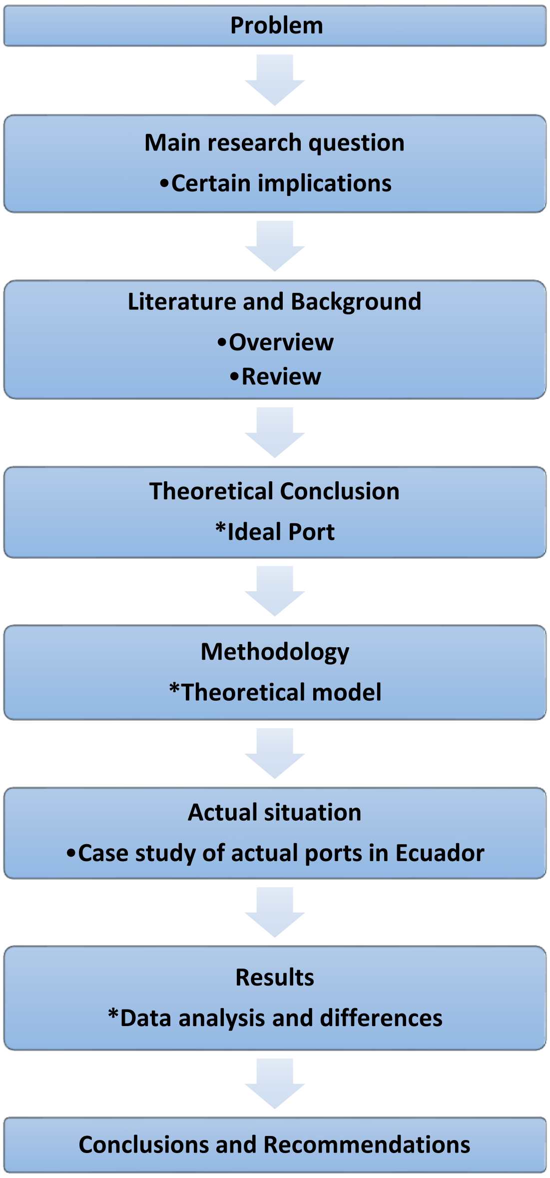
This question features three elements. First, the Panama Canal and the expectations after the opening of its expanded version, taking into account the flows and forecasts of traffic in the future. Second, the impact on Ecuadorian container ports – considering that containerised cargo constitutes the bulk of traffic passing through the Panama Canal and in the main ports of the region. Finally, the basic port infrastructure that is the responsibility of the Ecuadorian Port Authorities takes into account port assets such as the maritime access channel with its draught management and the basic infrastructure in ports and terminals such as locks and quay walls. To answer the main research question this study will seek to answer the following sub-research questions:

1. *How important is the Panama Canal for the region and the Ecuadorian Ports?*
2. *What does the use and deployment of New Panamax container vessels imply?*
3. *How is the port infrastructure affected by the increase of vessels' size?*
4. *What are the ideal characteristics of a container port in terms of the basic port infrastructure after the opening of the Panama Canal expansion?*
5. *What are the characteristics of Ecuador's container ports in terms of basic port infrastructure?*

The sub-research questions will help us to answer the main research question and to define how a container port should look like in terms of basic port infrastructure in order to meet the new requirement of the New Panamax container vessels. With the situation of the ideal port we can generate an ideal theoretical model which will give recommendations that may be taken into account for future improvement of the Port System in Ecuador given the actual reality of the container ports of Ecuador.

The structure of the study is summarised in the following figure:

Figure 1: Structure of the present study



The Panama Canal is an engineering work that brought many benefits to world trade since the beginning of its operation in 1914. Countries located close to the Panama Canal, such as Ecuador, for example, have benefited greatly from it. The new Panama Canal expansion will introduce the new standard size of vessel transiting the region, the New Panamax vessel.

This study is relevant for the actors and stakeholders in the maritime industry of Ecuador, for private as well as public sector in order to know, recognise and, to some extent, help to establish certain measures and actions in basic port infrastructure development which will allow, in the short term, to have a better picture of what will happen, how to be prepared and what improvements should be made once the Panama Canal expansion is operational and the New Panamax vessel is sailing in the region.

1.2 Research Design and Methodology

The research design of this study will follow the comparison of an ideal situation (SOLL situation) with an actual situation (IST situation), the results of this study will emerge in form of recommendations for the actual situation/scenario to improve the variables chosen for this study. In order to do so, a theoretical model will be designed to find the main implications for the basic port infrastructure of Ecuador's container ports as well as how major those implications are. The methodological approach will include the use of a linear regression model to forecast patterns in vessels' dimensions and analytical criteria, and evaluate the performance of each of the variables in the current situation, while at the same time looking ahead to gauge their possible impact in the future.

1.3 Thesis Structure

This study begins with chapter 2 that briefly describes the literature overview about the elements proposed in the main research question, the Panama Canal, the Port infrastructure and the container ports in Ecuador. This chapter elaborates on the importance of the three elements in the current study and includes the classification used by the World Bank to establish the port management models. Chapter 3 provides a literature overview about the above-mentioned elements, studies about the Panama Canal and its expansion, the Port Infrastructure and the proposed methods to assess projects, the market segment of the containers and its relevance in shipping and finally the economies of scale as a driver for the growth in size of vessels, particularly in container vessels. Chapter 4 provides a theoretical conclusion based on the literature overview and review. This conclusion leads to a theoretical model and an ideal situation proposed by the author. Chapter 5 develops the details of the container ports in Ecuador as a case study, the data gathering and the port selection criteria. Chapter 6 presents the main findings of the current situation of the container ports in Ecuador and the main differences in comparison with the ideal situation. In Chapter 7, the main research question will be answered. Conclusion summarises the key findings, the limitation of the study and additionally, suggestions for further research and recommendations.

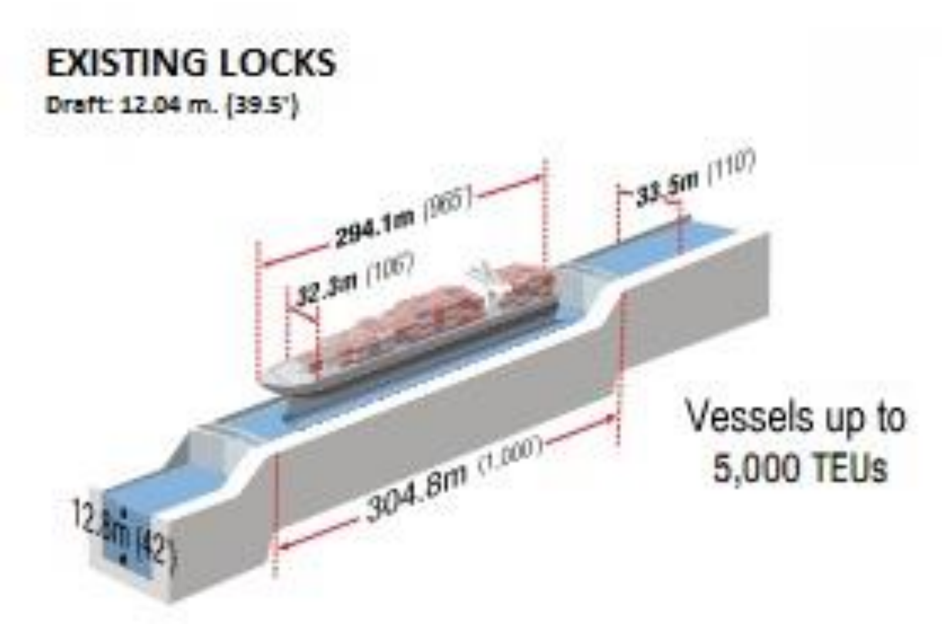
2 Literature Overview/Background

2.1 The Panama Canal

The Panama Canal and the two ports on different oceans, Balboa and Colon, have put Panama on the map as one of the most important logistics centres in the global supply chain. Its strategic location in Central America has helped to shorten distances in the region by becoming an important hub for the redistribution of cargo and a gateway between the Pacific and the Atlantic oceans.

The Panama Canal is the interoceanic passage that connects the Pacific and the Atlantic Ocean through a navigation canal that traverses the Isthmus of Panama. The Panama Canal Authority is the government body responsible for the management, operation and maintenance of the Panama Canal, offering transit service through the waterway at about 14,000 vessels per year (Sabonge & Sanchez, 2009). In terms of vessel handling the current capacity of the Panama Canal is limited by the dimensions of the locks that are used for the transit of vessels (Figure 2). These locks are used due to the difference in height of the sea level in the Pacific Ocean in comparison with the Atlantic Ocean. The current locks allow for the transit of vessels of up to 32.3 metres in length overall, 294.1 metres in beam, 12.04 metres in draught and 57.91 metres in air draught. In terms of volume limitation, it allows the passage of vessels of up to 65,000 deadweight tonnes (DWT). These dimensions gave origin to the Panamax class vessel, a standardised size that was an important factor in the construction of many vessels over the past decades (Rodrigue, 2015a).

Figure 2: Details of the existing locks of the Panama Canal



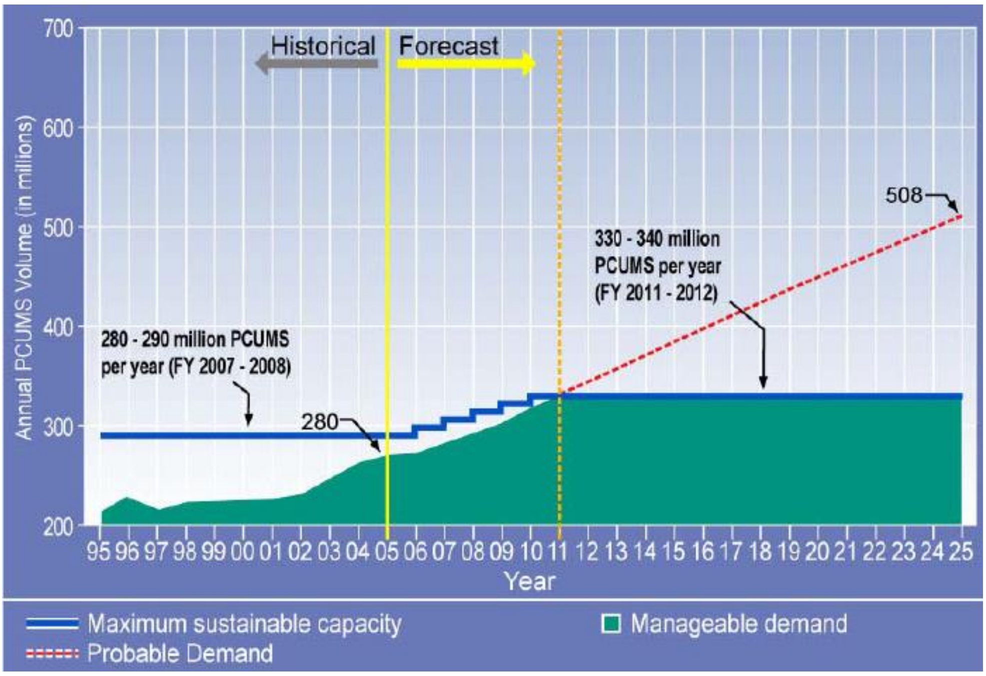
Source: Panama Canal Authority

According to Sanchez (2007) the main contribution of the current Panama Canal to the region is based on its global connection with the main trade routes from which South America benefits because Panama is seen as the regional hub before reaching any destination in the world via one or more of the 144 regular services crossing the canal every week.

The Panama Canal allows saving time and transportation costs compared with alternate routes. But the importance of the canal is even greater for the WCSA. For example, in the case of Ecuador, 34.2% of the country's maritime cargo flow uses the Panama Canal and 11 out of the 19 (58%) regular services that supply the country transit the canal. In Chile, 35.7% of the country's maritime cargo flow uses the Panama Canal and 13 out of 22 (59%) of regular services that supply the country transit the canal. In Peru, 20.7% of country's maritime cargo flow uses the Panama Canal while 46 regular services that supply the country transit the canal (Sabonge & Sanchez, 2009).

Given the economies of scale affecting the shipping industry, the tendency in the use of Post-Panamax vessel class around the world showed a constant and irreversible growth (Sabonge & Sanchez, 2009). However this type of vessel size cannot be handled by the current Panama Canal, therefore in view of the above, in 2006 the proposed expansion of the Panama Canal was approved and submitted to the Panama Canal Authority which mentioned the construction of a third lane and a new set of locks. The proposal stated that the purpose of the expansion was to achieve a sustainable and long-term growth of the contribution that the canal gives to the Panamanian society, maintain the competitiveness of the canal, increase the capacity to capture the growing demand for tonnage and finally to allow the canal operate in the most productive, safe and efficient way (Panama Canal Authority, 2006). The same study stated that the Panama Canal would reach its full capacity at certain point between 2009 and 2012 and after this, the Panama Canal would no longer be able to handle the increased demand, which would greatly reduce the quality of the service and the competitiveness of the route (Figure 3).

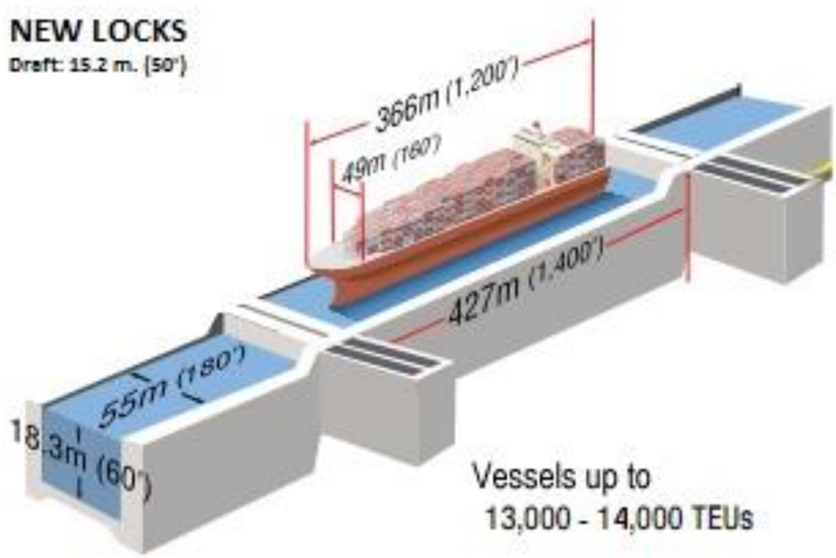
Figure 3: Maximum Sustainable Capacity of the Panama Canal



Source: Panama Canal Authority

The Panama Canal expansion, through the third lane and new set of locks, will allow the transit of Post-Panamax vessels (New Panamax) with dimensions up to 366 metres in length over all, 49 metres in beam, 15.2 metres in draught and 57.91 metres in air draught (Figure 4). In terms of volume, the new locks will allow the transit of vessels of up to 170,000 DWT.

Figure 4: Details of the new locks of the Panama Canal



Source: Panama Canal Authority

The entry into operation of the third lane shall mean that approximately 10 or 12 New-Panamax vessels can transit the canal every day. This amount of transit will be added to the total number of vessels that transits through the canal, reaching the amount of approximately 40 vessels per day (Panama Canal, 2015b).

The expectations regarding the effects of the Panama Canal expansion are based on the economic study commissioned by the Panama Canal Authority which indicates that in the most likely scenario, with regards to the demand, for the next 20 years (2005-2025) the volume of cargo transited will grow at about 3% per annum. In 2025, the volume of 2005 is expected to double (Panama Canal Authority, 2006). In terms of vessel size, a gradual deployment of bigger vessels transiting the Panama Canal is expected. Shipping lines will have to adjust their services on major trade routes to reach the optimisation of vessel size according to the current (and future) volumes of cargo.

2.2 The Containerisation

The globalisation and its main effect, the opening of the borders across the world, is seen as one of the main drivers to the introduction of the containerisation. More than half a century ago the container entered the market to stay and as of today its development continues to be subject of studies. In this context the container is not only seen as a means of transportation, but it is also seen as an important element in the complex system of the international supply chain (Notteboom & Rodrigue, 2008).

Within the containerisation, one of the theories that has been applied is the economies of scale, this theory has not affected the container itself but rather the container vessels. Shipping lines have experienced the effects of this theory with the massive growth in the size of vessels during the last decade. Considering that during the period 1984-1995 the size of vessels remained constant, with the Panamax standard size as the constraint for the design and construction of new vessels, from 1995 onwards the introduction of the Post-Panamax vessels class changed the patterns of vessels' deployment in the major trade routes (Cullinane & Khanna, 2000). Post Panamax vessels were mainly deployed on routes where the need for bigger vessels was critical; this is the case of the Asia-Europe or Asia-West Coast of United States routes. These routes were particularly interesting for the Post-Panamax vessels since there were no major infrastructural restrictions on the way from the place of origin to the destination.

According to Drewry (2014) the Panamax vessel class in its optimised version is able to carry up to 4,500 TEU's. On the other hand, the Post-Panamax vessel class allows the carriage of over 5,000 TEU's. But the introduction of the Ultra Large Container vessel class in the mid-2000s had another impact on the design of vessels, this new class has the capacity to carry more than 15,000 TEU's and nowadays, the deployment of vessels with a carriage capacity over 18,000 TEU's only suggests that the economies of scale are still affecting the containerisation.

In relation to the Panama Canal, the containerisation and its market segment, the container vessels, plays an important role in the traffic through the canal. According to the statistics provided by Panama Canal Authority (2015c) the market segment of container vessels is ranked first in terms of tolls paid and the cargo volume handled. However the segment of Dry Bulk vessels were ranked first in terms of the number of transits (Table 2). This fact shows that, even though there is less transit of container vessels, these vessels are carrying more cargo than the Dry Bulk vessels. With this information, it can be easily inferred that the Panamax container vessels are, perhaps, transiting the canal fully loaded or at the limit of their carriage capacity.

Table 2: Panama Canal Traffic by Market Segment 2014

Market Segment	Number of transits	Tolls (thousands)	Panama Canal UMS Net Tonnage (thousands)	Share in No. Of transits	Share in Tolls	Share in Volume
Container	2,891	911,422	111,025	24%	48%	34%
Dry Bulk	3,339	408,206	85,975	28%	21%	26%
RoRo	815	191,066	45,836	7%	10%	14%
Chemical Tankers	1,494	140,464	29,713	12%	7%	9%
Crude Product Tankers	585	72,188	15,650	5%	4%	5%
General Cargo	883	50,013	9,492	7%	3%	3%
Refrigerated	999	45,408	9,308	8%	2%	3%
Passengers	218	40,776	9,107	2%	2%	3%
Liquid Gas Carriers	274	27,044	6,043	2%	1%	2%
Others	458	20,915	3,733	4%	1%	1%
Total	11,956	1,907,502	325,882	100%	100%	100%

Source: Panama Canal Authority

2.3 The Port Structures

When talking about Port Structure, the World Bank (2001) defines 4 types of management models (Table 3), starting with the Public Service Port, as the model where the Public sector has the control of every aspect of the management of the port, this includes infrastructure, superstructure, port labour and other functions such as the administrative functions. This model is the basic model of ports around the world, mainly in developing countries where the government has the role of main investor, stimulator and even operator of the port activity. The Tool Port model differs from the previous one only in the aspect of port labour, the public sector still invests in infrastructure and runs the port but it lets others give some port services within the port area. The Landlord Port, instead, is the next stage in the evolution of the port management structure. In this model, the management of the port is given to a private company which is in charge of running the terminal operations, this includes the provision of all types of port services. The public sector remains only as a regulator of the port activity since it is the owner of the area in which the activity is being performed. Most of the state of the art ports around the world follow this type of model structure which see privatisation as the most effective way to improve efficiency. The last model is the Private Service Port where the private sector has the control of all the activities and functions. The public sector does not have any major role.

Table 3: Basic Port Management Models

Basic Port Management Models

Type	Infrastructure	Superstructure	Port Labor	Other Functions
Public Service Port	Public	Public	Public	Majority Public
Tool Port	Public	Public	Private	Public/Private
Landlord Port	Public	Private	Private	Public/Private
Private Service Port	Private	Private	Private	Majority Private

Source: (The World Bank, 2001)

Having the Public Service Port and the Landlord Port as the most common management models of ports around the world, it can be seen that the responsibility of the infrastructure remains in the hands of the public sector. In this context, the World Bank (2001) also proposes different categories of port assets for infrastructure: Basic Port Infrastructure, Operational Port Infrastructure, Port superstructure and Port equipment.

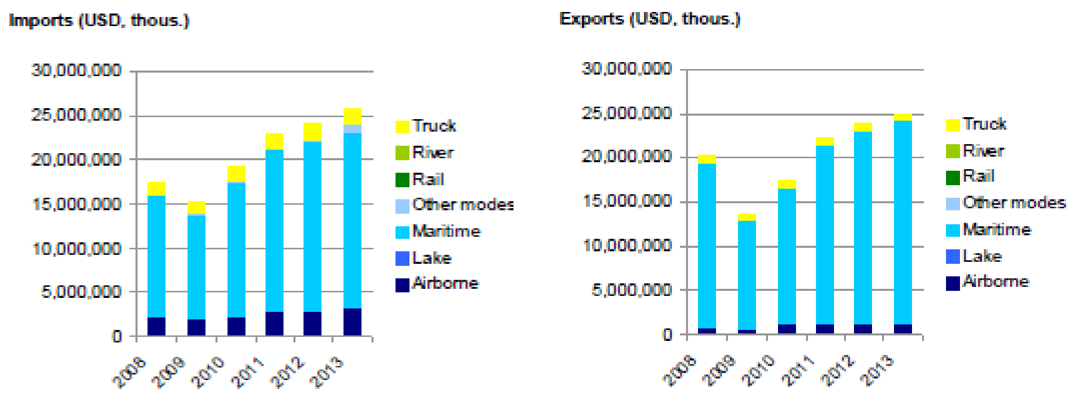
Since the scope of this study is the Basic Port Infrastructure, it is worth mentioning the port assets or the variable that are included in this category:

- Maritime access channels
- Basic quay walls

2.4 The Maritime and Port sector in Ecuador

The Maritime transport is the most important modal split in Ecuador. Considering that the transport sector represents 7.4% of the share in GDP, the maritime transport accounts for almost 85% of it (Figure 5) (ECLAC, 2015).

Figure 5: Modal Split in Imports and Exports (USD, thousands)



Source: Economic Commission for Latin America and the Caribbean (ECLAC)

To continue the line of research this study focuses on Ecuador and its port system that is comprised for three different port structures:

1. State Owned Ports / Public Service Ports
2. Private Ports
3. Special Ports or Superintendence

In Ecuador, there are four ports that are administered by separate Port Authorities, three of them follow the figure of State Owned Port / Public Service Port: Esmeraldas, Manta and Puerto Bolivar. The Port of Guayaquil is the exception since it is managed in two different models, as Landlord Port after the concession of its multi-purpose and container terminal and as fully Private Service Port operated by private companies. In relation to the area of geographic influence, the Port of Esmeraldas covers the north part of the country being the closest port to the Panama Canal, the Port of Manta covers the north-central area of the country, and the Port of Puerto Bolivar covers the southern area of the country where the majority of the banana industry is located. The Port of Guayaquil is the most important port in Ecuador; it is located in the centre of the country. It is accessed through a maritime access canal of shallow waters. This Port covers around the 75% of the Ecuador's maritime trade.

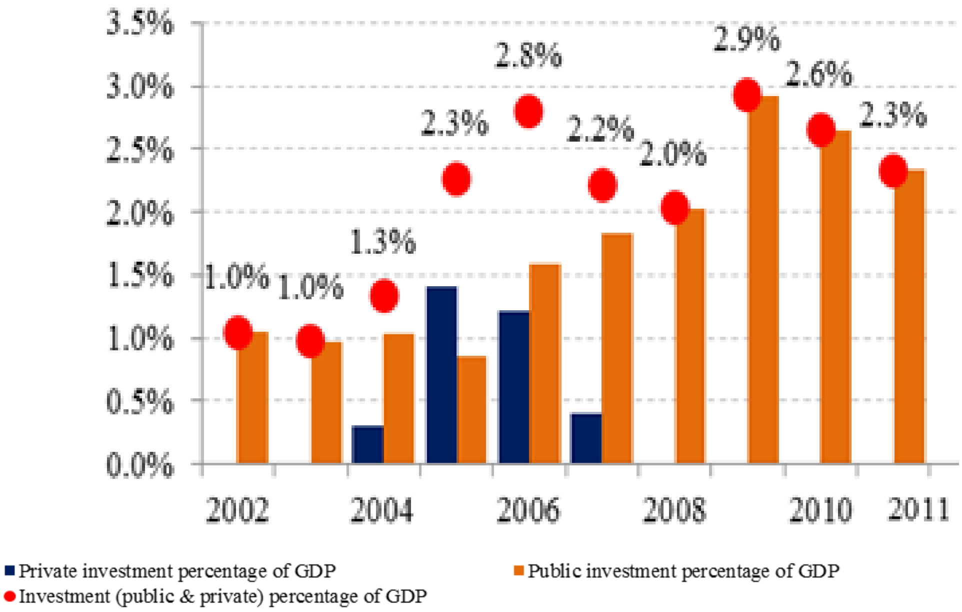
The Private Ports are entirely managed by private companies; these ports were developed and built with private capital. The Public sector only acts as a market regulator. Private Ports are concentrated only in Guayaquil, currently there are 12 private ports that perform specific operations such as handling of general cargo, discharge of break bulk cargo, lubricants and fertilizers and fish. The container handling is regulated; it is only permitted to shippers that can manage their fleet of vessels such as DOLE or Chiquita.

Special Ports or Superintendent are responsible only for handling oil cargo and derivatives.

1. Superintendence of Balao Oil Terminal, the main oil terminal where the Ecuadorian crude is exported and derivative products are imported, is located in Esmeraldas.
2. Superintendence of La Libertad Oil Terminal, where petroleum products are imported for consumption in the southern sector of the country. This terminal is also able to handle and store LPG.
3. Superintendence of El Salitral Oil Terminal, able to handle and store LPG for the consumption of Guayaquil city.

Another aspect of the port system is related to the Port Infrastructure. According to the World Bank (2015) the quality of port infrastructure in a country is measured by an index that indicates the perception of the shipping industry and foreign trade of port facilities in a given country. In the case of Ecuador, the index shows improvements that the country has achieved as a result of public and private investments in transport (Figure 6). This improvement is also – to a very large extent – due to the concession of the multipurpose and container terminal of Guayaquil in 2007 to a global container terminal operator (ITCSI group).

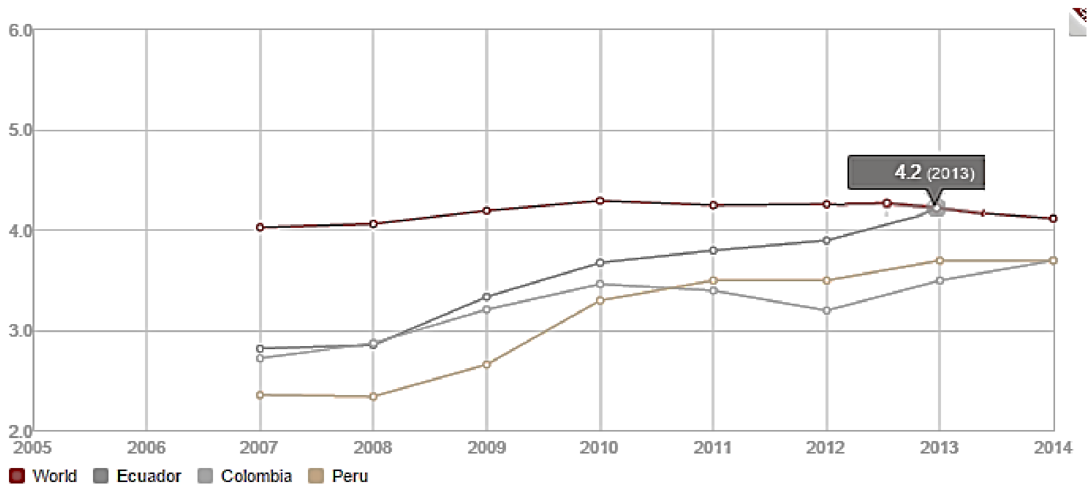
Figure 6: Public and Private Investment in transport infrastructure (% of GDP)



Source: Economic Commission for Latin America and the Caribbean ECLAC

In 2013, Ecuador reached the world average in the Quality of port infrastructure index of 4.2 (Figure 7), outperforming the index of the neighbouring countries like Colombia or Peru with 3.5 and 3.7 respectively.

Figure 7: Quality of port infrastructure, (1=extremely underdeveloped to 7=well developed and efficient by international standards)



Source: World Bank data

2.5 Conclusion

Once the theoretical concepts and previous studies have been reviewed, it can be concluded that the basic port infrastructure is among the most important aspects of the maritime sector around the world, particularly in the liner shipping where it plays a key role. In South America, public sector is solely responsible for the planning of port development especially the basic port infrastructure ensuring good accessibility by sea. Regarding the containers segment, the work is even more challenging for the public sector because in addition to the basic infrastructure, ports need continuous development and implementation of operational infrastructure, port superstructure and port equipment that, in theory, must be on par with the maritime development to withstand the increase in the size of vessels and the evolution of technology.

3 Literature Review

In the first paragraph of the literature review, the main findings of an optimum size of port design in terms of basic infrastructure are pointed out. These findings proposed a new draught capacity, quay length and super-infrastructure needed for new or existing ports in the region of the WCSA in order to be able to receive the new size of vessels forecasted in previous studies. In the second paragraph of the literature review we point out the existing literature about the Panama Canal expansion and its impact on the region. The third paragraph shows literature of the economies of scale as a driver for the increase in the size of vessels. The fourth paragraph presents the literature about the containerisation and its importance for the Panama Canal and the impact on port management. Finally, the last paragraph denotes the literature in Port Management, from its structure to investment decisions models.

In a report, prepared for the International Transport Forum of the Organization for Economic Cooperation and Development (OECD), Wilmsmeier (2013) stated that WCSA ports must urgently increase their investments in basic port infrastructure, e.g. adjustment in draught capacity to 15 metres or above. This statement is based on a study that forecasted that vessels with a capacity of around 13,000 TEUs should be calling ports in the region between 2016 and 2020 (Sanchez & Perroti, 2012). This study was conducted by using models that considered factors such as vessel size, seaborne trade, economic activity and some other relevant variables. But Implications of this type of vessels will also affect investment in port superstructure since taller and longer quay cranes are needed to reach the extended dimensions of the beam and the length overall (LOA) of the vessel.

3.1 The Panama Canal and its expansion

In relation to the literature of the Panama Canal and its expansion project, the Panama Canal Authority (ACP) is the leader in conducting research measuring the impact of the project on different areas but mainly on the economy of Panama as a country. The first report (Panama Canal Authority, 2006) presented the proposal for the Expansion of the Panama Canal, this report explained the objectives of the expansion of the Canal's capacity through the construction of the third set of locks, as well as the estimated schedule, the cost and the financing of the project as well as the potential impact on world trade. The ECLAC, one year later through its collaborators, prepared reports trying to explain the first findings of the effects of the expansion of the Panama Canal and the challenge of capacity management to the Latin American and Caribbean ports (Sanchez, 2007). Similarly to these reports, the ECLAC and the ACP jointly prepared the publication about the Panama Canal and its influence on the economy of Latin America and the Caribbean explaining impacts on the region (Sabonge & Sanchez, 2009) and looked at it as a driver of change for global trade flows in the main market segments of the Panama Canal: Dry bulks, Tankers and Containers (Sabonge, 2014). With respect to the possible impact of the Panama Canal Expansion in North America, several reports were produced trying to explain the macroeconomic, operational and competitive factors that have an impact on North American freight distributions (Rodrigue, 2010). Additionally, the Panama Canal has also been subject of research by independent experts. Organisations as The American Association of Port Authorities produced the report about the possible effects of the Panama Canal Expansion on Ports in the Western Hemisphere. This report mainly relates to the patterns of traffic regarding main trade routes. Its main finding was that possible changes would primarily affect the ports that serve as a hub in the region, the case of Panama itself, Kingston in Jamaica and Miami in the United States (Lam, 2010). What concerns the studies related to the impact on the economy, the methodology approach chosen to assess the different variables focused on the utilisation of Input-Output (IO) and Gravity models. One of them was conducted to estimate the return on investment, the level of agglomeration and the network effects in the economy and in the cluster of Panama as result of the Panama Canal expansion (Pagano, et al., 2012) this study provided an overview of the impact in ports and the maritime industry of Panama taking into account growth and development in the future.

3.2 Economies of Scale in the size of vessels

In order to explain the reasons for the introduction of the New Panamax vessel and the construction of the Panama Canal expansion for handling it, economies of scale play a significant role. The literature uses scale economies in trying to explain the importance of new technology developments to reach and satisfy the demand for higher efficiencies in shipping; i.e. to optimise capacities and diminish costs per unit of cargo by the introduction of bigger vessels. These bigger vessels, however, are not manageable by every port on every route. In fact, when – under certain conditions – the gap between bigger vessels and port development becomes too wide, it can even create diseconomies of scale when the ports do not adapt their capacities to the new situation (Perroti & Sanchez, 2011). However other studies indicate that port development is the driver for increasing size in vessels since in the search for efficiency in ports, new projects related to expansions and improvements lead to the increase in capacities letting the construction of vessels also improve following the trends of the most important ports around the world (Jansson & Shneerson, 1987) (McLellan, 1997) (Lim, 1998) and (Robinson, 1998). Bigger vessels are constructed because there are ports that can handle them by the time the orders are placed.

3.3 Containerisation and Ports

One delimitation of this study was proposed when it was decided to focus on the market segment of the containerised cargo in the New Panamax container vessel. As mentioned in the literature overview the containerised segment is one of the most important segments in the Panama Canal as well as in other major ports in general. The competitive environment that ports and maritime companies are facing has been observed and documented by many authors who state that ports are one of the main elements in value-driven chain systems. This observation is grounded in the fact that supply chains and logistics models have suffered, and it has become more pronounced since the introduction of the containerisation (Martin & Thomas, 2001), (Robinson, 2002). This relation between containerisation and the ports is also affected by globalisation, deregulation, and logistics integration. However, these variables are also affected by the unpredictable environment that makes markets totally unstable (Notteboom, 2004). About the Port Management Structure, the study by Notteboom and Winkelmans (2001) discussed how the Port Authorities face the challenge of the continuous development in the logistics structure.

3.4 Port management and expansion

Since this study follows the Basic Port Management Structure of the World Bank mentioned in the literature overview, our approach will also use the category related to the Basic Port infrastructure. In this category, the Port Authority is seen as the main developer and regulator of port assets. Thus, when talking about investments in port infrastructure due to a project such as a port expansion, justification of expenditure of public funds is highly relevant. In early literature about capacity expansion in the industry, the Manne model was used. The Manne model assumes a deterministic demand with constant growth in which the investment decision is based on economies of scale minimising investment costs (Manne, 1967). This approach was similar to the one taken in the Whitt-Luss model (Whitt, 1981). Newsboy model starts from an investment decision based on the level of utilisation of industry capacity with a capital intensity approach (Hayes & Wheelwright, 1984). Several models, looking at investments in the transportation industry, optimised vessel and investment size by minimising costs in pricing (Jansson, 1984). Dekker (2005) takes this argument a step further: in his queuing theory he optimised the transportation investment and pricing by also introducing “time” as a variable for an optimal investment decision. Following this line, Dekker & Verhaeghe (2008) indicated a new variable for developing a strategy for port expansion now considering the time, the size and the relief in interval capacity, this was called the Optimal Control Approach. This new concept was based on an optimal control theory that was first mentioned in the book written by Seierstad and Sydsaeter (1987). They first discussed the framework of this theory and later applied it as an investment decision method. One area where this theory has been applied is in the decision problem of a river-dike heightening for improving the safety against flooding in the area covered by the river Rhine (Eijgenraam, 2005).

3.5 Conclusion

The literature allows us to conclude that most of the previous studies on the Panama Canal expansion have been conducted only taking into account economic variables. In this context, elements such as GDP, international trade and even barriers to trade have been analysed, however in the present study the implicit effect of the Panama Canal enlargement, the introduction of the New Panamax vessel, is considered as the driver for the implementation of expansion projects in the regional ports of the WCSA, ports that are more likely to be affected in the future since they are part of the transport routes that are top users of the Panama Canal.

Moreover, the effect of economies of scale on ship size and specifically on container vessels has been subject to numerous studies and one of the main findings states that the introduction of bigger vessels affects the ports in every part of their structure and operations, from their management until the way in which projects are developed and decisions are taken.

4 Theoretical Conclusion

4.1 Theoretical model

Based on the literature review, there have been many attempts to answer the main research question proposed in the first chapter. Considering that the methodology chosen in this study is the comparison of an ideal situation (SOLL situation) with an actual situation (IST situation), the main findings of Wilmsmeier (2013) will be taken as the basis for the preparation of this ideal situation: an ideal port in terms of port infrastructure derived from the dimensions of the New Panamax vessel, that will be compared to the actual situation of some ports in Ecuador in terms of port infrastructure.

Following the above, the methodology chosen leads to the establishment of a theoretical model which is able to answer the main research question. This model will process the information in accordance with the following steps. First, this chapter will foresee and define the average size and capacity of vessels that can be deployed in the region of the WCSA after the opening of the Panama Canal expansion, considering the Panamax and the Post-Panamax vessels that are currently sailing in the region and the maximum vessels' dimensions allowed in the new locks. Second, based on the results of this forecast a conceptual design of an ideal port, in terms of basic port infrastructure, will be proposed. Third, since there are four multi-purpose ports in Ecuador all of them are supposed to have the capacity to handle containers. However, not all of them handle this segment as a main type of cargo. Therefore, this situation will be evaluated to define the Ecuadorian ports eligible for this study. Finally, the ideal port will be compared to the selected Ecuadorian ports where the following variables of the basic port infrastructure will be measured and assessed:

1. Maritime access channel
2. Quay wall length

The first two steps will comprise the SOLL situation and the following two the IST situation.

Once the main differences and their magnitudes are visible, this study will be able to recognise the implications of the New Panamax container vessel in the basic port infrastructure of Ecuador's container ports.

4.2 SOLL/Ideal Situation

The ideal situation will help this study to define how a container port should look like in terms of basic port infrastructure in order to meet the requirements of the New Panamax container vessel.

Following the first step mentioned above, the report and the data about the implications for port development on the WCSA, the case of Chile (Wilmsmeier, 2013) in particular, will be considered.

Three elements will be evaluated and forecasted using linear regression model: vessel capacity, vessel draught, and vessel length. In the end, the results of vessel capacity will be merged with the results of vessel draught since there is a strong relationship between both elements. Therefore, the final elements to be taken into account in the present study will be:

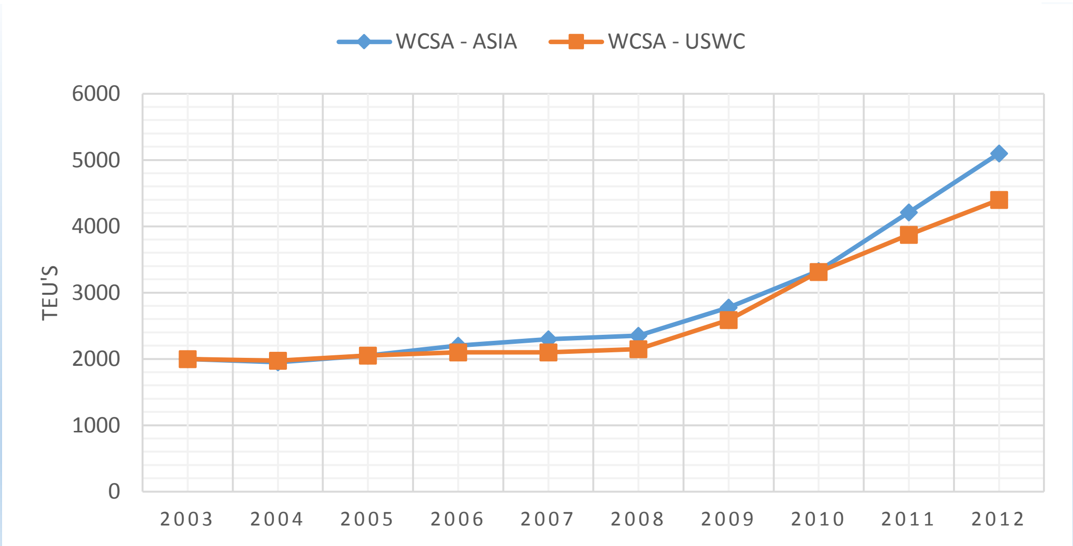
- Vessel draught
- Vessel length

Since this study seeks to address port management decisions that may be taken in the short term, the year 2018 was chosen to be the limit of the forecast.

4.2.1 Vessel Capacity

The data in the report shows the gradual increase of the average capacity of container vessels on two trade routes that serve the region of the WCSA: The WCSA – Asia service and the WCSA – USWC service. In the WCSA – Asia service experienced a significantly increase of vessels' average capacity from around 2,200 TEU's in 2006 to 5,100 TEU's in 2012 (130% increase). In the WCSA – USWC service, the average capacity of vessels increased from around 2,100 TEU's in 2006 to 4,400 TEUS's in 2012 (110% increase). This information shows since 2003 the average capacity of vessels in the WCSA almost doubled and the service that connects Asia with the WCSA deployed the biggest vessels in the region. (Figure 8).

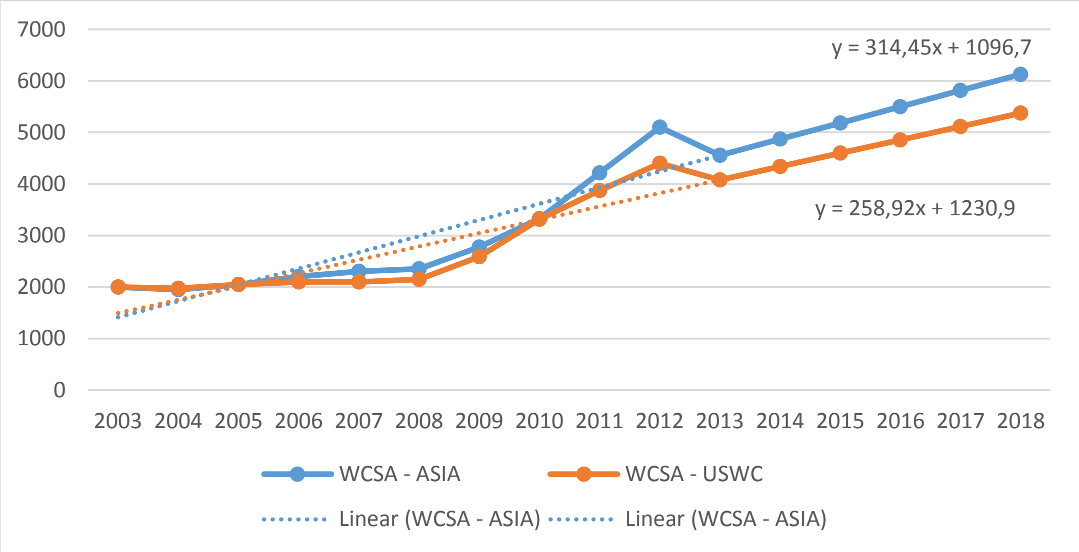
Figure 8: Evolution of vessel capacity on WCSA services that does not transit the Panama Canal 2003 - 2012 (TEU's)



Source: compiled by the author based ComPairData, Lloyd List and Wilmsmeier (2013)

By applying the linear regression model to forecast the trend of the vessel capacity in the WCSA, the results show that in 2018 the average vessel capacity deployed in the WCSA – Asia service will be around 6,100 TEU's and in the WCSA – USWC service the average vessel capacity will be around 5,400 TEU's (Figure 9).

Figure 9: Forecast of vessel capacity on WCSA 2003 - 2018 (TEU's)

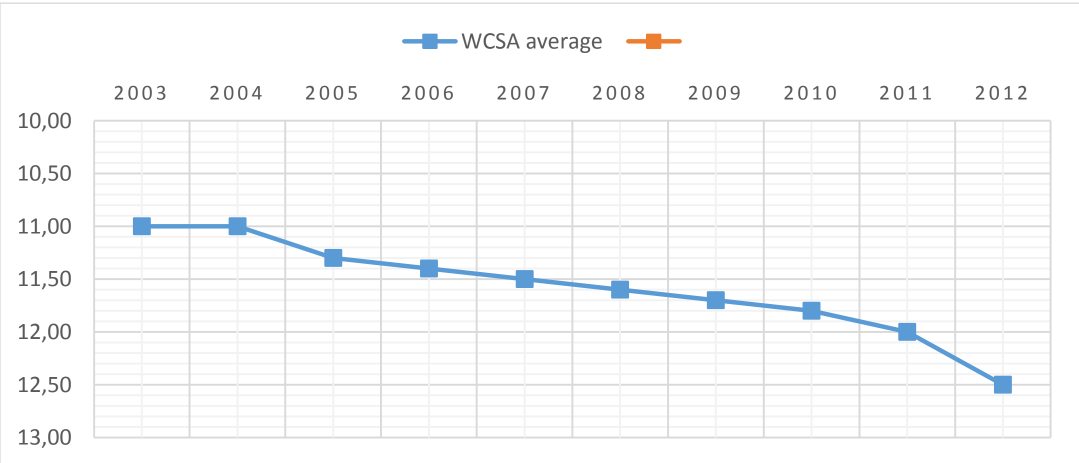


Source: forecast conducted by the author using the linear regression model in MS Excel

4.2.2 *Vessel draught*

Based on the reviewed literature it can be noticed that the draught restriction is one of the main elements when planning the deployment of vessels' fleet. According to Wilmsmeier (2013), the average vessel draught in the WCSA region in 2012 was about 12.5 metres (10% increase since 2008) this is far from the 16 metres average draught used in other trade routes (Figure 10).

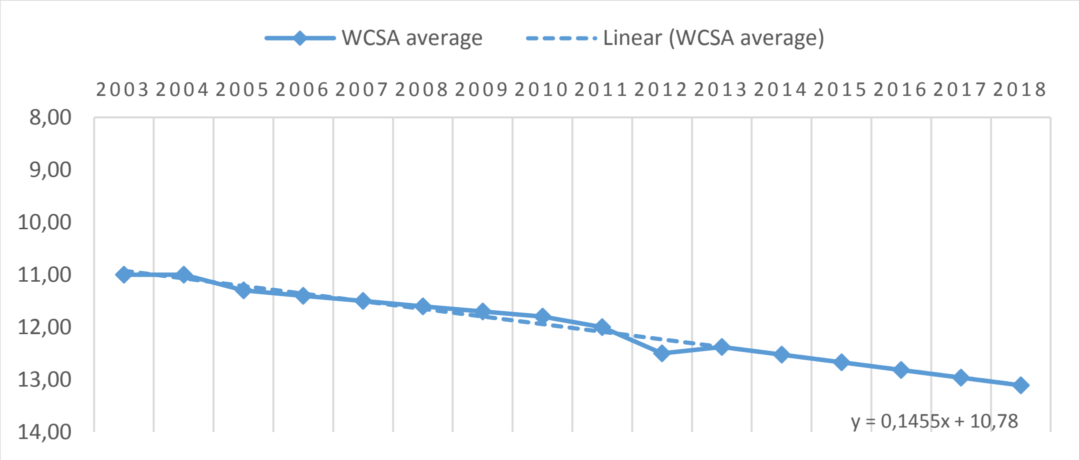
Figure 10: Evolution of vessel draught on WCSA services 2003 - 2012 (metres)



Source: compiled by the author based ComPairData, Lloyd List and Wilmsmeier (2013)

By applying the linear regression model to forecast the trend of the vessel draught in the WCSA, the result shows that in 2018 the average draught of the vessels sailing in the WCSA will be around 13.10 metres (Figure 11).

Figure 11: Forecast of vessel draught on WCSA 2003 - 2018 (metres)

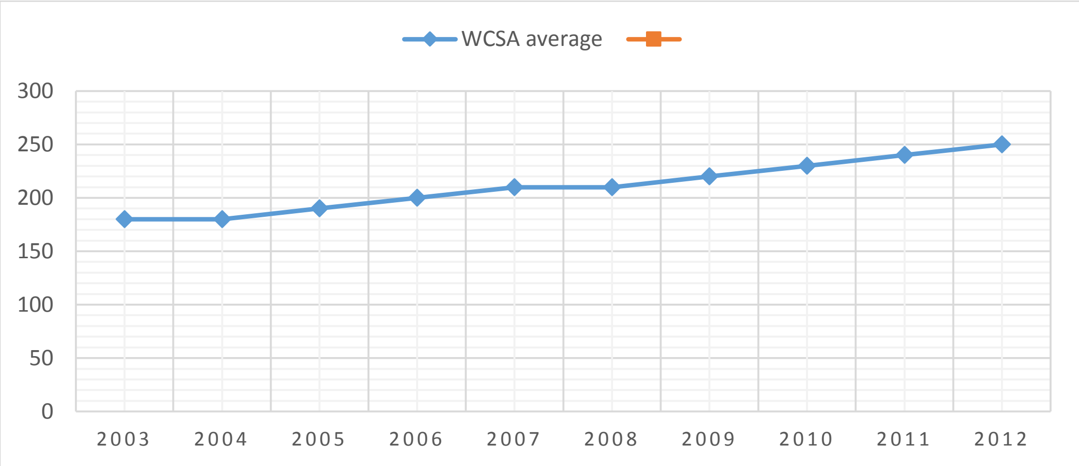


Source: forecast conducted by the author using the linear regression model in MS Excel

4.2.3 Vessel length

Following the literature, Wilmsmeier (2013) shows that the evolution of vessels in terms of length has gradually increased. From around 180 metres in 2002 to 260 metres on average in 2012 (which constitutes a 50% increase) (Figure 12).

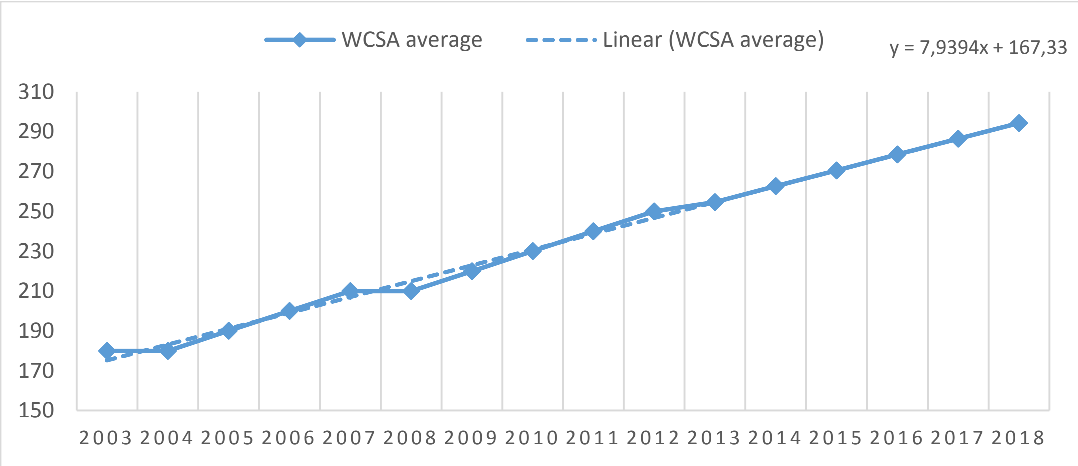
Figure 12: Evolution of vessel length on WCSA 2003 - 2012 (metres)



Source: compiled by the author based ComPairData, Lloyd List and Wilmsmeier (2013)

By applying the linear regression model to forecast the trend of the vessel length in the WCSA, the result shows that in 2018 the average length of the vessels sailing in the WCSA will be around 294.4 ≈ 295 metres length (Figure 13).

Figure 13: Forecast of vessel length on WCSA 2003 - 2018 (metres)



Source: forecast conducted by the author using the linear regression model in MS Excel

Summarizing this information, based on Wilmsmeier (2013) data the forecast of the average dimensions of the Post-Panamax vessel sailing in the region in 2018 will be:

- Average vessel capacity: 6,100 TEU's
- Average vessel draught: 13,10 metres
- Average vessel length: 295 metres

4.2.4 New Panamax maximum dimensions

According to the Panama Canal Authority (2006), the expansion of the Panama Canal will allow the transit of vessels of up to:

- Maximum vessel capacity: 13,000 TEU's
- Maximum vessel draught: 15.2 metres
- Maximum vessel length: 366 metres

Even though it is widely expressed by many authors (Rodrigue, 2010) (Benitez, 2014) that the New Panamax vessel with its maximum dimensions will primarily serve the route Asia – East Coast of United States (USEC), the container shipping lines are not prohibited to apply cascading to change the deployment of the vessels in the main services of the region of the WCSA. This uncertainty is present in this study and in order to consider this possibility, the average and the maximum dimension of vessels transiting the Panama Canal expansion will be combined and taken as the final dimensions proposed in the ideal situation.

Therefore:

- Final average vessel capacity: 9,500 TEU's
- Final average vessel draught: 14.15 ≈ 14 metres
- Final average vessel length: 330 metres

The second step takes the proposed vessel dimensions and develops the design of the basic port infrastructure of the ideal port. This ideal port represents the SOLL situation of this study.

4.2.5 Conclusion

The ideal port for receiving a New Panamax container vessels deployed in the region of the WCSA by 2018 should have a maritime access channel of at least 14 metres depth and quays walls large enough to receive vessels of up to 330 metres in length. Therefore the main implications for the ports in terms of basic port infrastructure should be focused on the management of the maritime access channel and the availability or construction of at least one quay wall large enough to receive and handle the new vessels' dimension (Table 4).

Table 4: Dimensions of the ideal port

SOLL situation	Ideal Port
Maritime access channel	14 metres
Quay walls length	330 metres

Source: Compiled by the author

5 Methodology

The primary objective of this study is to recognise the implications of the New Panamax container vessels in Basic Port Infrastructure. To assess these implications the study will focus on the case of Ecuador's container ports. The port system of Ecuador is comprised by four commercial ports, each of those ports were conceived under the concept of multi-purpose port able to handle any type of cargo, including containers. Over the years, this concept was adapted to the needs of the region where each port was located. Thus, not every port handles containers as the main type of cargo.

In this chapter, we will define which Ecuadorian ports will be evaluated in the ISL situation. The following elements will be taken into account:

- Vessel traffic
- Relevance in cargo handling
- Relevance in container handling

5.1 Data Gathering

In Ecuador, the government body which is in charge of the maritime sector is the Ministry of Transport and Public Affairs. It acts through its Sub-secretary of Ports and Waterborne Transport. The Sub-secretary is in charge of each Port Authority in four different ports, and it is the only institution which is allowed to publish official statistics on the maritime sector.

The data used for this analysis is taken mainly from the official statistics reports prepared by the Sub-secretary of Ports and Waterborne Transport in the period of 2010 – 2013. Some Port Authorities also publish limited information but for this study the data of the Port Authorities is only used for comparison reasons. Additional data was gathered from a private database prepared by a company that analyses the custom manifests in Ecuador: Manifiestos Ecuador S.A.

5.2 Port Selection Criteria

Information based on the official statistics shows that the number of vessels that arrived at the Port System in Ecuador follows an irregular pattern. Starting in 2010, the data shows the arrival of 3,880 vessels to the different port in Ecuador, the following year, in 2011, the 1% increase in vessel traffic does not cause greater impact on the system, but in 2012, the vessel traffic decreased 12% to reach 3,465 vessels, being the Port of Guayaquil the most affected by the reduction of about 22% of vessel attention over the previous year. By 2013, the 3% increase of vessel traffic showed a recovery of the Port System in Ecuador.

Concerning the relevance in vessel traffic, the Port of Guayaquil is the port that receives the largest number of vessels in its facilities with around 30% of the market share, in second place the private ports of Guayaquil receive 22% of the total traffic.

Since the Port of Guayaquil shares the same maritime access channel with the Private Ports, for this study both locations will be seen as one big Port of Guayaquil. Therefore, the updated Port of Guayaquil will have around 51% of market share of vessel traffic. In the second position is the Port of Manta with around 12% of the market share, Puerto Bolivar with 10% and Esmeraldas with 8% (Table 5).

Special Ports or Superintendence, as explained before, are not taken into account in this study since they are only specialized in oil products and located in special areas with enough depth to perform operations related to oil and its derivatives.

Table 5: Vessel traffic in Ecuadorian Ports by number of calls (2010 – 2013)

Ports	2010	2011	2012	2013	Share 2013
Port Authority of Esmeraldas	208	287	312	294	8%
Port Authority of Manta	354	359	378	425	12%
Port Authority of Guayaquil	1185	1254	983	1029	29%
Port Authority of Puerto Bolivar	536	479	381	355	10%
Private Ports (Guayaquil)	917	911	722	777	22%
Superintendence of Balao Oil Terminal	406	358	345	374	10%
Superintendence of La Libertad Oil Terminal	239	237	266	226	6%
Superintendence of El Salitral Oil Terminal	35	36	78	94	3%
TOTAL	3,880	3,921	3,465	3,574	

Source: Compiled by the author based on Port and water transport statistics – Ministry of Transport and Public Work of Ecuador

In 2013, the Port System in Ecuador registered that containerised cargo had the biggest market share with about 59% of participation among all the ports in terms of metric tonnes handled. Other types of cargo such as dry bulk, general, liquid bulk cargo had 20%, 19% and 3% market share respectively (Table 6). This information shows that the relevance of containerised cargo in Ecuador is high, and any significant change in this segment will impact the Port System of Ecuador heavily.

Table 6: Cargo flow by type of cargo and port in metric tonnes

Ports	Esmeraldas	Manta	Guayaquil	Private ports	Puerto Bolivar
Type of Cargo	2013	2013	2013	2013	2013
General Cargo	447,246	75,133	1,459,502	231,767	1,508,243
Containers	182,590	11,385	8,026,804	3,152,871	202,629
Dry bulk	222,541	545,611	1,560,066	1,565,779	-
Liquid bulk	151,979	185,461	34,056	123,424	-
TOTAL	1,004,356	817,590	11,080,428	5,073,841	1,710,872

Source: Compiled by the author based on Port and water transport statistics – Ministry of Transport and Public Work of Ecuador

Containerised cargo is very important in Ecuador as Table 6 shows. It is also clear that in this segment the Port of Guayaquil has the largest market share with 64% of participation. Considering that Private Ports are also part of the jurisdiction of Guayaquil, together they represent about 92% of market share in contrast with the rest of the ports in Ecuador (Table 7). The Port of Esmeraldas is located in second place with around 5% of market share, The Port of Puerto Bolivar is third with almost 3% of market share and in the last place the Port of Manta with almost no relevance in the container sector, 0.05% of market share.

Table 7: Cargo flow of containers in Ecuadorian ports by TEU'S

Ports	2010	2011	2012	2013	Share 2013
Port Authority of Esmeraldas	62017	66764	86687	77,621	4.72%
Port Authority of Manta	3808	913	864	783	0.05%
Port Authority of Guayaquil	693489	945344	971036	1,056,605	64.29%
Port Authority of Puerto Bolivar	61940	53943	54814	46,022	2.80%
Private Ports (Guayaquil)	429609	460419	477805	462,455	28.14%
TOTAL	1,250,863	1,527,383	1,591,206	1,643,486	100%

Source: Compiled by the author based on Port and water transport statistics – Ministry of Transport and Public Work of Ecuador

5.3 Conclusion

Considering that this study focuses on the container sector, it is not a surprise that the Port of Guayaquil is the port that meets all the necessary requirements to be eligible for this study. The fact that the port handled 1,519,060 TEU's in 2013 shows its importance as a container port in the country and in the region in general. The port of Guayaquil is ranked among the top 10 ports in Latin America and the top 100 ports in the world based on its container throughput (Lloyd's List, 2013).

Even though the Port of Esmeraldas has only 5% of the market share in the container sector it is the port that shows continuous development in this area. Over the last years container handling significantly increased from around 1,275 TEU's in 2004 to 77,621 TEU's in 2013 (Ministerio de Transporte y Obras Publicas del Ecuador, 2013). Therefore this port is also eligible for this study.

The Port of Puerto Bolivar with a market share of 2.8% in the container sector is another port that shows an increase in container handling from approximately 22,500 TEU's in 2004 to 46,022 TEU's in 2012 (Ministerio de Transporte y Obras Publicas del Ecuador, 2013). This port, in particular, reached its peak of 68,500 TEU's handled in 2009, but external and widely known factors affected its steady growth. Given its relevance in the Port System of Ecuador, this port is also eligible for this study.

The Port of Manta with a market share of 0.05% in the container sector is not relevant enough for this study. Therefore, we will not include it in the analysis.

6 IST Situation

6.1 Actual situation

The overview of the actual situation of the ports in Ecuador in terms of basic port infrastructure reflects the attitude of the authorities that were in charge of the development of this critical sector over the past years. Before 2007, some ports even kept the same physical structure from the original design used since the mid-twentieth century. From 2007 onwards some improvements were made. In particular the concession of the multipurpose and container terminal of Guayaquil has been a driving factor in the increase in container throughput of the country. In the port of Manta, another concession was granted. However, the international operator unilaterally abandoned the project, and the management of the port returned to the public sector. Some other projects have been planned but none were completed so far. Therefore, since the conception of the four original public ports, no other milestone has marked the development of the maritime sector in Ecuador.

The current situation of basic port infrastructure of the ports chosen for this study is presented below:

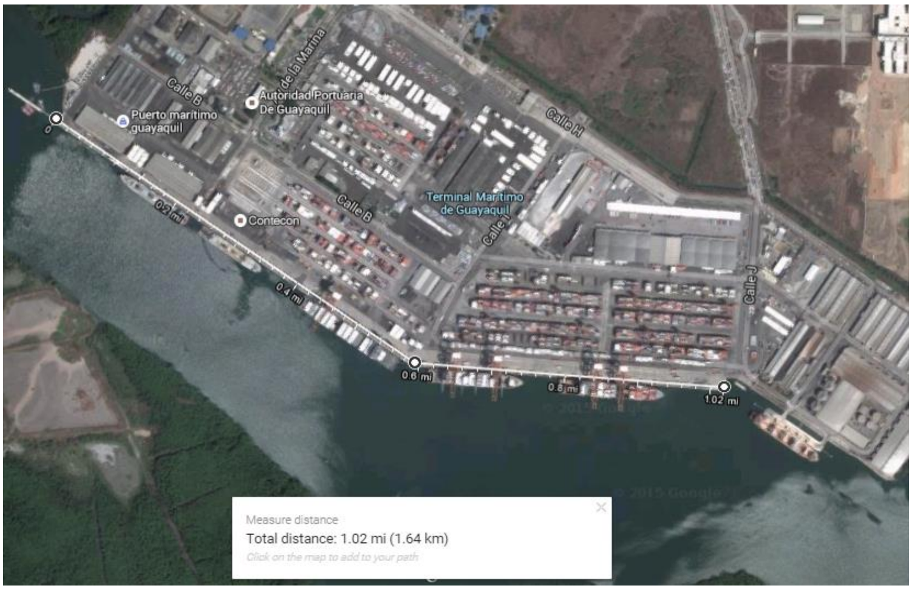
6.1.1 The Port of Guayaquil

The Port of Guayaquil is the largest port in Ecuador. It handles more than 75% of the international trade of the entire country (see Table 6 and Table 7). It consists of two types of ports, the concessioned port and the private port. But for the purpose of this study we will treat it as one port.

The concessioned port in Guayaquil has multipurpose terminals for handling containerised cargo, general cargo and dry bulk cargo. Currently, it has 11 docks that allow the berthing of vessels of up to 9.75 metres draught. This restriction is established since the maritime access channel is affected by a rocky seabed that limits the depth of the channel up to 8.20 metres at low tide and 9.75 metres at high tide. In terms of quay length, the concessioned port has no limitations since it has 1,625 metres of linear quays that are able to receive container vessels and another single quay of 145 metres which is able to receive bulk vessels (Figure 14).

The private ports are part of the jurisdiction of the Port Authority of Guayaquil; they are scattered in the coastal profile of the city of Guayaquil, and they share the maritime access channel with the Port of Guayaquil. The private ports handle 11 docks with a draught restriction of 9.75 metres and an average quay length of 350 metres.

Figure 14: Layout of the concessioned port in Guayaquil



Source: Google maps 2015

6.1.2 The Port of Esmeraldas

The Port of Esmeraldas is a multipurpose port located on the northern coast of Ecuador. The port has three docks for the use of vessels in international traffic, two of them are 175 metres long (350 metres of linear Quay) and the third one has 104 metres of quay length mainly used for local services (Figure 15). The Port of Esmeraldas is considered to be a river port even though it is physically located between the boundary of the river and the sea. Given the proximity to the sea, the maritime access channel allows the transit of the vessels of up to 11.50 metres draught.

Figure 15: Layout of the Port of Esmeraldas

Source: Google maps 2015

6.1.3 The Port of Puerto Bolivar

The Port of Puerto Bolivar is a multipurpose port located on the southern coast of Ecuador. The port has five berths: the quay number 1 is 178.88 metres long, the quays 2 and 3 are both 241 metres long. Together quays 1, 2 and 3 have a total length of 660 metres. Finally two independent quays are each 160 metres long. The Port has a maritime access channel of 4.5 nautical miles which has a draught restriction of 12 metres (Figure 16).

Figure 16: Layout of the Port of Puerto Bolivar

Source: Google maps 2015

6.1.4 Actual situation (IST)

Table 8 below shows the recap of the current dimensions of the selected Ecuadorian ports in terms of basic port infrastructure: variables of draught and length.

Table 8: Current dimensions in the actual situation of the Ecuadorian ports

IST situation	Actual Port	
	Draught	Length
Guayaquil	9.75 metres	1,625 metres
Esmeraldas	11.5 metres	350 metres
Puerto Bolivar	12 metres	660 metres

Source: Compiled by the author

6.2 Assessment of the actual situation

6.2.1 The Port of Guayaquil

The statistical information obtained from the report of the Ministry of Transport and Public Affairs (2013) indicates that regarding the draught limitation, about 38% of the vessels calling at Guayaquil arrive or sail with a draught between 9.01 and 9.75 metres, which is the maximum draught permitted (Table 9). This percentage is high compared to other major ports in the region; this may indicate that the port of Guayaquil has reached its limit on the level of operation. The opening of the Panama Canal expansion and the new level of traffic resulting from this will surely bring negative consequences to the port including the possibility of being designated as a secondary port.

Table 9: Vessel traffic in the Port of Guayaquil by arrival and sailing draught

ARRIVAL DRAUGHT	2012	Share (%)	2013	Share (%)
Less than 8.20 metres	491	50%	490	48%
Between 8.21 and 9.00 metres	166	17%	163	16%
Between 9.01 and 9.76 metres	325	33%	376	37%
Between 9.77 and 11.00 metres	1	0%	0	0%
Between 11.00 and 12 metres	0	0%	0	0%
More than 12 metres	0	0%	0	0%
TOTAL	983	100%	1029	100%
SAILING DRAUGHT	2012	Share (%)	2013	Share (%)
Less than 8.20 metres	429	44%	400	39%
Between 8.21 and 9.00 metres	199	20%	225	22%
Between 9.01 and 9.76 metres	355	36%	404	39%
Between 9.77 and 11.00 metres	0	0%	0	0%
Between 11.00 and 12 metres	0	0%	0	0%
More than 12 metres	0	0%	0	0%
TOTAL	983	100%	1029	100%

Source: Compiled by the author based on Port and water transport statistics, Ministry of Transport and Public Affairs of Ecuador.

Concerning the quay length, the majority of the vessels arriving at the port of Guayaquil have a length design between 150 and 250 metres (around 70%). Vessels with the length of 250 metres or more represent only 13% of the total traffic, mostly because of the draught restriction. The physical configuration of vessels allows to increase the length by increasing draught at the same time and, since in the Port of Guayaquil the maximum draught permitted is only 9.75 metres, the deployment of larger vessels may lead to the their underutilisation (Table 10).

Table 10: Vessel traffic in the Port of Guayaquil by length overall

LENGHT OVER ALL	2012	Share (%)	2013	Share (%)
Less than 100 metres	27	3%	23	2%
Between 100.01 and 150 metres	129	13%	126	12%
Between 150.01 and 200 metres	426	43%	527	51%
Between 200.01 and 250 metres	301	31%	221	21%
Between 250.01 and 300 metres	100	10%	132	13%
More than 300 metres	0	0%	0	0%
TOTAL	983	100%	1029	100%

Source: Compiled by the author based on Port and water transport statistics, Ministry of Transport and Public Affairs of Ecuador

6.2.2 The Port of Esmeraldas

The statistical information obtained from the report of the Ministry of Transport and Public Affairs (2013) indicates that regarding the draught limitation, the largest share of vessels (90%) has less than 9.00 metres in draught. Knowing that the maximum permitted draught is 11.50 metres, it can be determined that the draught is not a constraint in this port (Table 11).

Table 11: Vessel traffic in the Port of Esmeraldas by arrival and sailing draught

ARRIVAL DRAUGHT	2012	Share (%)	2013	Share (%)
Less than 8.20 metres	202	65%	204	69%
Between 8.21 and 9.00 metres	85	27%	60	20%
Between 9.01 and 9.76 metres	13	4%	15	5%
Between 9.77 and 11.00 metres	7	2%	10	3%
Between 11.00 and 12 metres	5	2%	5	2%
More than 12 metres	0	0%	0	0%
TOTAL	312	100%	294	100%
SAILING DRAUGHT	2012	Share (%)	2013	Share (%)
Less than 8.20 metres	233	75%	216	73%
Between 8.21 and 9.00 metres	58	19%	59	20%
Between 9.01 and 9.76 metres	15	5%	16	5%
Between 9.77 and 11.00 metres	5	2%	3	1%
Between 11.00 and 12 metres	1	0%	0	0%
More than 12 metres	0	0%	0	0%
TOTAL	312	100%	294	100%

Source: Compiled by the author based on Port and water transport statistics, Ministry of Transport and Public Affairs of Ecuador.

The same situation can be recognised by the length of the vessels. Even though the port can handle the berthing of vessels of up to 350 metres in length, the majority of the vessels arriving at the port of Esmeraldas have a length design between 150 and 250 metres (Table 12). Based on this information it is noticeable that being a secondary port affects the level of cargo handling. Thus, this situation limits the arrival of larger vessels.

Table 12: Vessel traffic in the Port of Esmeraldas by length overall

LENGHT OVER ALL	2012	Share (%)	2013	Share (%)
Less than 100 metres	4	1%	5	2%
Between 100.01 and 150 metres	126	40%	122	41%
Between 150.01 and 200 metres	141	45%	132	45%
Between 200.01 and 250 metres	41	13%	35	12%
Between 250.01 and 300 metres	0	0%	0	0%
More than 300 metres	0	0%	0	0%
TOTAL	312	100%	294	100%

Source: Compiled by the author based on Port and water transport statistics, Ministry of Transport and Public Affairs of Ecuador.

6.2.3 The Port of Puerto Bolivar

The statistical information obtained from the report of the Ministry of Transport and Public Affairs (2013) indicates that regarding the draught limitation the largest share of vessels (90%) has less than 8.20 metres in draught. Knowing that the maximum permitted draught is 12.00 metres, it can be determined that the draught is not a constraint in this port (Table 13).

Table 13: Vessel traffic in the Port of Puerto Bolivar by arrival and sailing draught

ARRIVAL DRAUGHT	2012	Share (%)	2013	Share (%)
Less than 8.20 metres	366	96%	353	99%
Between 8.21 and 9.00 metres	9	2%	2	1%
Between 9.01 and 9.76 metres	6	2%	0	0%
Between 9.77 and 11.00 metres	0	0%	0	0%
Between 11.00 and 12 metres	0	0%	0	0%
More than 12 metres	0	0%	0	0%
TOTAL	381	100%	355	100%
SAILING DRAUGHT	2012	Share (%)	2013	Share (%)
Less than 8.20 metres	330	87%	290	82%
Between 8.21 and 9.00 metres	41	11%	61	17%
Between 9.01 and 9.76 metres	8	2%	2	1%
Between 9.77 and 11.00 metres	2	1%	2	1%
Between 11.00 and 12 metres	0	0%	0	0%
More than 12 metres	0	0%	0	0%
TOTAL	381	100%	355	100%

Source: Compiled by the author based on Port and water transport statistics, Ministry of Transport and Public Affairs of Ecuador.

The same situation can be seen based on the length of the vessels. Even though the port has a linear quay length of 660 metres, all the vessels arriving at the port of Puerto Bolivar in 2013 had a length design of less than 200 metres (

Table 14: Vessel traffic in the Port of Puerto Bolivar by length overallTable 12. Since this

LENGHT OVERALL	2012	Share (%)	2013	Share (%)
Less than 100 metres	2	1%	28	8%
Between 100.01 and 150 metres	154	40%	166	47%
Between 150.01 and 200 metres	194	51%	161	45%
Between 200.01 and 250 metres	31	8%	0	0%
Between 250.01 and 300 metres	0	0%	0	0%
More than 300 metres	0	0%	0	0%
TOTAL	381	100%	355	100%

port is mainly used for the export of bananas in bulk, the deployment of reefer vessels with an average of 150 metres in length is expected.

Table 14: Vessel traffic in the Port of Puerto Bolivar by length overall

LENGHT OVERALL	2012	Share (%)	2013	Share (%)
Less than 100 metres	2	1%	28	8%
Between 100.01 and 150 metres	154	40%	166	47%
Between 150.01 and 200 metres	194	51%	161	45%
Between 200.01 and 250 metres	31	8%	0	0%
Between 250.01 and 300 metres	0	0%	0	0%
More than 300 metres	0	0%	0	0%
TOTAL	381	100%	355	100%

Source: Compiled by the author based on Port and water transport statistics, Ministry of Transport and Public Affairs of Ecuador.

6.3 Differences between ideal and current situation

The main difference between the ideal port in terms of basic port infrastructure and the actual situation of the ports in Ecuador is the contrast that appears when comparing the draught limitation of both situations. Gaps of around 4.25, 2.25 and 2 metres in Guayaquil, Esmeraldas and Puerto Bolivar respectively are considerable and highly relevant for the shipping lines when planning the vessel deployment in the region (Table 15). In container vessel design longer than 10 metres, every metre represents around 1,800 TEU's of added capacity (Rodrigue, 2015b).

With respect to the length of quay walls, there are several criteria to choose. While it is true that the Port of Guayaquil and the Port of Puerto Bolivar are able to receive vessels of up to 366 metres due to the length of the current quay walls, it is also true that in the case of the Port of Guayaquil it can receive 4 of these vessels at the same time. The Port of Puerto Bolivar, however, is only able to receive one of such vessels at a time and this situation would leave only 300 metres available for other vessels. In case of Esmeraldas, with the current conditions this port will not be able to receive the expected type of vessels, to receive only one of these vessels would require the current quay to be extended by 16 more metres.

Table 15: Comparison of SOLL and IST situation

	SOLL situation	IST situation		
	Ideal Port	Actual Port		
		Guayaquil	Esmeraldas	Puerto Bolivar
Maritime access channel	14 metres	9.75 metres	11.5 metres	12 metres
Quay walls length	330 metres	1,625 metres	350 metres	660 metres

Source: Compiled by the author

7 Conclusion

The introduction of the New Panamax container vessel will definitely bring a major challenge for the ports in the region of the WCSA. Since the capacity of the Panama Canal will almost double with the expansion, the shipping lines will try to gain the most benefit possible from this route. For this reason, the deployment of bigger vessels is expected. According to global trends, the size of these new vessels will gradually increase up to the maximum allowed by the expansion. This means that over time vessels of up to 366 metres in length overall, 49 metres in beam and 15.2 metres in draught can be expected to arrive in the ports in the area.

In this study, considering the draught limitations of the ports, it has been predicted that the biggest New Panamax vessels will not arrive to the ports of the WCSA soon. Therefore, an ideal port that is able to handle the forecasted size of vessels has been designed and it has been found that the differences between its characteristics and the actual conditions of the Ecuadorian ports are significant.

Any of the ports in Ecuador will be able to receive vessels with the predicted dimensions mainly because any of them have a maritime access channel that is deep enough to allow the entry of that type of vessel, at least not fully loaded. Regarding the vessel length, only the Port of Guayaquil will be able to handle 3 or more New Panamax vessels at the same time, the other two ports have limited capacity possibilities due to the length of the quay wall. The quay wall of the Port of Esmeraldas is long enough to receive one New Panamax vessel at a time. However, if it uses the entire length of the quay for one vessel, there is a high chance for congestion due to the longer dwell time needed to operate the vessels with big dimensions. Given the length of its longest quay wall, the Port of Puerto Bolivar will be able to receive maximum two of these vessels at the same time, but this will leave very little room for manoeuvrability which in the end compromises the security of the entire port. Additionally this situation can also lead to congestion although to a less degree than in the Port of Esmeraldas since in Puerto Bolivar there are more quays available.

Since the main variables in this study are the maritime access channel depth and the quay walls length, both were evaluated based on the current level of traffic, operation and relevance in the Ecuadorian ports. In the Table 16 we present the degree of the impact of each of the elements in the actual conditions of the Port of Guayaquil, Port of Esmeraldas and Port of Puerto Bolivar respectively.

Table 16: Matrix of impact of the port infrastructure's element in the actual conditions of the Ecuadorian Ports

	Impact of elements in the actual conditions	
	Maritime access channel depth	Quay wall length
Port of Guayaquil	Very high	Low
Port of Esmeraldas	High	High
Port of Puerto Bolivar	High	Medium

Source: Compiled by the author

Given the results of the comparison between the ideal situation and the actual situation this study is now able to answer the main research question proposed in the first chapter:

What are the implications for the basic port infrastructure of Ecuador's container ports considering the opening of the Panama Canal expansion and the introduction of the New Panamax container vessel?

Since all the ports in Ecuador follow the figure of a Public Service Port, public sector is the only one responsible for the development of the basic port infrastructure. The public sector, as well as Port Authorities, Sub-secretary of Ports, Ministry of Transport and Government will have to be ready to face the obligation of the ports to adapt their facilities to be able to receive the new sized vessels deployed after the opening of the Panama Canal expansion.

Taking into account the data on the assessed implications for each port in Ecuador resented in Table 16, we can conclude the following:

- The implications for the Port of Guayaquil:

Draught restriction: considering that in the current situation most of the vessels arrive or sail with the maximum draught permitted, the implementation of projects to increase the depth of the maritime access channel and the docks up to 14 metres on average is urgent, either through dredging or through the extension of the current port by building new facilities in locations with greater depth.

Quay walls length: the current length allows the receipt of up to 4 vessels of 330 metres long at the same time, therefore at the moment this situation does not require immediate action in the short or medium term.

- The implications for the Port of Esmeraldas:

Draught restriction: since the difference between the ideal draught and the actual draught of this port is 2.5 metres, the introduction of vessels with deeper draught would have a high impact on its basic port infrastructure. However, the impact could not be that high as in the Port of Guayaquil because given the fact that the current draught restriction is 11.5 metres, most of the vessels that arrive at this port have a draught of up to 9.00 metres. Therefore it seems that, in terms of vessel deployment, the port can still be seen as a secondary port.

Quay walls length: the current length of 350 metres is seen as a limitation for the vessels' operations. Considering that around 40% of the vessels that arrive at the port have a length of 150 to 200 metres, the current situation does not allow the operation of two vessels of 200 metres simultaneously. Therefore, port authorities need to consider the possibilities of lengthening the extension of the quay walls in the nearest future. Projects for the deepening of the maritime access channels can be taken as a secondary priority.

- The implications for the Port of Puerto Bolivar:

Draught restriction: since this is one of the container ports with the deepest draught in the country, the difference with the ideal port would be only 2 metres. Similar to the case of the Port of Esmeraldas, most of the vessels that arrive or sail in this port have less than 8.20 metres draught even though the limitation allows the vessels of up to 12.00 metres. Based on this information, it also seems that, in terms of vessel deployment, this port can still be seen as a secondary port.

Quay walls length: the length of 660 metres would be enough to handle the New Panamax container vessels but it would mean working to the limit considering that there would not be many other docks available. Therefore, implementation of projects for the deepening of the maritime access channel and the extension of the quay walls require the same level of priority in the short and medium run.

7.1 Limitations

Knowing that the ideal port for the region of the WCSA does not have to become the world leader port, the port dimensions established in this study are the result of applying the linear regression model to historical data only without taking into account any other external factors. Therefore this study is limited to a linear model that implies a steady growth in vessel size over time. Nonetheless we are conscious that in naval architecture, some other factors such as the increase in vessel beam or a new hold configuration may also affect the increase in length and draught of vessels. In the same line, external factors such as other canals, straits or even economic crisis or any other event of global impact may restrict the design of new vessels.

7.2 Recommendations

This study focuses on the basic port infrastructure of a port, however, as mentioned in chapter 2, there are some other aspects such as Operational Port Infrastructure, Port superstructure and Port equipment that can be subject to studies in further research. It is also important to recognise that the deployment of vessels in determined regions depends exclusively on every shipping line and its own strategy based on market or operational efficiency among other aspects, so the depth study of these strategies would allow the maritime sector to understand and to foresee more accurately the new trends to come.

Once the findings of this study have been observed, the next step would be recognising the role of the Port Authorities in a decision model created to accomplish the objective proposed in the projects.

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